
An Evaluation of Hunter Surveys to Monitor Relative Abundance of Bobcats

RH: Bobcat indices

TYLER J. MAHARD, Department of Natural Resources and the Environment, University of New Hampshire, Durham, NH 03824, USA

JOHN A. LITVAITIS¹, Department of Natural Resources and the Environment, University of New Hampshire, Durham, NH 03824, USA

PATRICK TATE, New Hampshire Fish and Game Department, Durham, NH 03824, USA

GREGORY C. REED, Department of Natural Resources and the Environment, University of New Hampshire, Durham, NH 03824, USA

DEREK J. A. BROMAN, Department of Natural Resources and the Environment, University of New Hampshire, Durham, NH 03824, USA

¹ Corresponding author: john@unh.edu

KEY WORDS: carnivores, citizen science, Lynx rufus, population index, program MONITOR

ABSTRACT We examined the utility of bobcat (Lynx rufus) detections by hunters as an index of relative abundance. To validate the index, the number of hunter outings that detected bobcats per 1000 outings was compared to a statewide map of habitat suitability after both were partitioned by wildlife management units (WMUs) and annual hunter-detection rates were compared to tallies of road-killed bobcats. We also evaluated power to detect specific rates of increase or decrease in hunter-detection rates. Habitat-suitability indices and bobcat road mortalities were correlated with hunter-survey indices. Linear and exponential trends in hunter-
detection rates of +/- 10%/year could be detected with power $\geq 99\%$ over 5-year periods. As a result, we suspect that major changes in bobcat abundances could be detected by the hunter-survey index. However, without the information needed to calibrate the relationship between the index and bobcat populations (e.g., linear or exponential), it is not possible to estimate the extent of change in bobcat abundance by a specific change in detection rate. We consider hunter detections a useful approach to monitor bobcats if applied in concert with other indices (e.g., road-kill tallies, trapper harvests, etc) to obtain a reliable gauge of population trends.

*Wildlife Society Bulletin: 00(0): 000-000, 2016*

Bobcat (*Lynx rufus*) populations in New Hampshire have undergone dramatic changes during the past 50 years. Initially, land-use changes, exploitation, and expanding populations of coyotes (*Canis latrans*) were suspected of contributing to a precipitous decline of bobcats throughout the state (Litvaitis 1993, Litvaitis et al. 2006). In response to that decline, trapping and hunting seasons have been closed since 1989 (Litvaitis et al. 2006). However, incidental sightings and the frequency of bobcat-vehicle collisions in recent years suggest that their distribution and abundance are increasing (Broman et al. 2014).

Understanding the current and future status of bobcats in New Hampshire is important for several reasons. First, along with coyotes, bobcats are functioning as an apex predator since the extirpation of wolves (*C. lupus*) and cougars (*Puma concolor*) throughout much of eastern North America (Roemer et al. 2009). As a wide-ranging carnivore, bobcats require large areas of suitable habitat and are often selected as a focal or umbrella species in large-scale conservation efforts (Crooks 2002, Rubino and Hess 2003, Litvaitis et al. 2015). In northern New England, the Nature Conservancy’s “Staying Connected” initiative recently identified bobcats as a focal
species for maintaining landscape linkages (The Nature Conservancy 2013). As a result, it will be important to understand how bobcats respond to land management efforts that emerge from that initiative. Additionally, Canada lynx (*L. canadensis*), a federally-listed species, have recently re-colonized northern townships of the state. Bobcats may displace lynx in areas of sympatry (Peers et al. 2013) if warming temperatures result in milder winters in northern regions where deep snow has limited bobcat abundance (Reed 2013). Finally, trapping and hunting seasons may re-open in New Hampshire in response to public requests. Because bobcats are listed on Appendix II of the Convention on the Trade in Endangered Species of Wild Fauna and Flora (CITES), state agencies that regulate trapping and hunting seasons are required to provide information that indicates harvests do not jeopardize bobcat populations (CITES 2014). Based on these information needs, we set out to identify a monitoring protocol that is practical, low cost, and able to reveal changes in the relative abundance of bobcats throughout New Hampshire.

