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Land Cover Composition, But Not Weather, Affects Female Wild Turkey Roost Site Selection

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LAND COVER COMPOSITION, BUT NOT WEATHER, AFFECTS FEMALE WILD TURKEY ROOST SITE SELECTION

by

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ABSTRACT

Populations at a species' northern range extent are often presented with more challenges than those in more southern regions, given that winters are generally harsher, and the reproductive season is shorter in these northern regions. Wild turkeys (*Meleagris gallopavo*) are near their northern range limit in Maine, and there have been no studies that have researched turkey roosting here. Wild turkeys roost in trees at night, and we predicted that roost selection would be affected by changing weather conditions, particularly during winter when temperatures are expected to be coldest. We also predicted that land cover composition would affect roost site selection due to spatial variability in food availability. We captured and GPS-tagged wild turkeys in Penobscot County, Maine, to analyze their selection for four forest attributes during roosting: tree height, basal area, softwood percentage, and distance to forest edge. We also explored the potential for wind chill, precipitation, or land cover composition, particularly human development or agricultural land, to have moderating effects on selection. We used resource selection functions, implemented as generalized linear mixed models (GLMMs), to evaluate attributes of used versus available roost sites and considered interactions between weather and land cover. We found evidence to support selection across all habitat characteristics. The effects of wind chill and precipitation on roost site selection were not supported, while land cover effects were. Our results suggested that either a factor potentially linked to land cover that we did not consider, such as predation risk, has a greater effect on selection than weather, or that wild turkeys in our study area had access to sufficient food resources to not be forced to select primarily for thermal cover when roosting.

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INTRODUCTION

The northern limits of a species' range can present a variety of challenges. Winter conditions are often much more severe than in the southern portions of the range, and spring and summer seasons, usually used for breeding and raising young, are shorter. Organisms at these northern extremes can deal with these challenges through physiological, morphological, or behavioral mechanisms. Physiologically, some species may rewarm from torpor at different rates. Bat species at higher latitudes have been shown to have higher rewarming rates (Menzies et al. 2016). Morphologically, many species follow Bergmann's rule, which states that organisms within a species grow larger at the northern extent of their range (Ashton 2002, Meiri and Dayan 2003). Behaviorally, some species may alter their habitat selection or behaviors to take advantage of more thermally protected areas within their home range. Moose (*Alces* a*lces*), for instance, have been found to avoid open areas of their home range when temperatures are above critical thresholds (Van Beest et al. 2012). Wild turkeys (*Meleagris gallopavo*; hereafter turkeys) may increase their rate of food intake as temperatures drop to compensate for elevated thermoregulatory costs (Haroldson et al. 1998), and may also select for thermal cover during winter (Rumble and Anderson 1996). Both weather and the land cover type organisms occupy may therefore affect strategies used by individuals to cope with extreme conditions at northern range limits.

Wild turkeys are found in every U.S. state other than Alaska, and have expanded their geographic range over the past half century (Niedzielski and Bowman 2015). Turkeys were historically present throughout much of their current range, but were widely extirpated due to overhunting and habitat loss. Turkeys were reintroduced to parts of their historic range and areas beyond it, and have been expanding northwards naturally as well as through translocations (Kane et al. 2007, Niedzielski and Bowman 2015). Maine is a part of the northernmost extent of current wild turkey range, and as such, sees some of the coldest temperatures experienced by the species during winter.

Turkeys roost in trees at night, which is typically the time of most extreme cold temperatures during winter. Roosting is an important part of turkey ecology as it provides protection from nocturnal ground predators, which are a major cause of death (Leman et al. 2010). Areas of otherwise good turkey habitat are less likely to be occupied if suitable roost trees are lacking, emphasizing the importance of roosts in turkey ecology (Scott and Boeker 1977, Rumble 1992). Turkey habitat selection during winter has been studied, but not always with a direct focus on roosting. Past studies have found that turkeys selected roost sites with taller trees and higher basal areas (Boeker and Scott 1969, Mackey 1984; Rumble 1992). Turkeys have been found to select softwood stands during winter (Haegan 1989), although this study did not focus on roosting, and other studies have found that pine trees (*Pinus* spp.) are selected in particular for roosting (Chamberlain et al. 2000). Turkeys have been shown to select for edge habitat during winter (Haegan et al. 1989, Holbrook et al. 1987), but these studies did not investigate roost site selection. Mackey (1984) speculated that turkeys may select for roost sites closer to the forest edge, but without conclusive statistical evidence. Many past studies of roosting ecology have been conducted in more southerly states, or have focused on different turkey subspecies. There has never been a roosting study conducted in Maine, part of the northernmost range extent of the eastern wild turkey (M. g. *sylvestris*) subspecies.

Additional to general lack of knowledge on wild turkey roosting in northern climates, we also lack information on how turkeys modify roosting behavior in response to changing land cover and variable weather. Past studies have researched how land cover composition can affect turkey survival and reproduction (Fuller et al. 2013, Pollentier et al. 2014), but not on how it affects selection of roost sites. Our specific objectives were to 1) examine the effects of forest structural characteristics (e.g. tree height, softwood percentage) on turkey roost site selection and 2) determine if weather and land cover had a moderating effect on selection. We predicted that land cover composition would affect selection for roosting attributes, particularly in areas with greater amounts of available food resources, such as those provided by human residential areas or agriculture. Haegan et al. (1980) found that turkeys selected for agricultural fields during winter as they provided one of the only reliable sources of food. We therefore expected to see land cover composition have some effect on the selection for roost site attributes. We also predicted that inclement weather would lead to the selection for more thermally protected roost sites, likely in stands with more coniferous trees (Johnson and Beck 1988). We used data from GPS-marked turkeys monitored in variable land cover compositions to analyze selection for site covariates.

STUDY AREA

This study was conducted in and around the Penobscot Valley in central Maine, USA, during two winters (2018-2019). This location features a gradient of land uses ranging from urban to rural to forested, allowing us the opportunity to study turkey roosting behavior under a variety of conditions representative of the larger region. Wild turkeys were captured at several sites, spread out among three broad study areas (hereafter central, eastern, and western; Figure. 1). The central area was located on the western side of the Penobscot River in the towns of Old Town, Orono, Bangor, and Hampden, which have a greater degree of urban-suburban land use than the surrounding area and a much higher human density (100-500+ people per square mile) (Gonnerman et al. 2019.) The western area was centered around the towns of Corinth, Charleston, and Exeter, which have a greater extent of small-scale agriculture than the other study areas and a low human density (<50-100 people per square mile) (Gonnerman et al. 2019). The eastern area was centered around the township of Greenfield, which was heavily forested and had a very low human density (<50 people per square mile) (Gonnerman et al. 2019) (Figure 1).

