ROOSTING SELECTION BEHAVIOUR OF THE EASTERN WILD TURKEY AT ITS NORTHERN RANGE EDGE

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ABSTRACT

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As wild turkeys (*Meleagris gallopavo silvestris)* move farther north, informed management decisions are critical to support the sustainability of this reintroduced species. We tracked roost tree selection and patterns of the network of roost trees, for wild turkeys, over 2 years in Peterborough, ON, using GPS and VHF transmitters. Wild turkeys showed preference for taller and larger roost trees, with winter roosts closer to buildings. The roost network exhibited a scale-free network, meaning certain roosts served as hubs, while other roosts were less frequently used. The fine scale results suggest that roost trees are selected for predator avoidance, and that selection changes with the season, probably because of its influence on foraging ability. At a larger scale, winter roosts were chosen for their proximity to supplemental food sources. These findings demonstrate the dependence of wild turkeys on humans and the supplemental sources we unintentionally provide.

KEY WORDS: Eastern wild turkey, *Meleagris gallopavo silvestris*, roosting selection, northern range edge, network, binomial logistic regression

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CHAPTER 1: GENERAL INTRODUCTION

The success of species may, in part, be explained by understanding the evolutionary basis of behavioural adaptations to specific ecological pressures. Roosting is a behaviour where a group of individuals, usually of the same species, congregate in an area for a certain period of time (Beauchamp 1999). Roosts are the locations where these congregations occur. Roost locations can change frequently, or individual roosts may be used consistently for longer periods of time. The behaviour of communal roosting is thought to have several potential benefits: reduced thermoregulation costs, decreased predation risk, and increased foraging efficiency (Beauchamp 1999). For many species however, the origins and the main reasons for communal roosting remain unclear.

There are three main hypotheses that aim to explain why communal roosting evolved. The first is the Information Center Hypothesis (Ward and Zahavi 2008) which states that roosts act as information sharing centers for food source locations. The second is the Two Strategies Hypothesis which builds off of the first hypothesis by suggesting that individuals in a roost are there for at least two different reasons dependent on their social status (Weatherhead 1983). For example, lower status individuals take lower quality roost perches in exchange for benefitting from knowledgeable individuals who lead them to the higher quality foraging locations. The higher status individuals gain the higher quality perch locations in exchange for showing the lower status individuals where to forage. These high quality perch locations within a roost benefit the higher status individuals by providing protection from not only predators, but also protection from the weather and increasing their thermoregulation abilities (Weatherhead and Hoysak 1984, Adams et al. 2000). The final hypothesis, The Recruitment Centre Hypothesis (Richner and Heeb 1996) states that recruiting new members benefits the flock as a whole through predator dilution and increased foraging.

There are many potential benefits to roosting communally, but there are also some risks. Territorial species have to travel to and from roosts, opening up the opportunity for territory takeovers. Roosts may also be beneficial for decreasing the risk of predation by being in large groups with more chances of an individual spotting a predator, but those large congregations of individuals could also attract predators (Beauchamp 1999). Staying in large groups also increases food competition, increases the chances for diseases and parasites to spread in a population, and plumage deterioration from droppings by individuals above in the roost (Weatherhead 1983). Even with these potential costs of communal roosting, the behaviour persists, meaning that in some contexts the benefits of roosting must outweigh the costs. Therefore, understanding the importance of the roosting benefits to a species could help to further understand the evolution of the behaviour.

The complexity of interactions between individuals living or interacting with each other can provide a deeper understanding of the species itself. Individuals that interact with one another can create interesting relationships and social connections. Discovering those connections and patterns in a biological system can help to better understand the community- and ecosystem-level properties. The study of networks, where there are nodes with connections (links) between them, has been used widely to understand those community- and ecosystem-level properties (Proulx et al. 2005, Wey et al. 2008, Aplin et al. 2012, Farine et al. 2015). For example, the nodes within a network can be individuals within a population, and the network can help to describe the transmission of a disease within that population with the connections between each individual being an edge in the network. Nodes can also be specific locations within a system, with the network highlighting hub locations based on the links being the individuals moving between those locations.

With the increasing availability of biological data, we now are able to look at the networks that can be found at most, if not all levels in biological systems. Networks are being used to represent ecological systems because of their ability to identify and highlight features within a system (May 2006, Farine 2017). Network studies represent issues of centrality; which is how connected some features are to others and what that influence is, and connectivity; which is what is being connected to something else through the network (Newman 2003).

Using network analysis, one is able to look at association or interaction data to address broad biological questions, like mating behaviour, genetic networks, interspecific interactions, and help to describe elements such as the social structure of a system (Farine and Whitehead 2015).