Carnivores present substantial challenges to efforts intended to track their distribution and abundance because of their low population densities and secretive nature (Gompper et al. 2006, Long et al. 2008). Citizen science, or enlisting members of the public as data collectors, has become prevalent in ecological research (Silvertown 2009, Dickinson et al. 2012). In addition to increasing public engagement, a volunteer approach may offer a low-cost boost in detection power when monitoring elusive species (Watkins and Moskowitz 2007, Erb et al. 2012, Nagy et al. 2012, Sequeira et al. 2014). Over the past 5 years, personnel of the New Hampshire Fish and Game Department have solicited observations of bobcats from hunters, an approach commonly used by state agencies to monitor the status of bobcats (Roberts and Crimmins 2010). However, such indices cannot be assumed to reflect bobcat abundances unless validated by other measures or estimates of abundance (Conn et al. 2004, O’Brien 2011).
A common tactic used to validate or calibrate wildlife indices is to estimate actual abundance in several areas and then compare estimates of abundance to index values (i.e., double sampling; Eberhardt and Simmons 1987). However, when the species of interest exists at low densities, cost of such efforts can be substantial (Gopalaswamy et al. 2015). For example, we expended ~15 technician days searching for bobcat scats in an area that contained transmitter-equipped bobcats to generate a DNA-based capture-recapture estimate for that area. Our effort yielded 10 putative bobcat scats of which 9 were subsequently identified as coming from coyotes (M. Litvaitis, University of New Hampshire, unpublished data). Detection dogs can improve scat retrieval rates (Long et al. 2007), but can be costly. Using contracted handlers and trained dogs, Clare et al. (2014) estimated the cost per bobcat detection at >US$600.

With these limitations in mind, we decided to compare hunter surveys and a recently completed map of bobcat habitat suitability in New Hampshire (Litvaitis et al. 2015). Our goal was to evaluate the use of hunter observations as an efficient index for monitoring the abundance of bobcats at regional and statewide scales. Specific objectives were to: i) compare hunter-detection rates of bobcats to the habitat-suitability ranks of various regions within the state, ii) compare statewide hunter-detection rates to statewide tallies of bobcat-vehicle collisions as a second validation method, and iii) assess the statistical power (i.e., signal to noise ratio) to detect specific rates of change in hunter-detection rates over time.

STUDY AREAS

New Hampshire (24,217-km²) is near the northern limit of the geographic range of bobcats (Fig. 1). Average human population density in 2010 was 57 persons/km², ranging from uninhabited northern townships to 1278 persons/km² in the city of Manchester (U.S. Census Bureau, Washington, DC). Elevations range from sea level, along the Atlantic coast, to 1917 m on the
summit of Mt. Washington. The state is approximately 74% forested (National Land Cover Database 2011; USGS, Sioux Falls, SD). *Pinus, Fagus, Tsuga, Acer, Quercus,* and *Betula* are prominent forest constituents, and dominate southern New Hampshire, whereas *Picea* and *Abies* are prevalent in northern regions (Morin and Pugh 2014). Sympatric carnivores that may influence bobcats include coyotes, red foxes (*Vulpes vulpes*), gray foxes (*Urocyon cinereoargenteus*), fishers (*Martes pennanti*), and lynx. White-tailed deer (*Odocoileus virginianus*), cottontail rabbits (*Sylvilagus* spp.), snowshoe hares (*Lepus americanus*), gray squirrels (*Sciurus carolinensis*), red squirrels (*Tamiasciurus hudsonicus*), and other small mammals constitute the bulk of bobcat prey items (Litvaitis et al. 1984).