METHODS

Field Methods

We caught wild turkeys with rocket nets or drop nets and equipped females with Litetrack GPS transmitters (Lotek Wireless Fish and Wildlife Monitoring, Newmarket, Ontaria, CA). These GPS transmitters weighed 90 grams and were attached with a backpack-style harness (Kölzsch et al. 2016). Only females were monitored because they were marked as part of an ongoing study was examining turkey nesting ecology. Turkey locations were recorded hourly during the day, and once per night between 12 and 1 AM. We used only locations taken during the night, as we assumed that turkeys were roosting during this time. All capture and monitoring of turkeys was approved by the University of Maine Institutional Animal Care and Use Committee (IACUC Protocol A2017-11-03).

Data Management

Spatial error was present in both our turkey locations and the GIS layers of forest metrics used (described below). We had to evaluate the error of the GPS units attached to the turkeys in order to match with the scale of error of the GIS layers. We used two groups of turkeys, one from the eastern and one from the western study area, with three and five turkeys, respectively, for error calculations. We set each GPS unit to record one location per hour during the night for three nights before shifting back to recording a single location per night. Because we assumed turkeys remained roosted in a constant location overnight, variation in the recorded position of the bird should reflect imprecision in the location estimates. We were provided with 24 turkey-nights of data, collectively, with which to evaluate transmitter accuracy. We calculated a point-to-point distance matrix for each nightly cluster of points in ARCGIS pro, and calculated the mean distance among points, its standard deviation, and 95% confidence intervals. We used the upper 95% confidence limit of the distance distribution (~12.7 meters) as our measure of GPS error. Guthrie et al. (2011) found mean GPS error to be 15.5 meters, which was similar to our measured value.

We determined the dates with which to define the winter period using both turkey behavior and weather data taken from the NOAA local climatological database for the Bangor International Airport (https://www.ncdc.noaa.gov/cdo-web/datatools/lcd). Data collection began on January 1st for both years. To determine the data collection end dates for each year we used Brownian bridge motion models (Kranstauber et al. 2012) to determine turkey movement patterns and compared dates of shifting movement patterns with daily minimum temperature. Temperatures began to increase in a linear manner around March 15th for both 2018 and 2019 (Figure 2), and turkeys also began moving greater distances around this time. We chose to define this date as the end of winter for the purposes of our study, because it represented the combined time when temperatures began to steadily increase and turkeys began to move out of their winter home ranges.

We created 95% home ranges during the winter period for each turkey (Figure 3) in order to define what areas were available for roosting. We calculated separate home ranges for both 2018 and 2019 if a bird was monitored during both years. We generated home ranges by fitting a dynamic Brownian Bridge Movement Model (dBBMM) to the movement track of each marked turkey using the move package (Kranstauber and Smolla

2013) in program R (R Core team 2013). Individual 95% utilization distributions (hereafter winter home ranges) were created based on patterns of movement change that indicated areas used during the winter (Kranstauber et al. 2012). Only turkeys that were moving independently of one another were used for analysis; if two or more turkeys were observed moving alongside each other in our data (i.e. members of the same winter flock), one was selected randomly for analysis. We only used roosting points that fell within the generated home ranges in the analysis. Some past studies were limited in the number of roost sites they were able to analyze, in some cases having fewer than a dozen roost and random sites (Kilpatrick et al. 1988), but we overcame this limitation during our study by using GPS transmitters.

We acquired data detailing several forest stand metrics within our study areas using LiDAR (light detection and ranging) maps detailing each forest metric, derived and validated by Ayrey et al. (2016). LiDAR maps allow for the quantification of wildlife habitat features in high detail over large areas (Merrick et al. 2013). We used LiDAR derived maps detailing the forest metrics of New England to analyze hundreds of roost sites and thousands of random sites while still using high quality habitat data. These maps provided forest metric information at a 10m resolution. Our upper 95% confidence limit for GPS error was 12.7m, so a moving window analysis was done one pixel out, which brought the total distance considered for each data point (30m) greater than our GPS error.

Using these LiDAR derived layers, we analyzed four site covariates, average tree height, basal area, softwood percentage, and distance to the forest edge. Turkeys have been found to select for large trees (Craft 1986, Rumble 1992), and we predicted that softwood trees would be selected for given higher thermal coverage (Johnson and Beck 1988). Ruffed grouse (*Bonasa umbellus*) selected for coniferous trees in inclement weather (Thompson and Fritzell 1988), and past studies demonstrated that turkeys selected for coniferous trees, and especially pine trees (Chamberlain et al. 2000). We predicted that the distance turkeys roosted from the forest edge would be dependent on the land cover composition or weather conditions, with turkeys being more likely to roost close to the edge in areas with reliable food resources (potentially agricultural areas) and more likely to move further into the forest for thermal protection as weather became more severe.

To determine the distance of each point to the forest edge, areas of no data within the raster layers (i.e. cells with no measurable tree cover) were set to 1, with all other values set to zero. The Euclidean distance tool in ARCGIS pro was used to determine the distance to forest edge (no forest cells) for all points.

The weather data obtained from the Bangor International Airport detailed maximum, minimum, and mean daily temperatures, as well as mean and maximum wind speeds and precipitation. To evaluate the effect of changing weather on turkey roosting behavior, we combined minimum temperature and mean wind speed into a wind chill metric, which better reflected the realized minimum temperature experienced by a turkey. The minimum wind chill metric was calculated with the equation (Wind Chill = 13.12 + (.6215 x T) - (11.37 x $V^{0.16}$) + (.3965 x T x $V^{0.16}$), where T was minimum temperature and V was average wind speed. We used the previous daytime minimum wind chill as our predictor value in roost selection models, because we assumed that turkeys used information from the previous day when selecting a roost site. Chamberlain et al. (2000)

found that turkeys did not increase their movement prior to roosting, suggesting that turkeys may take account of conditions as they move throughout the day.

Land cover maps detailing areas of agriculture and developed land were obtained from the Maine Office of GIS (https://www.maine.gov/megis/catalog/index.shtml). We calculated the percentage of both agricultural and developed land uses within each turkey's home range in order to determine if either percentage had an effect on site attribute selection. Agricultural and residential areas may be associated with food resources during winter (e.g. waste grains, bird feeders) and may have an effect on selection. Agricultural land types (hereafter agriculture) included all land cover categories typically associated with agriculture such as row crops, pasture/hay, blueberry barrens, etc. Developed land types (hereafter developed) included rural, suburban, and urban residential areas as well as other forms of anthropogenic development (e.g. commercial/industrial). We selected these two broad categories because they are associated with greater available food resources during winter (e.g. Haegan et al. 1989). To determine if a full range of roost site characteristics were present in all land cover compositions, we plotted land cover composition vs. roost site characteristics. Had some characteristics not been present in certain areas (e.g. high basal area, tall trees, etc.) the analysis results may have been misinterpreted. In general, all roost site characteristics were present in all the areas that turkeys occupied.