Past research on roosts has often focused on specifics at the roost, mainly focusing on the characteristics of a roost as a single unit (e.g., tree species, height, DBH, etc.). Visualizing the network of roosts used can help to show patterns and highlight important roost locations. Communal roosting is common in almost all birds, as well as many other taxa like bats (Beauchamp 1999, Reckardt and Kerth 2007), and using network analysis as a method to determine structure of roosting groups in populations and find potentially critical roosting sites will be beneficial for conservation of those roosting species, especially with species at risk for indicating critical habitat (Watts and Dyer 2018). Taking it one step further by linking selection of roost sites and their specific characteristics with their importance in the network of roosts will improve our understanding of roost selection even further.

Wild turkeys (*Meleagris gallopavo)* historically were common in forests of southern Ontario, before human settlement, as far north as Lake Simcoe (44.4636° N). The pressures from unregulated deforestation and hunting resulted in the population becoming extirpated from Ontario by 1909 (Ontario Ministry of Natural Resources 2007). Starting in 1984, the provincial government, Federation of Ontario Naturalist, and the Ontario Federation of Anglers and Hunters began a reintroduction program, distributing over 4400 turkeys across

275 sites in the province (Ontario Ministry of Natural Resources 2007). Their reintroduction was so successful that by 1987 a spring hunting season was introduced, followed by a fall hunting season in certain areas by 2008.

Today, wild turkeys are a common sight in agricultural fields across southern Ontario, and the birds have spread north past their historical range. Their ability to adapt post-reintroduction is a well-known success story, and turkeys have economic value as a game species (Ontario Ministry of Natural Resources 2007). However, as they continue to move farther north, inhabiting areas that historically they never occupied, the need for well-informed management decisions at the species' northern range is important to maintain a healthy, harvestable population. Discovering how wild turkeys use tree roosts as social hubs will help increase understanding of the evolutionary adaptation and persistence of communal roosting.

Our study area in Peterborough, Ontario is near the wild turkeys' northern range edge and is an interesting location to study the species for many reasons (Ontario Ministry of Natural Resources 2007). Currently, most studies on winter biology of wild turkeys comes from the United States in states such as Massachusetts, and Minnesota as examples (Vander Haegen et al. 1989, Kane et al. 2007, Restani et al. 2009). Furthermore, the energetic demands on northern species make winter a stressful time, and turkeys in Ontario are experiencing a different climate and habitat than turkeys who live at lower latitudes. The winter stresses of low temperatures, limited food supplies, and limited foraging times add to other common stresses. One of the proposed benefits of roosting is improved thermoregulation, as birds could huddle together in a tree to keep warm, and possibly even select a roost tree that is better at protecting them from the weather (Beauchamp 1999, Adams et al. 2000, McGowan et al. 2006).