**MATERIALS AND METHODS**

**Hunter Surveys**

Personnel of New Hampshire Fish and Game Department mailed survey cards to licensed deer hunters before the start of each deer-hunting season from 2009 through 2013. Hunters were asked to record date, township and wildlife management unit (WMU) they hunted in, duration of each hunt (hours), and number of deer, bears, moose, and bobcats seen for each of their hunting outings during the season. After cards were returned, outings for which the reported WMU and township were not spatially coincident, or for which the entry in the “town” field could not be matched to a township in New Hampshire were excluded from analyses due to ambiguity in location of occurrence. To provide some standardization to the duration of outings, we also excluded those that lasted less than 0.5 or greater than 15 hours.

**Bobcat Habitat Suitability**

A model of habitat suitability for bobcats in New Hampshire ranked 30-m raster cells covering the state on a scale of increasing suitability from 0 to 1 (Litvaitis et al. 2015). Briefly, raster rank
at a course resolution was influenced by the locations of 665 incidental sightings of bobcats by the general public (collected December 2007 through January 2013) in relation to mean monthly snow depth. That pattern of bobcat distribution was corroborated by trail cameras (Litvaitis et al. 2015). At a fine resolution, raster rank was influenced by habitat selections of GPS-collared bobcats in relation to environmental variables expected to influence probability of bobcat use of established home ranges (Litvaitis et al. 2015). The habitat-suitability value for each WMU was taken as the average of all raster cells coincident with potential bobcat habitat. Potential habitat was defined by excluding open water, medium and high development, and barren land (National Land Cover Database 2011; USGS, Sioux Falls, SD). Processing of these data was accomplished using ArcMap 10 software (ESRI, Redlands, CA).

**Abundance Index**

As New Hampshire is contained within the extent of occurrence for bobcats, we sought to describe relative abundance statewide. Given the often small and irregular size of townships (5-754 km²; μ = 93 km²), we used WMUs (398–2407 km²; μ = 1041 km²) to describe relative abundances (Fig. 1). Because WMUs are predominantly bounded by major highways that may act as barriers to bobcat movements (Riley et al. 2006, Litvaitis et al. 2015) and factors that affect bobcat abundance (e.g., land use, climate, forest types, topography, and human densities) were used to delineate WMUs, they provide a convenient stratum for assessing relative abundance of bobcats.

We used hunter surveys from the 2009 through 2013 harvest seasons to generate an index for the relative abundance of bobcats per WMU. Many townships straddle WMU boundaries. Thus, when summarizing by WMU, records for which the WMU was not fully-specified (e.g.,
“A” instead of “A1” or “A2”; see WMU labels in Fig. 3) were excluded unless the fully specified WMU could be inferred based on the reported township and the geography of its boundary.

The number of hunter outings that detected one or more bobcats \( O_B \) was used as a parameter for abundance, and number of hunter outings \( O \) was used as a parameter for detection effort. Using \( O_B \) instead of the number of bobcats observed was expected to reduce bias due to chance encounters of bobcat family groups, and from repeated observations of the same individual during one outing. Although hunters reported the number of hours they spent during each outing, we felt that the number of outings was a better parameter for effort (contrary to Kindberg et al. 2009, Linde et al. 2011, and Cooper et al. 2012). This was based on the notion that bobcats have large home ranges relative to the area we expected most hunters to cover in one outing, and that many short outings in different locations would likely produce more bobcat detections than a small number of longer outings. Incidentally, the number of hunter outings and total hunter hours was very strongly correlated by WMU \( r = 0.996, P<0.0001 \) and use of either parameter would have likely yielded similar index values. After screening, \( O_B \) and \( O \) were summed by WMU and used to generate an index of relative abundance based on hunter surveys.