Resource Selection Analysis

To compare used versus available roost sites, we added random points to forested areas within each home range (Figure 3). We aimed to have at least 10 times more random points than roost points within each home range (Northrup et al. 2013). We constrained our analysis to exclude cells with no LiDAR values, as they indicated that no trees were present and were therefore not available to turkeys for roosting; relatively few roost points (<1%) had to be excluded as a result of them falling in cells with no data. Many random points fell within cells with no data, but they accounted for less than 2% of total random points. The largest home range had 74 roost locations, so we added 740 random locations to each home range, and imposed a minimum distance of 12.7 meters apart, to match our upper 95% GPS error. Some home ranges were not large enough to accommodate 740 random locations, and in those cases the maximum number of random points were used that could fit, given the constrained distance.

We analyzed turkey roost site selection using resource selection functions, implemented as generalized linear mixed models (GLMMs), in program R using the lme4 package (Bates et al. 2015). We compared roost sites within each home range to the random points generated within the respective home range, and included the individual turkey ID as a random intercept term in all models. All roost site covariates were z-standardized. We ran a correlation matrix on weather and site covariates in order to ensure all covariates used in the analysis were independent of one another; variables that were highly correlated ($r>0.6$) may not have unique effects on selection. If two variables were highly correlated, only one was used in the analysis. Maximum, minimum, and average temperatures were highly correlated (Table 3), but we only used minimum temperature for our wind chill index. No other correlations with r>0.6 were found (Tables 1, 2).

We tested four hypotheses for each site covariate which related to the form of model we used to capture the relationship. First, selection would occur in a linear manner, such as for a simple positive or negative selection for a resource. Second, selection may be non-linear (e.g. a threshold), in which case a quadratic effect would capture the relationships. Third, weather would have an effect on the selection for covariates, in which case we considered an interaction between wind chill and precipitation and each covariate. Fourth, land cover composition (percentage of agriculture or developed land within each home range) would have an effect on the selection for covariates, in which case we considered an interaction between agriculture and developed land and each covariate. We ran a series of univariate linear and quadratic models for each covariate, as well as models for the interaction between the covariates (both linear and quadratic) and wind chill, precipitation, agriculture, and development. All were compared to an intercept-only null model. The land cover composition variable for human development was skewed strongly towards zero, so we applied a log transformation prior to analysis. The model with the lowest Akaike Information Criterion score (Akaike 1987) adjusted for low sample size (AICc) (Burnham and Anderson 2002) for each covariate was included in a final multivariate model. Beta estimates, standard errors, and P-values for covariates in the final model can be found in Table 3.

RESULTS

A total of 15 females were used for analysis, with three providing data only for 2018, nine for only 2019, and three for both years. This resulted in 18 unique home ranges. Home ranges varied from 0-81% developed and 0-29% agriculture. Minimum temperatures ranged from -23 to 9 C, and the wind chill index ranged from -24 to 4 C. A total of 676 roost sites were used and compared with 9920 random locations.

There was some evidence that wind chill had an effect on roost site selection, but models that included land cover composition effects were better supported for all covariates (Table 4). Effects of precipitation on selection were not supported. Development had the most support for modifying selection for softwood percentage and basal area, while agriculture had the most support for modifying selection for height and distance to forest edge (Table 4). We compiled AICc weights for the four types of models- linear, quadratic, weather effect, and land cover effect- and found that the models containing a land cover interaction effect had a much greater cumulative weight than all other model types (Table 5).

Descriptive statistics for all habitat variables for use and available points are provided in Table 6. Turkeys exhibited positive selection for taller trees in general, however the type of land cover they inhabited affected these decisions. Turkeys whose home ranges contained lower proportions of agriculture exhibited positive selection for medium height trees more than those whose home ranges contained greater proportions of agriculture. Turkeys whose home ranges contained greater proportions of agriculture exhibited positive selection for shorter and taller trees more than those whose home ranges contained lower proportions of agriculture (Figure 4a).

Turkeys whose home ranges contained greater proportions of agriculture also exhibited greater selection for distances very close and very far from the forest edge slightly more than those whose home ranges contained lower proportions of agriculture, although they exhibited positive selection for closer distances overall. Turkeys whose home ranges contained lower proportions of agriculture exhibited positive selection for medium distance from the forest edge more than those whose home ranges contained greater proportions of agriculture. Selection became increasingly linear as agricultural levels increased (Figure 4b).

Turkeys whose home ranges contained greater levels of development selected areas of lower softwood percentages than those whose home ranges contained lower levels of development. Turkeys whose home ranges contained lower levels of development exhibited positive selection for higher softwood percentages than those whose home ranges contained greater levels of development (Figure 4c).

Turkeys whose home ranges contained greater levels of development also exhibited positive selection for medium basal areas more than those whose home ranges contained lower levels of development. Selection became increasingly quadratic as the developed percentage increased, with low levels of development having generally linear positive selection for basal area (Figure 4d).

DISCUSSION

In contrast to our predictions, we found that turkeys did not appear to alter their roost site selection behaviors in response to changing weather. Maine experiences some very low temperatures during winter, and past studies have suggested that extreme winter conditions combined with low access to food can lead to major mortality events for turkeys (Haroldson et al. 1998, Kane et al. 2007). Thus it is surprising that turkeys did not alter their selection for more thermally protected areas during severe weather. There are a few possibilities for this result. We did not collect any data on predation or predator abundance, and it may be that the threat of predation had a larger effect on roost site selection than weather. Past studies have found that some bird species may alter their decisions based on predation risk (Sergio et al. 2003, Fontaine and Martin 2006). If turkeys make decisions about site selection based more on predation risk than other factors, we may not see selection based on weather conditions. Another possibility is that the turkeys we monitored were not stressed enough by the cold temperatures to force them to select for more sheltered roosts. Past studies have found that smaller birds, such as ruffed grouse, regularly select for more thermally protected roosts in inclement weather (Thompson and Fritzell 1988) as a mechanism to retain body heat and decrease net energy expenditure. Turkeys have substantially greater body mass than ruffed grouse, weighing, at a minimum, four times more, so the effects of weather may not force selection for thermally protected roosts as strongly as a result of their ability to retain body heat longer (Kuehny et al. 2014). It is also possible that the turkeys in our study areas had adequate amounts of food, as specified by Haroldson et al. (1998).