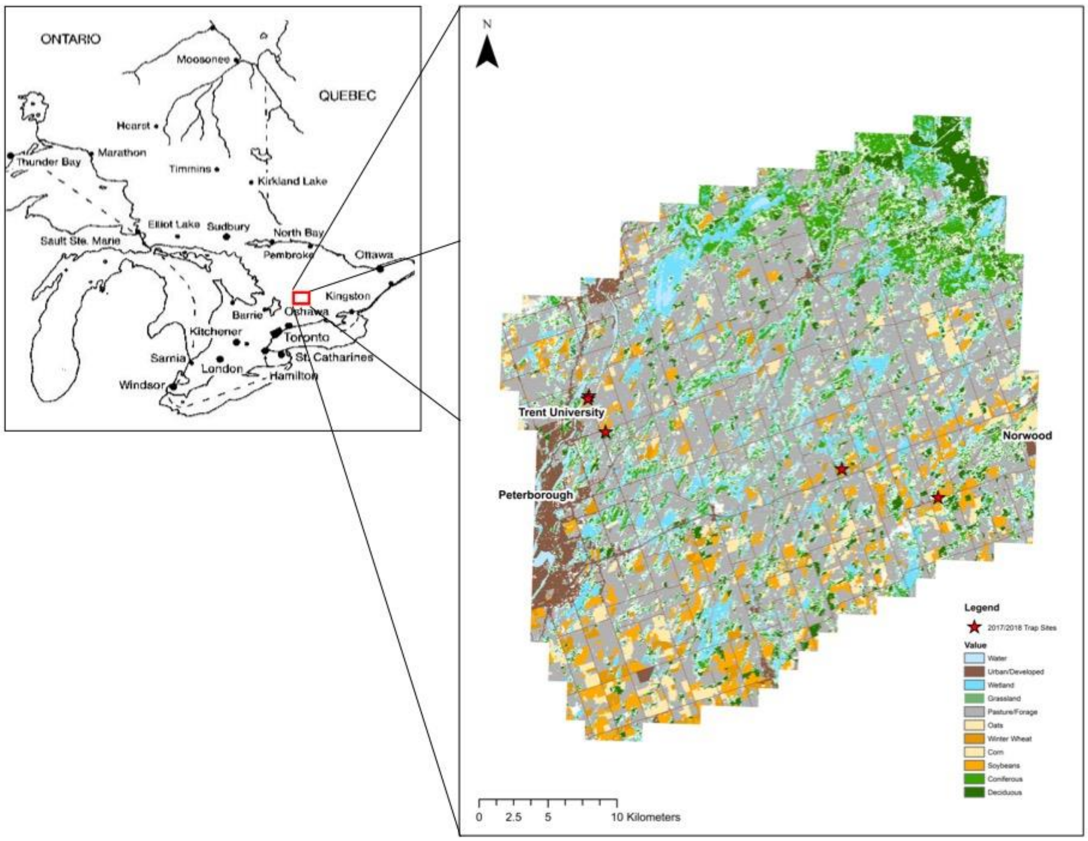

Figure 1. Map of study area with 2017 and 2018 trap sites (red stars) in Peterborough ON, Canada.

The main objectives of my research were to explore the roosting behaviour of wild turkeys and link roosting behaviour to social and survival strategies at their northern range edge. We used a population of turkeys that were trapped using rocket nets and outfitted with GPS or VHF tags to obtain location information for detailed information on their roost use. In my second chapter, I will look at the seasonality of roost use and its relation to thermoregulation properties of the roost. In the third chapter, I will build off of the second chapter by looking at the roosting network of the wild turkey to highlight disproportional use of roosts in the network and look further into seasonal patterns. In the final discussion chapter I will summarize my findings from the second and third chapter and discuss implications and future research possibilities.

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CHAPTER 2: SEASONAL ROOSTING SELECTION

ABSTRACT

We tested the hypothesis that multiple benefits exist for roost tree selection by wild turkeys, including thermoregulation, resource acquisition, and protection from predators. We compared 48 roost trees used by eastern wild turkeys (*Meleagris gallopavo silvestris*) in Peterborough County, Ontario to 48 non-roost trees between 2017-2019 to determine roost site selection between seasons and selection of roost characteristics. The mean roost tree heights were taller than the non-roost locations, and were also larger in diameter at breast height. Using ibuttons to collect microclimate temperatures at the tree, we found that mean temperature (± SE) at deciduous roosts (14.5 ± 0.09°C) were higher than temperatures at either coniferous trees (13.9 ± 0.09°C) or ambient (13.2 ± 0.09°C) during the summer months. In winter we did not find any significant effect of tree type on temperature. Roosts were closer to buildings (150.8 ± 26m) in the winter compared to summer and year-round roosts, and winter roosts were also farther away from crops (395.2 ± 63.7m) compared to roost sites used year round. Summer roosts were closer to roads (143 ± 36.3m) than the roosts in the winter and roosts used year-round. Our data showed that thermoregulation might not be the driving force behind roost selection, but that resource acquisition and predator avoidance may play a more important role in roost tree selection.

2.1 INTRODUCTION

Communal roosting can have long-term benefits such as information gathering and mate acquisition (Blanco and Tella 1999) as well as short-term benefits like thermoregulation, predator avoidance, and social status (Draulans and Vessem 1986, Summers et al. 1987, Bishop and Groves 1991, Buckley 1998). There are three main hypotheses that aim to explain why communal roosting occurs. The first is the Information Center Hypothesis (Ward and Zahavi 2008) which states that roosts act as information sharing centers for food source locations. The second is the Two Strategies Hypothesis which builds off of the first hypothesis and proposes that individuals in a roost are there for multiple different reasons dependent on their social status (Weatherhead 1983). A higher social status could allow individuals to benefit from higher quality perch locations that provide predator avoidance, and increased thermoregulation as a trade-off for informing the lower status individuals where the resource locations are. The final hypothesis, the Recruitment Centre Hypothesis (Richner and Heeb 1996) states that recruiting new members benefits the flock as a whole through predator dilution and increased foraging.