**Comparing Hunter Detections to Habitat Suitability and Bobcat-Vehicle Collisions**

To reduce potential sampling noise, WMUs were included in our analyses only if they received at least the number of hunter outings needed to yield 5 bobcat detections at the average statewide detection rate (determined by dividing the statewide total of hunter outings by total outings that detected bobcats). A Spearman-rank correlation was used to compare spatial associations between hunter-detection rates and habitat suitability ranks of WMUs, with \( P<0.05 \) considered significant. We used JMP Pro 11.2.2 (SAS Institute, Cary, North Carolina) to calculate this and all other correlations and regressions in this study.
We then examined the statewide trend in reported bobcat road mortalities from 2009 to 2013. These records are considered a reasonable approximation of bobcats killed on roads because it is illegal for citizens to possess a bobcat carcass in New Hampshire. Carcasses are retrieved by New Hampshire Fish and Game Department personnel and used to gather information on bobcat reproductive rates, food habits, and physical condition. Although the use of roadkills as an index of animal abundance has been questioned when compared to other indices, such as hunter or trapper harvests (e.g., Rolley and Lehman 1992), the tally of vehicle mortalities may indeed reveal changes in abundance (Bright et al. 2015), especially when applied to large areas (Mallick et al. 1998). Linear correlation was used to assess temporal association between annual hunter-detection rates and bobcat road mortality counts, statewide, with P<0.05 considered significant.

Estimating Power to Detect Trends

Program MONITOR (Gibbs and Ene 2010) estimates the statistical power of monitoring protocols to detect trends in wildlife count data. After inputting various protocol-specific parameters (e.g., number of regions, survey frequency) and coefficients of variation among successive counts, the program uses regression and Monte Carlo simulations to estimate the probability (i.e., power) of detecting user-defined trends (e.g., 5% decline) over a time period of interest. This approach has been used to assess monitoring protocols for birds (Gibbs and Melvin 1997, Flesch and Steidl 2006, Pollock 2006, Hinojosa-Huerta et al. 2013), tigers (Hayward et al. 2002, Jhala et al. 2011), tortoises (Couturier et al. 2013), and guanaco (Travaini et al. 2013). We used MONITOR (v. 11.0.2) to assess statistical power to detect trends in our hunter survey index under a pivotal assumption that annual changes in index values reflected annual changes in bobcat abundance.
To improve our ability to detect changes in relative abundance, we lumped WMUs into 4 regions (Fig. 1) based on patterns in annual snowfall and road density known to influence the distribution of bobcats (Reed 2013). When summarizing hunter survey records by region, we excluded outings from townships that straddled region boundaries and lacked fully-specified WMU designations (e.g., “D2” instead of “D2W” or “D2E”). For each region and year, we sampled 4 index values corresponding to the first 4 weeks of each hunting season. For example, a sampled index value from the k\(^{th}\) week of region i during year j (\(x_{ijk}\)) would be calculated as the total number of hunter outings with bobcat detection (\(O_{ijk}\)) multiplied by 1000 and divided by the total of number of hunter outings (\(O_{ijk}\)):

\[
x_{ijk} = 1000 \frac{O_{ijk}}{O_{ijk}}
\]

(Eqn. 1)

Four samples per region for 5 years provided a total of 80 samples. For each region, we used the mean of the 4 samples from 2009 as a starting value for simulations in MONITOR.

Variation in count data is influenced by both process and sampling variation (Thompson et al. 1998). Process variation is caused by between-season changes in population numbers whereas sampling variation is observed among within-season measurements and caused mostly by measurement error (Thompson et al. 1998). MONITOR simulates count data using either total (i.e., process and sampling variation pooled into one estimate) or partitioned (i.e., separate estimates for process and sampling variation) measures of variation for each region (see the software’s help files, Gibbs and Ene 2010). We followed the approach used by Gibbs and Melvin (1997) and Flesch and Steidl (2006), and calculated an estimate representative of both the temporal component of process variation and sampling variation. To generate that estimate for each region, we subtracted the mean index value for each region and year (\(\tilde{x}_{ij}\)) from each
observation \((x_{ijk})\) within the same region and year to generate zeroed index values with the annual component of abundance removed (Gibbs and Melvin 1997, Flesch and Steidl 2006). Then, for each region, an estimate for variation was taken as the standard deviation of all zeroed index values pooled across the 5 years.