The effects of the land cover composition on roosting decisions was supported, and variation in food abundance in various land covers may help to explain why selection differed between them. Turkeys likely depend on anthropogenic food subsidies during winter in northern environments (Porter et al. 1980; Kane et al. 2007). Agricultural and urban areas are often associated with more abundant food resources (e.g. waste grains, bird feeders) during the winter than in areas that are strictly forested (e.g. Haegan et al. 1989). Turkeys living in areas with more abundant food resources may not be as dependent on specific types of roost sites, while those without as much access to food may need to be more selective. This would predict that selection would be evident most strongly in areas with low food resources. We unfortunately lacked the data to test this directly.

Our study is among the first to simultaneously evaluate the effects of land cover and weather as potential moderators of wild turkey roost selection. Some previous studies have incorporated the effects of weather and elements of land cover effects into studies of turkey resource selection, however, many of these studies did not take place entirely within the winter months, didn't study roosting, or didn't evaluate the importance of land cover in their roosting models. Past studies have shown that turkeys select softwood stands during the winter (Haegan 1989), and have even shown an increase in selection for these stands as temperatures drop (Bortner and Bennett 1980). These studies did not study roosting, however. Many studies have incorporated the distance roost sites are from water into their analysis (Kilpatrick et al. 1988, Chamberlain et al. 2000), but we chose not to include this as we assumed that most bodies of water are frozen over during the Maine winter, and are therefore not a likely water source.

There were some general trends in selection, although the percentages of developed or agricultural land within a home range altered these trends to varying degrees. Turkeys tended to select for taller trees and for higher basal area. Distances fairly close to the forest edge were selected for, as well as sites with lower percentages of softwoods. Wild turkeys have been shown to selectively use conifers, and especially pine trees for roosting (Chamberlain et al. 2000), but have not been shown to select for all softwood dominated stands in general for roosting. In the cases where this selection was found outside of roosting, the exact species composition of the softwood forests was not given (Bortner and Bennett 1980, Haegan et al. 1989). Turkeys tend to prefer fairly open areas and do not utilize dense brushy areas except for escape cover (Schroeder 1985). Dense spruce or fir cover, which is common in Maine, may not be ideal for roosting. Had there been a reliable LiDAR layer available for white pine (*Pinus strobus*) percentage, selection for this species may have been observed. It should be noted, however, that positive selection for higher softwood percentages was exhibited by turkeys whose home ranges contained lower levels of development.

We found agriculture had the most support for modifying selection for height and distance from forest edge. Turkeys whose home ranges contained greater proportions of agriculture selected mid-height trees at a lower rate than turkeys whose home ranges contained lower proportions of agriculture. The reasons behind this are not entirely clear. Turkeys whose home ranges contained greater proportions of agriculture selected for distances very close to the forest edge more than turkeys whose home ranges contained lower proportions of agriculture, and selected for medium distances much less. This suggests that turkeys may tend to roost close to agricultural fields when available within their home range. Porter et al. (1980) found that turkeys provided with additional food during periods of harsh weather had a higher survival rate than those without additional food, exemplifying how important food availability can be in winter. Eastern wild turkeys have been found to rely on agricultural fields and farms during the winter as they provide one of the only reliable sources of food (Haegan et al. 1989). Turkeys tend to stay in close proximity to fields during winter, when available (Haegan et al. 1989). It is therefore not surprising that agricultural percentage affected the selection for roost site attributes.

We found the effects of development to be most significant on the selection for basal area and softwood percentage. Turkeys in all home ranges selected for high basal areas, but turkeys whose home ranges contained lower proportions of development exhibited lower selection for very high basal areas than turkeys whose home ranges contained greater proportions of development. This may be a result of the availability of greater basal areas between home ranges with low and high development. Highly developed areas may be more likely to have mature forest stands than areas with low development, which are frequently logged in our study areas. Turkeys with more highly developed home ranges selected for stands that had a lower softwood percentage than those that had less developed home ranges. Although we did not observe increased selection for softwoods as the wind chill became colder, it could be that turkeys in areas with lower development did select for thermally protected roosts overall, potentially due to lower access to food resources in forested regions that lacked widespread anthropogenic food subsides.

Our study was presented with some limitations that may have influenced our results. For example, we could not identify the individual trees turkeys selected for roosting. Determining this would have resulted in more fine scale data about roost site use, but also would have resulted in a vastly smaller data set due to time constraints associated with field sampling. Indeed, some past studies that have identified individual roost trees have relatively few data points (Kilpatrick et al. 1988). While our study had a large volume of roost points, these points came from 18 unique home ranges, which is a fairly moderate sample size and we recognize that our inferences are restricted to this modest number of individual turkeys. Our study relied on LiDAR derived maps, a first for wild turkey roosting studies, and any error present in the LiDAR data could have been carried over to our results. Given the large number of roost points collected across a large area we believe that error present in the LiDAR layers may have added some statistical noise to our results, but systematic bias was unlikely. However, we assume a lack of bias associated with the LiDAR data. These maps restricted our ability to determine forest composition beyond hardwood-softwood, which is problematic as it is likely that certain species of trees were selected for more strongly than others. Access to maps with other forest metrics may allow future studies to create more refined resource selection models. The land cover maps we used detailed areas of development and agriculture, but combined many distinct land cover types associated with each category. Developed areas were a combination of residential, commercial, and industrial, while agricultural areas were a combination of various forms of agricultural land use. The different types of cover in each broad category likely do not have equal effects on turkey habitat selection, and this may have affected our results in some way.

MANAGEMENT IMPLICATIONS

Our results suggest that roosting sites are not likely to limit northward turkey range expansion. Selection for specific types of roost sites did not increase during periods of severe weather, suggesting that the presence or absence of specific roost characteristics may not limit expansion to colder regions. Our results also suggest that while there are general trends in winter turkey roost selection in regards to the site attributes we analyzed, this selection can be altered based on the land cover composition within individual home ranges. This may be important to consider when managing for turkey roost sites in different land cover types. In general, areas being managed for wild turkey roosts should have stands with high basal area and tall trees. The selection for softwood percentage varied more strongly based on land cover, so management for this attribute should be more case-specific. In general, land cover composition may be important to consider when managing for wild turkey roost sites.

FIGURES AND TABLES

Table 1. Correlation matrices for all weather variables: average wind speed (AWND), precipitation (PRCP), snow fall (SNOW), snow depth (SNWD), average temperature (TAVG), maximum temperature (TMAX), and minimum temperature (TMIN). Given high correlations among some variables (R>0.6), only precipitation, average wind speed, and minimum temperature were used. Weather data were from the NOAA local climatological database for the Bangor International Airport during the winters of 2018 and 2019.