Neither the Information nor Recruitment Centre Hypotheses explain the benefits of helping out the naive members, as more members in the flock also increase disease and parasitism, leading to increased costs for the successful forager (Beauchamp 1999). Furthermore, in cooperatively breeding species, the priority of communal roosts is unlikely to be related to recruitment centres since roosts tend to be cohesive family- based units that already spend all their time together

(McGowan et al. 2006). However, consistent with the Two Strategies Hypothesis, it is likely that cooperative species benefit from communal roosts for multiple reasons, such as both thermoregulation and resource acquisition, as higher-ranking individuals would gain higher quality perch locations within a roost in exchange for resource information. Specifically in relation to thermoregulation, energetic savings of communal roosting can be as high as 37% compared to solitary roosting, as seen in Acorn Woodpeckers (*Melanerpes formicivorus*) in California (Du Plessis et al. 1994). Because of these benefits, seasonal differences in the quality of the roosts might be expected.

Winter survival for animals in the northern latitudes is difficult, mainly because of restricted access to food, longer nights, and colder temperatures. Minimizing their nocturnal energy expenditure is critical in order to increase their fasting endurance as lower temperatures require greater energy and food use to maintain thermoregulation (Paclík and Weidinger 2007). Selecting favorable roost sites and the act of communal roosting are two mechanisms available to save energy (Calf et al. 2002, Tattersall et al. 2016). During winter, diurnal birds tend to spend more time roosting during the day than during the summer, and also, of course, experience lower night-time temperatures.

As endotherms, birds maintain relatively constant body temperatures, and are able to increase their body temperatures by generating heat within their tissues instead of relying on heat gained from their environment. The temperatures in the summer could also play a role in roosting selection, as birds do not have sweat glands, and they rely on evaporative cooling. For example, Buchholz

(1996) found that wild turkey (*Meleagris gallopavo*) heads are used to help dissipate heat during high temperatures. During the summer, behavioural strategies such as avoiding heat can lead to energetic savings.

Many communal roosting avian species have shown differences in their selection of roost sites, as well as perch sites within the roost location. Yackel Adams et al. (2000) found that bald eagles relocate within roosts to obtain favorable microclimate conditions when subject to cold stress, with most evening relocations moving to the centre of the roost and the frequency of the relocations increased as temperatures decreased. Stalmaster and Gessaman (1984) also found that eagles roosted in conifers for improved microclimate advantages. Swingland (1977) saw rooks (*Corvus frugilegus*) seeking better microclimate locations, specifically the leeward side of roosts as determined by wind speed, direction, and temperature, when weather conditions deteriorated. One study, completed in 2001 in Ontario, examined winter roost selection of wild turkeys after a northern introduction and found they selected mostly conifers and linked that selection to the likelihood of the trees to reduce impacts of wind and heat loss to the birds (Nguyen et al. 2004).

The eastern wild turkey, *M. g. silvestris*, roosts communally year-round, in trees, with the exception of the period when females are nesting. It has been proposed in various studies that turkeys choose roosts based on the benefits of being close to foraging sites, close to water, protection from predators, and, finally, because of thermoregulatory benefits (Boeker and Scott 1969, Kilpatrick et al. 1988, Rumble 1992, Chamberlain et al. 2000). However, there are few studies looking at roosting selection by wild turkeys at the edge their northern range. Nguyen et.al (2004) found that roost site selection near Sudbury Ontario, was related to species composition and tree height, and that the availability of tall trees was critical for successful introductions.

Information on roosting behaviour for eastern wild turkeys comes from more studies in the southern and central part of their range. A study in Rhode Island looking at roost site selection found selection by wild turkeys of larger DBH trees, trees close to open water, and white pines (*Pinus strobus*) (Kilpatrick et al. 1988). Winter survival in Minnesota, has been linked to roost site selection near supplemental food sources, such as waste grain from agricultural activities (Kane et al. 2007). Similar results were found in Massachusetts during the winter where flocks restricted their movements by selecting roost sites that were close to pastures and fields spread with manure (Vander Haegen et al. 1989). We were interested in selection of roost trees by wild turkeys in Ontario, specifically the characteristics of roosts selected, and also the relationship of the roost site to the resources around it, and the potential for seasonal changes.

Figure 2. Approximate range of the eastern wild turkey in Ontario.

Our study site, in Peterborough Ontario, is near the northern edge of the eastern wild turkey's geographic range (Figure 2). The winters can be severe with low temperatures, and more snowfall than what turkeys experience in the core parts of their range. It has been found that winter survival is a limiting factor for sustainable populations of wild turkeys in northern latitudes (Kane et al. 2007). Understanding roost tree selection during the winter may help to test whether thermoregulation is a driver of communal roosting behavior in turkeys, and may be linked to their survival and success as a reintroduced species in their northern range. The need for roost sites that increase survival, especially during the winter months when resources are limited, might outweigh the cost of sharing roost information with others when members receive a variety of communal benefits. This idea would support the Two Strategies Hypothesis, since we expect that multiple different benefits arise from the communal roost. We hypothesize that multiple benefits exist for roost selection by wild turkeys, including thermoregulatory, resource acquisition, and predator protection benefits. We predict that roosting locations change based on the seasons, and that winter roosting sites have better thermoregulation properties than summer roost sites. Finally, we predict that winter roost sites will be in close proximity to food resources.