We assumed a constant coefficient of variation (suggested by the help files, Gibbs and Ene 2010). We then used 1000 iterations and route regression to determine our ability to detect both linear and exponential trends ranging from -25% to +25% annually (in 5% increments) for the entire state over a 5-year simulation period. We used two-tailed tests and specified \(P<0.05\) to determine whether the slopes of the regressed simulated index values differed from zero. Using JMP Pro 11.2.2, all 80 samples were regressed by year to estimate an overall trend in the hunter-survey index from 2009 through 2013. We calculated the percent change in the hunter-survey index from 2009 through 2013 and used our results from MONITOR to determine our statistical power to observe that trend. Finally, we were concerned about statistical noise due to small sample sizes and about assigning equal weight to regions of unequal area. To investigate this, we compared the percent increase (from 2009 to 2013) in the trend regressed from the 80 samples to that of a trend based on annual index values generated by pooling all 4 weeks of data statewide. Then, we simply subtracted the two percent changes to assess discrepancy between the two approaches.

RESULTS

Comparing Hunter Detections to Habitat Suitability and Bobcat-Vehicle Collisions

During the entire 5-year period, 75,248 hunter survey cards were sent out, and 10,232 (13.6%) of those were received and were correctly completed by the hunter. Annually, response rates were relatively consistent (Table 1). Collectively, the completed cards contained 93,120 records of
hunter outings. Of these, 89,748 were successfully screened and identified to WMUs. A summary at the township level revealed that the distribution of hunter effort was uneven with northern townships yielding the least effort (Fig. 2). Based on the screened data, hunter outings with bobcat detections ($O_B$) occurred at a statewide rate of 1 per 132 outings over the 5-year period. Each of 4 adjacent WMUs in the White Mountains had <660 outings (i.e., not enough for 5 $O_B$ at statewide rate). Rather than exclude these WMUs from our comparison with the model of habitat suitability, we combined them into a single sample that had a total of 628 hunter outings. We felt 628 was enough to indicate hunter-detection rates (and relative abundance) in this mountainous part of the state. Lumping of these 4 WMUs provided a total of 21 spatial units, for which hunter survey index values ranged from 1.4 to 12.0 $O_B/1000$ $O$ ($\bar{x} = 7.4$, SD = 3.6). The model of habitat suitability provided habitat-area suitability means that ranged from 0.28 to 0.59 ($\bar{x} = 0.50$, SD = 0.10) for the 21 units. Both indices ranked northern and central New Hampshire lower in relative abundance than the remainder of the state and there was moderate agreement between hunter survey and habitat-suitability indices ($r_s = 0.56$, $P<0.01$; Fig. 3). Ninety-two bobcat-vehicle collisions were recorded from 2009 through 2013. Annual road mortality counts and hunter-detection rates had similar trends, but correlation between the two was not significant ($r = 0.80$, $P = 0.10$). Additionally, the two indices had blatant disagreement in 2013 (Fig. 4).

**Estimating Power to Detect Trends**

Results from MONITOR indicated that exponential trends in the hunter survey indices of +/- 5%/year over the 5-year period could be detected with power near or slightly under 90% (Table 2). However, linear or exponential trends of magnitudes in excess of +/- 10%/year for 5 years could be detected with power > 95%. Linear regression of all 80 samples (summarized in Table 3) by year generated a modeled hunter survey index (measured in $O_B/1000$ $O$) that increased
from 5.9 in 2009 to 8.1 in 2013 (37% net increase; $r^2 = 0.05, P = 0.06$; Fig. 5). Based on regression of pooled index values (i.e., one sample for the entire state per year), the regression model of the hunter-survey index increased from 5.9 in 2009 to 9.3 in 2013 (59% increase; $r^2 = 0.80, P = 0.04$). We observed a discrepancy of 22% between the 59% increase from the pooled samples and the 37% increase based on all 80 samples. Importantly, both approaches demonstrated an increasing trend in the hunter-survey index over the five-year period.