	AWND	**PRCP**	**SNOW**	**SNWD**	**TAVG**	**TMAX**	**TMIN**
AWND	1	0.17	0.26	-0.03	0.13	-0.07	0.26
PRCP	0.17	1	0.48	0.22	0.14	0.14	0.13
SNOW	0.26	0.48	1	0.27	0.05	-0.07	0.14
SNWD	-0.03	0.22	0.27	1	-0.10	-0.09	-0.16
TAVG	0.13	0.14	0.05	-0.10	1	0.89	0.90
TMAX	-0.07	0.14	-0.07	-0.09	0.89	1	0.69
TMIN	0.26	0.13	0.14	-0.16	0.9	0.69	1

Table 2. Correlation matrices for all forest stand covariates: softwood percentage, basal area, height, and distance to the forest edge, as measured at wild turkey roost site locations and random locations located within wild turkey home ranges. Roost locations and home ranges were collected from GPS-marked wild turkeys monitored in central Maine during 2018 and 2019. R>0.6 indicates high correlation.

	Softwood percentage	**Basal Area**	**Height**	**Distance to Forest Edge**
Softwood percentage	1	-0.09	-0.23	0.12
Basal Area	-0.09	1	0.60	0.31
Height	-0.23	0.60	1	0.21
Distance to Forest Edge	0.12	0.31	0.21	1

Table 3. Beta estimates, standard errors, and P-values for covariates in the final model (Table 4).

	Estimate	**Std. Error**	**z value**	**Pr(>|z|)**
(Intercept)	-1.61	0.33	-4.86	1.15E-06
Height.z	0.23	0.10	2.36	0.02
I(Height.z^2)	-0.07	0.06	-1.19	0.23
Agriculture	-4.34	1.62	-2.68	0.01
Basal area.z	0.78	0.11	7.40	1.38E-13
I(Basal area.z^2)	-0.28	0.07	-3.94	8.24E-05
Development	0.04	0.02	1.79	0.07
Softwood %.z	-0.20	0.10	-2.02	0.04
I(Softwood %.z^2)	-0.39	0.08	-4.85	1.26E-06
Distance to edge.z	0.19	0.11	1.80	0.08
I(Distance to edge.z^2)	-0.42	0.09	-4.60	4.30E-06
Height.z:Agriculture	0.90	0.61	1.48	0.14
I(Height.z^2):Agriculture	0.93	0.34	2.73	0.01
Basal area.z:Development	0.02	0.01	1.84	0.07
I(Basal area.z^2):Development	-0.02	0.01	-2.56	0.01
Development:Softwood %.z	-0.02	0.01	-2.49	0.01
Development:I(Softwood %.z^2)	-0.02	0.01	-3.42	0.00
Agriculture:Distance to edge.z	-2.39	0.72	-3.31	0.00
Agriculture:I(Distance to edge.z^2)	2.12	0.52	4.06	4.89E-05

Table 4. AICc, delta AICc, AICc weight, and cumulative AICc weight scores for all candidate models. The number of variables per model is represented by K. The best model for each covariate (height, basal area, softwood percentage, and distance to the forest edge) was included in a final model

Model	K	AICc	ΔAICc	Wt	CumltvWt
Agriculture*Height^2	7	4469.63	0.00	0.69	0.69
Development*Basal area^2	7	4472.88	3.25	0.14	0.82
Height	3	4474.90	5.27	0.05	0.87
Development*Height	5	4475.54	5.92	0.04	0.91
Height^2	4	4476.12	6.49	0.03	0.93
Agriculture*Height	5	4477.1	7.47	0.02	0.95
Development*Height^2	7	4477.67	8.04	0.01	0.96
Precipitation*Height	5	4477.79	8.16	0.01	0.97
Wind chill*Height^2	7	4478.54	8.91	0.01	0.98
Wind chill*Height	5	4478.54	8.91	0.01	0.99
Agriculture*Basal area^2	7	4478.92	9.29	0.01	1.00
Precipitation*Height^2	7	4480.92	11.29	0.00	1.00
Basal area^2	4	4486.48	16.85	0.00	1.00
Precipitation*Basal area^2	7	4488.81	19.18	0.00	1.00
Wind chill*Basal area^2	7	4491.03	21.40	0.00	1.00
Agriculture*Basal area	5	4494.33	24.71	0.00	1.00
Development*Basal area	5	4497.85	28.22	0.00	1.00
Basal area	3	4501.77	32.14	0.00	1.00
Precipitation*Basal area	5	4503.62	33.99	0.00	1.00
Wind chill*Basal area	5	4505.30	35.67	0.00	1.00

Table 4 continued

Model	K	AICc	ΔAICc	Wt	CumltvWt
Development*Softwood percentage^2	7	4635.10	165.47	0.00	1.00
Agriculture*Distance^2	7	4636.07	166.45	0.00	1.00
Development*Distance^2	7	4646.30	176.67	0.00	1.00
Development*Softwood percentage	5	4653.68	184.05	0.00	1.00
Wind chill*Distance^2	7	4654.23	184.60	0.00	1.00
Distance^2	4	4659.15	189.52	0.00	1.00
Agriculture*Softwood percentage^2	7	4660.11	190.48	0.00	1.00
Wind chill*Softwood percentage^2	7	4660.26	190.64	0.00	1.00
Softwood percentage^2	4	4661.48	191.85	0.00	1.00
Agriculture*Softwood percentage	5	4662.89	193.26	0.00	1.00
Softwood percentage	3	4663.29	193.66	0.00	1.00
Precipitation*Distance^2	7	4664.91	195.28	0.00	1.00
Wind chill*Softwood percentage	5	4665.46	195.83	0.00	1.00
Precipitation*Softwood percentage^2	7	4665.79	196.16	0.00	1.00
Precipitation*Softwood percentage	5	4666.99	197.36	0.00	1.00
Wind chill*Distance	5	4699.96	230.33	0.00	1.00
Development*Distance	5	4702.30	232.67	0.00	1.00
Null	2	4703.70	234.07	0.00	1.00
Distance	3	4704.51	234.88	0.00	1.00
Agriculture*Distance	5	4704.79	235.16	0.00	1.00
Precipitation*Distance	5	4708.33	238.70	0.00	1.00

Table 5. Combined AICc weights for the four model types run, as well as the null model.