**DISCUSSION**

Agreement among indices is often interpreted as an indication that they are appropriately describing the status of a species (e.g., Rolandsen et al. 2011). Despite cautions against using indices (MacKenzie et al. 2006, O’Brien 2011), they are frequently used by agency biologists (Clark and Andrews 1982, Gese 2001, Cooper 2012; Roberts and Crimmins 2010); and researchers (Conn et al. 2004, Evangelista et al. 2009, Kindberg et al. 2009, Bengsen et al. 2011, Letnic et al. 2011) to gauge status or responses by populations to management actions or environmental change. Thus, overcoming some of the limitations of indices is warranted (Sollmann et al. 2013).

We demonstrated a positive relationship between our hunter-survey and habitat-suitability indices. As a result, we suspect that spatial variation in hunter-detection rates does describe spatial variation in the abundance of bobcats, but to an unknown degree. Further, agreement between hunter-detection rates and bobcat-vehicle collisions suggest that hunter surveys may reveal major changes in bobcat numbers over time. However, it is difficult to quantify “major change” because of the unknown functional relationship between these indices and abundance. For example, an exponential change in an index may coincide with a linear change in bobcat abundance, and that relationship could vary over time or space. It is also
important to acknowledge the inherent differences in observed agreements in trends of hunter-detection rates versus ranks of habitat suitability (spatial correlation) and detection rates versus road mortalities (temporal correlation). To conclude that these results support the application of hunter detections ignores the importance of understanding what other factors may affect detection rates and how their influence may vary over time or space (Anderson 2001, 2003).

We suspect that hunter-detection rates are influenced by factors we did not record, including hunting method and the presence/absence of snow cover during the hunt. Hunting method (e.g., still, stalking or over bait) can affect encounter rates between the hunter and wide-ranging species, such as black bears (*Ursus americanus*, Bunnell and Tait 1980) and possibly bobcats. Among New Hampshire deer hunters, the popularity of hunting over baited sites has substantially increased in recent years (D. Bergeron, New Hampshire Fish and Game Department, personal communication), potentially affecting bobcat detection-rates over time. Additionally, the presence of even a modest covering of snow likely enhances the ability of hunters to see a bobcat moving through the immediate area. Even within a WMU, snowfall likely varies among years.

Confounding factors such as these are likely responsible for the obvious disagreement between our hunter-survey index vehicle-collision counts in 2013. Our vehicle-collision counts dropped in 2013 while the hunter-survey index remained similar to the previous year. The drop in the vehicle-collision tally could be attributed to a change in the probability of a road-killed bobcat being documented, an actual change in the number of road-killed bobcats, or some combination of the two. Given the fairly small number of road-killed bobcats per year, we do not consider these data suitable for areas smaller than the entire state and this index is likely insensitive to changes in bobcat abundance even at that spatial scale.
Regarding our approach of grouping all hunter-detections by year, groupings by regions and weeks provided a more rigorous indication that hunter-detection rates generally increased in New Hampshire during the 5-year period. However, uneven distribution of hunter effort within regions revealed substantial spatial bias in the hunter-survey index toward areas that received more effort. Consequently, changes in bobcat abundance where effort was low were less represented among regional hunter-detection rates. We suspect bobcat densities may have been lower in some areas with lower effort (e.g., White Mountains and urban areas). In addition, high effort may be spatially associated with abundances of deer, other bobcat prey items, and bobcats. To avoid spatial bias, it may be possible to randomly sample hunter-detection data at a constant density. Future efforts may investigate if the quantity of data is sufficient for such an analysis, as this approach would involve excluding records in oversampled areas.

We considered the application of occupancy models to monitor bobcat abundance because that approach provides an opportunity to incorporate covariates that may affect detection probability and abundance (MacKenzie et al. 2002). For occupancy models, changes in abundance may be detected when spatial units are about the size of an animal’s home range or smaller, but changes in density may go undetected if occupancy is assessed at a more coarse resolution (MacKenzie and Royle 2005). The maximum spatial resolution of our hunter survey data is achieved by overlaying township and WMU boundaries, creating 418 spatial units ranging in size from 8x10^-3 to 398 km^2. This, paired with mean home range sizes of bobcats (females, 23.84 km^2; males, 81.6 km^2) observed by Reed (2013), makes the hunter survey data poorly suited for occupancy modeling. We suspect that increasing the spatial resolution of future hunter survey data may be difficult because hunters are likely unwilling to identify their locations beyond the levels of township and WMU.
If such modifications are not possible, we recommend using hunter-detection rates in conjunction with other existing indices (e.g., road-kill tallies), and indices that may emerge if trapping and hunting of bobcats in New Hampshire resumes (e.g., captures per unit effort). We also suggest adding questions on hunting method used and the presence/absence of snow cover during each outing to the survey cards. Calibrating the hunter-survey index to bobcat densities is a desirable addition to this approach, but such information would be difficult and expensive to obtain. According to Gopalaswamy et al. (2015), such efforts should only be undertaken if detection rates are relatively high and do not vary over time. We do not believe hunter observations of bobcats satisfy those criteria.

**Management Implications**

Hunter surveys provided useful information on the status of bobcats in New Hampshire. Hunter-detection rates can be a useful approach to monitor bobcat abundance if applied in concert with other indices (e.g., road-kill tallies, trapper harvests, etc) to obtain a reliable gauge of population trends. We suggest that managers consider the potential limitation and possible drawbacks of citizen science-based approaches. Our hunter survey data were collected by a large number of individuals, and we had no control over the accuracy of the information they supplied to us. Our findings were based on an assumption that the influence of false data was negligible.

**ACKNOWLEDGMENTS**

We thank M. Ducey, M. Ellingwood, M. Litvaitis, and L. Verville, and for their assistance in many phases of this investigation. R. Carroll, J. Clare, W. Jakubas, and R. Rolley provided insightful comments on early drafts of this report. We also thank C. Ribic, L. McDonald, and several anonymous reviewers for helpful comments on final drafts of this paper. New Hampshire Fish and Game Department, and the Wildlife Restoration Program (grant W-90-R-1) in
cooperation with the United States Fish and Wildlife Service, Wildlife and Sport Fish
Restoration Program, and the College of Life Sciences and Agriculture provided support.

LITERATURE CITED

Anderson, D. R. 2001. The need to get the basics right in wildlife field studies. Wildlife Society


Transportation. Center for Transportation and the Environment, North Carolina State University, Raleigh, USA.
Table 1. Number of hunter survey cards mailed, number received that were completed correctly, and response rates for each year from 2009 through 2013.

<table>
<thead>
<tr>
<th>Year</th>
<th>Cards mailed</th>
<th>Cards received</th>
<th>Response rate (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2009</td>
<td>15,516</td>
<td>2,091</td>
<td>13.5</td>
</tr>
<tr>
<td>2010</td>
<td>13,901</td>
<td>2,064</td>
<td>14.9</td>
</tr>
<tr>
<td>2011</td>
<td>13,949</td>
<td>2,042</td>
<td>14.6</td>
</tr>
<tr>
<td>2012</td>
<td>16,000</td>
<td>2,038</td>
<td>12.7</td>
</tr>
<tr>
<td>2013</td>
<td>15,882</td>
<td>1,997</td>
<td>12.6</td>
</tr>
</tbody>
</table>

Table 2. Annual trends entered into program MONITOR and subsequent net changes (for annual increments) and power estimates for linear and exponential trends.