Models	Combined AICc WT
Landscape effect interactions	0.89
Weather effect interactions	0.03
Linear	0.05
Quadratic	0.03
Null	0

Table 6. Mean**,** Standard error (SD), 95% confidence intervals (95%), upper 95% confidence interval limits (Upper), and lower 95% confidence interval limits (Lower) for the four forest metrics analyzed: tree height, basal area, softwood percentage, and distance to forest edge compared between used roost sites and randomly generated points (Available). Roost locations and home ranges were collected from GPS-marked wild turkeys monitored in central Maine during 2018 and 2019

		Mean	SD	95%	Upper	Lower
Used	Height (m)	15.84	2.52	0.19	2.71	2.4
	Basal area (m^2/Ha)	25.85	7.91	0.6	8.51	7.31
	Softwood percentage	19.02	10.72	0.82	11.53	9.9
	Distance to forest edge (m)	55.14	36.78	2.8	39.57	33.98
Available	Height (m)	14.34	3.43	0.07	3.51	3.36
	Basal area (m^2/Ha)	21.28	9.02	0.19	9.21	8.83
	Softwood percentage	20.89	12.27	0.26	12.52	12.01
	Distance to forest edge (m)	59.41	49.72	1.04	50.75	48.68

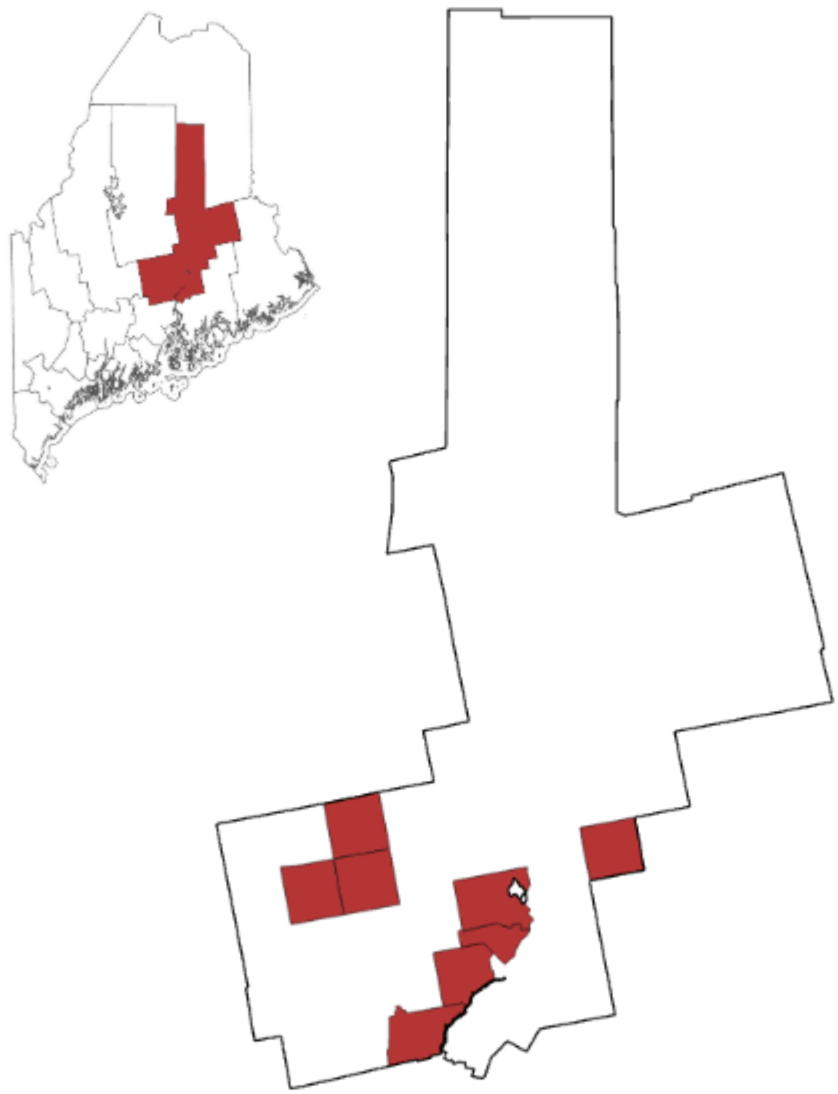

Figure 1. Map of the study area. This study was conducted in Penobscot County, Maine, USA. Captures occurred in three study areas: western, central, and eastern. The western area was centered around Exeter, Corinth, and Charleston, the central area was centered around Old Town, Orono, Bangor, and Hampden, and the eastern area was centered around Greenfield.

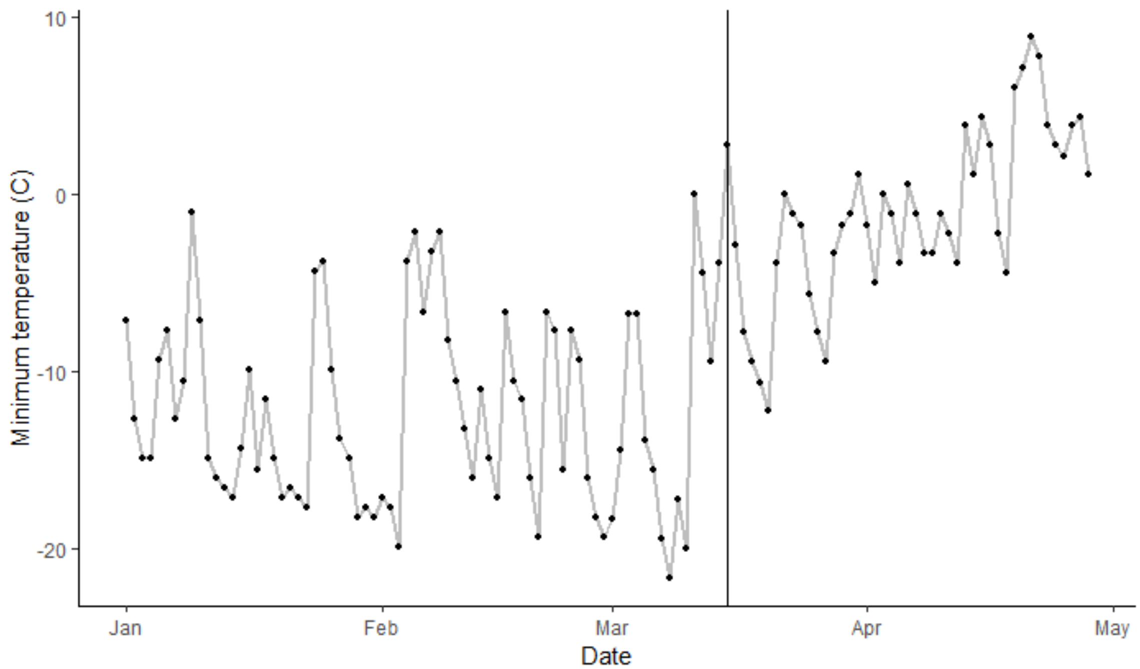

Figure 2. The minimum temperature corresponding to each day from January through April 2019. These data were used to help inform when to define the end of the winter season. Linear increase in temperature began around March 15th and is indicated by the vertical line