<table>
<thead>
<tr>
<th>Trend value (%)</th>
<th>Net change (%)</th>
<th>Power estimate, linear</th>
<th>Power estimate, exponential</th>
</tr>
</thead>
<tbody>
<tr>
<td>-25</td>
<td>-68</td>
<td>1.000</td>
<td>0.999</td>
</tr>
<tr>
<td>-20</td>
<td>-59</td>
<td>0.985</td>
<td>0.988</td>
</tr>
<tr>
<td>-15</td>
<td>-48</td>
<td>0.997</td>
<td>0.996</td>
</tr>
<tr>
<td>-10</td>
<td>-34</td>
<td>0.990</td>
<td>0.997</td>
</tr>
<tr>
<td>-5</td>
<td>-19</td>
<td>0.893</td>
<td>0.891</td>
</tr>
<tr>
<td>0</td>
<td>0</td>
<td>0.000</td>
<td>0.003</td>
</tr>
<tr>
<td>5</td>
<td>22</td>
<td>0.992</td>
<td>0.804</td>
</tr>
<tr>
<td>10</td>
<td>46</td>
<td>0.997</td>
<td>0.992</td>
</tr>
<tr>
<td>15</td>
<td>75</td>
<td>0.992</td>
<td>1.000</td>
</tr>
<tr>
<td>20</td>
<td>107</td>
<td>0.998</td>
<td>0.999</td>
</tr>
<tr>
<td>25</td>
<td>144</td>
<td>1.000</td>
<td>0.996</td>
</tr>
</tbody>
</table>
Table 3. Minimum, maximum, and mean number of outings \((O)\) and outings with bobcat detection \((O_B)\) for Regions N, E, S, and W. Results come from 20 samples in each region (4 weeks x 5 years).

<table>
<thead>
<tr>
<th>Region</th>
<th>Min (O)</th>
<th>Max (O)</th>
<th>Mean (O)</th>
<th>Min (O_B)</th>
<th>Max (O_B)</th>
<th>Mean (O_B)</th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
<td>143</td>
<td>642</td>
<td>463</td>
<td>0</td>
<td>7</td>
<td>2.3</td>
</tr>
<tr>
<td>E</td>
<td>288</td>
<td>1398</td>
<td>945</td>
<td>1</td>
<td>17</td>
<td>8.4</td>
</tr>
<tr>
<td>S</td>
<td>423</td>
<td>2291</td>
<td>1634</td>
<td>1</td>
<td>26</td>
<td>10.0</td>
</tr>
<tr>
<td>W</td>
<td>356</td>
<td>1992</td>
<td>1352</td>
<td>1</td>
<td>26</td>
<td>12.6</td>
</tr>
</tbody>
</table>
List of figures


Figure 2. Density of hunter-survey effort (outings per km² of total township area) from 2009 through 2013 for 384 spatial units created by overlaying township and WMU boundaries (spatial units <5km² were excluded).

Figure 3. Comparison between hunter-survey index (hunter outings that detected bobcat per 1000 outings) and habitat suitability index (mean of all habitat suitability raster values coincident with potential bobcat habitat) for 21 units (wildlife management units with WMUs D2E, E1, E2, and E3 combined). The maps on the right depict units ranked into 4 categories based on quantile breaks.

Figure 4. Annual statewide trends in hunter detections of bobcats (hunter outings that detected bobcat per 1000 outings) and bobcat road mortalities. Hunter-detection rates were calculated from 92,396 records, where records with <0.5, >15, or an unknown number of hunter hours were excluded.

Figure 5. Means of hunter-survey indices (expressed as number of outings with bobcat observed per 1000 outings) for each region and year, and the resulting trend. Lines indicate standard error based on 4 samples corresponding to each of 4 weeks during hunting season. Overall index trend (solid line) was calculated by regressing all 80 samples (4 weeks x 5 years x 4 regions).
Fig. 1
Outings per km$^2$
- < 1
- 1 - 2
- 2 - 5
- 5 - 10
- 10 - 20
- Not surveyed

Region boundary
WMU boundary

0 — 50 Kilometers

Fig. 2
Fig. 3
Fig. 5