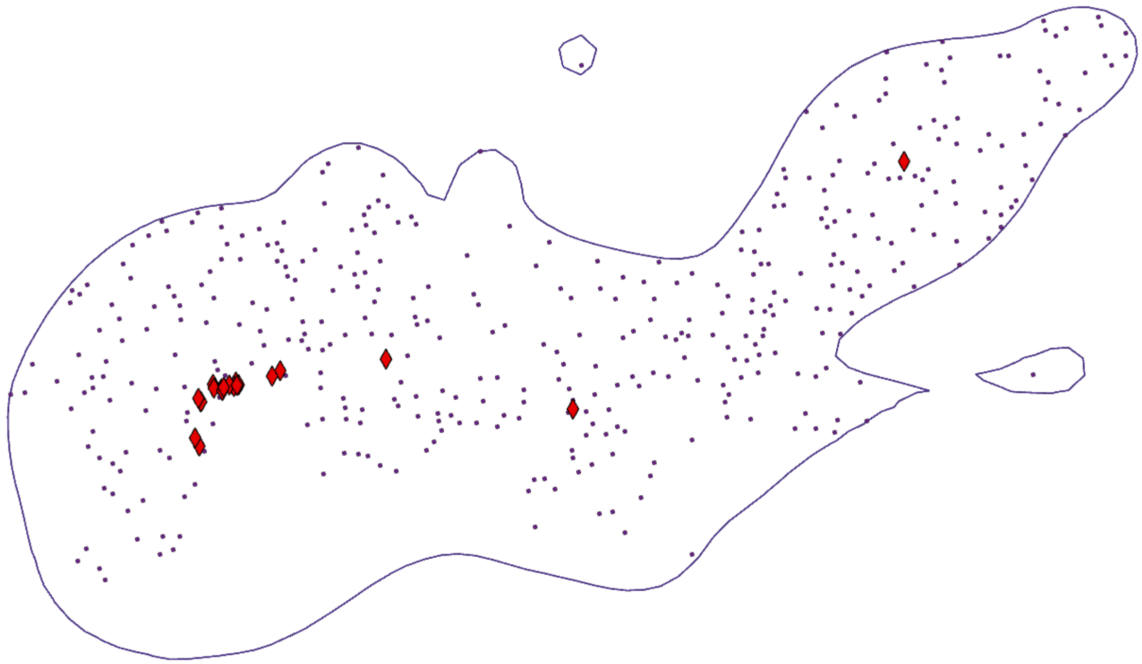

Figure 3. An example 95% home range with roost and random points included. Roost points are indicated by diamonds and random points are indicated by circles. Random points were set at minimum 12.7 meters apart and were not generated in areas with no forest metric data.

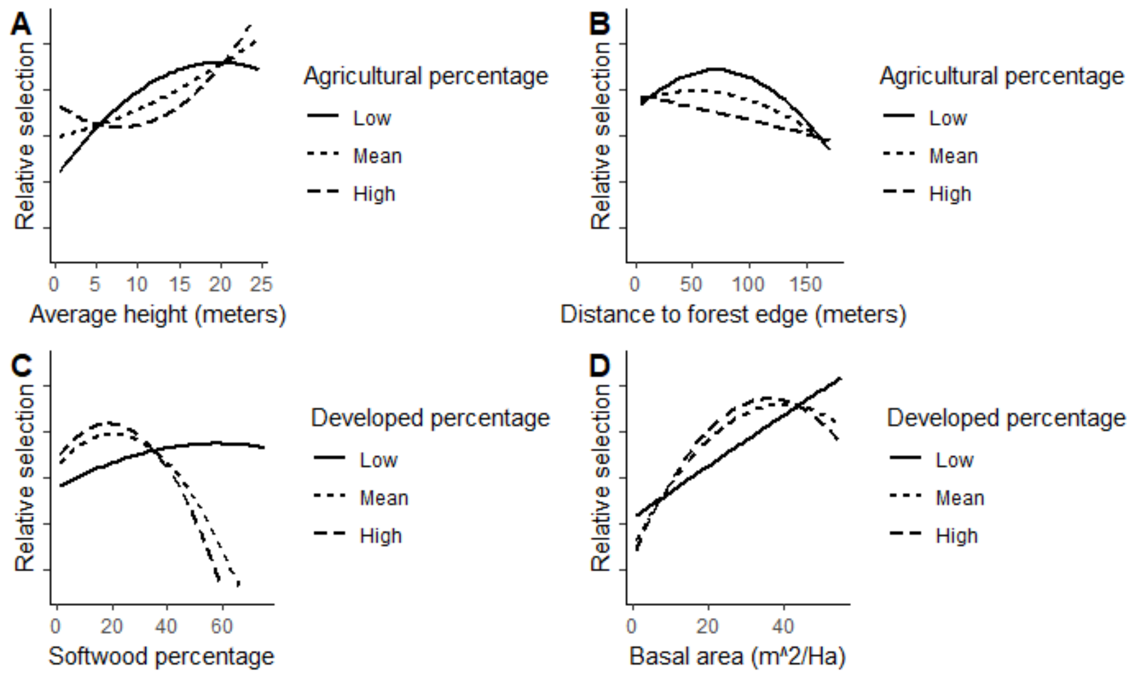

Figure 4. Relative selection for each covariate: average height (A), Distance to the forest edge (B), softwood percentage (C), and basal area (D). The best supported model for each covariate include an interactive effect with either agriculture or development. The effects of agriculture were best supported for height and distance to forest edge and the effects of development were best supported for basal area and softwood percentage

WORKS CITED

Akaike, H. 1987. Factor analysis and AIC. Psychometrika, 52(3): 317-332.

Ashton, K. G. 2002. Patterns of within-species body size variation of birds: strong evidence for Bergmann's rule. Global Ecology and Biogeography, 11: 505-523.

Ayrey, E., S. Fraver, J. A. Kershaw Jr, L.S. Kenefic, D. Hayes, A. R. Weiskittel, and B. E. Roth. 2016. Layer Stacking: A novel algorithm for individual forest tree segmentation from LiDAR point clouds. Canadian Journal of Remote Sensing, 43: 16-27.

Bates, D., M. Maechler, B. Bolker, and S. Walker. 2015. Fitting linear mixed-effects models using lme4. Journal of Statistical Software, 67: 1-48.

Boeker, E. L., and V. E. Scott. 1969. Roost tree characteristics for Merriam's turkey. The Journal of Wildlife Management, 33: 121.

Bortner, J. B., and J. W. Bennett. 1980. Observations of wild turkey winter range at Snake Mountain, Vermont. Trans. Northeastern Sect. Wildl. Soc., 37:243-248. Cited from Schroeder et al. 1985.

Burnham, K. P., and D. R. Anderson. 2002. Model selection and multimodel inference. Colorado State University, Fort Collins, Colorado, USA.

Chamberlain, M., B. Leopold, and L. Burger. 2000. Characteristics of roost sites of adult wild turkey females. The Journal of Wildlife Management, 64: 1025-1032.

Craft, R. A. 1986. Characteristics and use of wild turkey roost sites in southcentral South Dakota. Thesis. South Dakota State University.

Fontaine, J. J., and T. E. Martin. 2006. Parent birds assess nest predation risk and adjust their reproductive strategies. Ecology Letters, 9: 428-434.

Fuller, A. K., S. M. Spohr, D. J. Harrison, and F. A. Servello. 2013. Nest survival of wild turkeys *Meleagris gallopavo silvestris* in a mixed-use landscape: influences at nest-site and patch scales. Wildlife Biology, 19: 138-146.

Gonnerman, M., S. Shea, P. Kamath, E. Blomberg, and K. Sullivan. 2019. Unpublished Technical Report.

Guthrie, D. J., M. E. Byrne, J. B. Hardin, C. O. Kochanny, K. L. Skow, R. T. Snelgrove, M. J. Butler, M. J. Peterson, M. J. Chaimberlain, and B. A. Collier. 2011. Evaluation of a global positioning system backpack transmitter for wild turkey research. The Journal of Wildlife Management, 75: 539-547.

Haegen, W. M. V., M. W. Sayre, and W. E. Dodge. 1989. Winter use of agricultural habitats by wild turkeys in Massachusetts. The Journal of Wildlife Management, 53: 30.

Haroldson, K. J., M. L. Svihel, R. O. Kimmel, and M. R. Riggs. 1998. Effect of winter temperature on wild turkey metabolism. The Journal of Wildlife Management, 62: 299.

Holbrook, H. T., M. R. Vaughan, and P. T. Bromley. 1987. Wild turkey habitat preferences and recruitment in intensively managed piedmont forests. The Journal of Wildlife Management, 51: 182.

Johnson, R. J., and M. M. Beck. 1988. Influence of shelterbelts on wildlife management and biology. Agriculture, Ecosystems & Environment, 22: 301-335.

Kane, D. F., R. O. Kimmel, and W. E. Faber. 2007. Winter survival of wild turkey females in central Minnesota. The Journal of Wildlife Management, 71: 1800-1807.

Kilpatrick, H. J., T. Husband, and C. Pringle. 1988. Winter roost site characteristics of eastern wild turkeys. The Journal of Wildlife Management, 52: 461–463.

Kölzsch, A., M. Neefjes, J. Barkway, G. J. D. M. Müskens, F. van Langevelde, W. F. de Boer, H. H. T. Prins, B. H. Cresswell, and B. A. Nolet. 2016. Neckband or backpack? Differences in tag design and their effects on GPS/accelerometer tracking results in large waterbirds. Animal Biotelemetry, 4:13

Kranstauber, B., R. Kays, S. Lapoint, M. Wike, and K. Safi. 2012. A dynamic Brownian bridge movement model to estimate utilization distributions for heterogeneous animal movements. Journal of Animal Ecology 81:738-746

Kuehny, G., B. Hendrickson, S. Kimbrough, J. Kaplan. 2014. Bulky badger heat retention: the relationship between surface area to volume ratios and thermoregulation. Journal of Introductory Biology Investigations, 1.

Leman, C. P., D. J. Thompson, and M. A. Rumble. 2010. Ground roost resource selection for Merriam's wild turkeys. Journal of Wildlife Management, 74: 295-299.

Lotek. Pinpoint GPS VHF for birds and bats. <lotek.com/products/pinpoint-gps-vhf/>. Accessed 21 Nov 2019.

Mackey, D. L. 1984. Roosting habitat of Merriam's turkeys in south-central Washington. The Journal of Wildlife Management, 48: 1377.

Meiri, S., and T. Dayan. 2003. On the validity of Bergmann's rule. Journal of Biogeography, 30: 331-351.

Menzies, A. K., Q. M. R. Webber, D. E. Baloun, L. P. McGuire, K. A. Muise, D. Coté, S. Tinkler, and C. K. R. Willis. 2016. Metabolic rate, latitude and thermal stability of roosts, but not phylogeny, affect rewarming rates of bats. Physiology & Behavior, 164: 361-368.

Merrick, M. J., J. L. Koprowski, and C. Wilcox. 2013. Into the third dimension: benefits of incorporating LiDAR data in wildlife habitat models. In: Gottfried, Gerald J.; Ffolliott, Peter F.; Gebow, Brooke S.; Eskew, Lane G.; Collins, Loa C. Merging science and management in a rapidly changing world: Biodiversity and management of the Madrean Archipelago III and 7th Conference on Research and Resource Management in the Southwestern Deserts; 2012 May 1-5; Tucson, AZ. Proceedings. RMRS-P-67. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. p. 389-395.

Niedzielski, B., and J. Bowman. 2015. Survival and cause-specific mortality of the female eastern wild turkey at its northern range edge. Wildlife Research, 41: 545-551.

Northrup, J. M., M. B. Hooten, C. R. Anderson Jr, and G. Wittenmyer. 2013. Practical guidance on characterizing availability in resource selection functions under a use–availability design. Ecology, 94: 1456-1463.

Pollentier, C. D., R. S. Lutz, and S. D. Hull. 2014. Survival and productivity of eastern wild turkey females in contrasting landscapes in Wisconsin. Journal of Wildlife Management, 78: 985-996.

Porter, W.F., R. D. Tangen, G. C. Nelson, and D. A. Hamilton. 1980. Effects of corn food plots on wild turkeys in the upper Mississippi valley. The Journal of Wildlife Management. 44: 456-462.

R Core Team. 2013. R: A language environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. http://www.R-project.org/

Rumble, M. A., and S. H. Anderson. 1996. Microhabitats of Merriam's turkeys in the Black Hills, South Dakota. Ecological Applications, 6: 326–334.

Rumble, M. A. 1992. Roosting habitat of Merriam's turkeys in the Black Hills, South Dakota. The Journal of Wildlife Management, 56: 750.

Schroeder, R. L. 1985. Habitat suitability index models: eastern wild

turkey. U.S. Fish and Wildlife Service. Biological report 82

Scott, V. E., and E. L. Boeker. 1977. Responses of Merriam's turkey to pinyon-juniper control. Journal of Range Management, 30: 220.

Sergio, F., L. Marchesi, and P. Pedrini. 2003. Spatial refugia and the coexistence of a diurnal raptor with its intraguild owl predator. Journal of Animal Ecology, 72: 232-245.

Thompson III, F. R., and E. K. Fritzell. 1988. Ruffed grouse winter roost site preference and influence on energy demands. The Journal of Wildlife Management, 52: 454-460.

Van Beest, F. M., B. Van Moorter, and J. M. Milner. 2012. Temperature-mediated habitat use and selection by a heat-sensitive northern ungulate. Animal Behaviour, 84: 723-735.

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