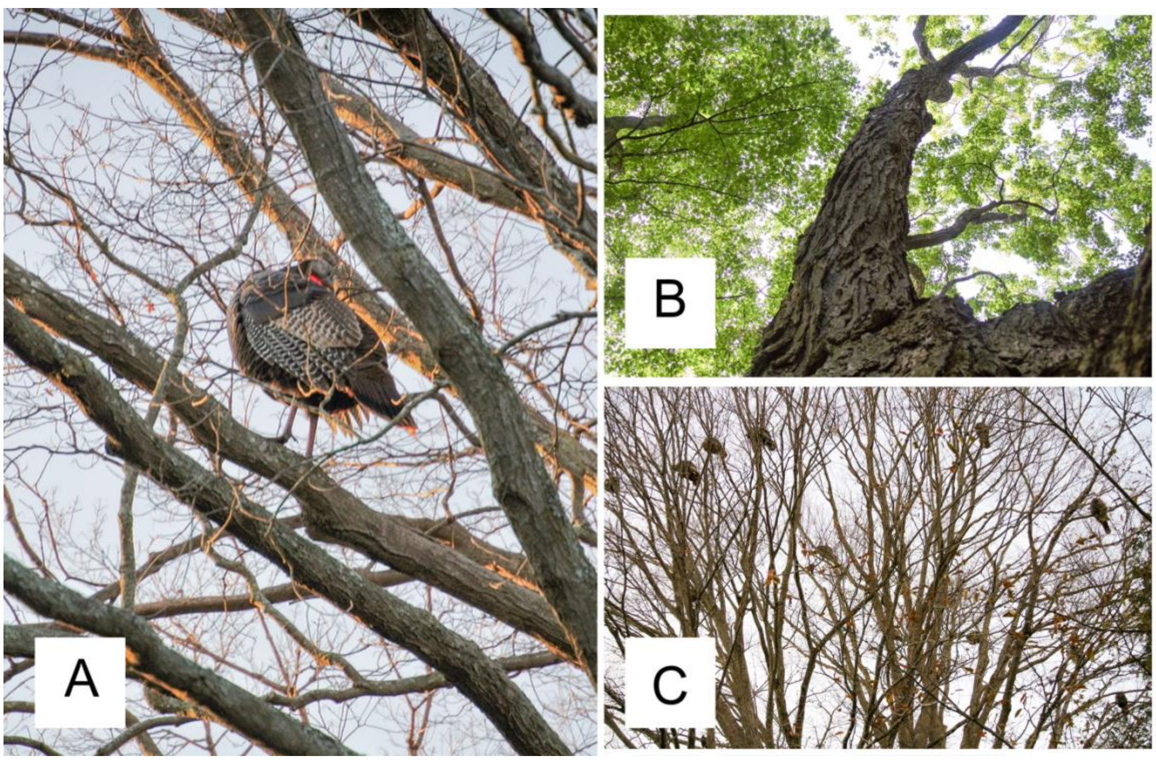

Figure 3. A. Wild turkey preening in a roost tree. B. One of the most used roost trees in our study area. C. A flock of turkeys perched in their roost. All photos were taken in our study site at a Sugar maple (Acer saccharum) roost tree that was heavily used.

2.2 METHODS

Wild turkeys were trapped using rocket nets (Grubb 1988) between January and March of 2017 and 2018, in open fields with bait piles consisting of corn. Locations to trap were based on driving surveys of the larger study area in Peterborough County and locating flocks of wild turkeys that were fairly consistent in their daily movements and flock size. We also needed landowner permission and a safe area to operate a rocket net. Our study area consisted of mainly agricultural fields, mixed forests, wetlands, active farming properties, as well as deciduous and coniferous trees lining properties. Trapping in the winter allowed us to target larger flocks and increase our chances of deploying GPS and VHF tags on an equal number of males and females. Capture and handling methods were in compliance with the Animal Care Committee protocols at Trent University.

To track turkey movements we used GPS transmitters (model PinPoint VHF-3600L, Ontario, Canada) weighing 85 g (<3% average weight of an adult hen, average mass = 4.3kg). Transmitters were attached using a backpack-style harness made of shock cord (Norman et al. 1997). The tags were programmed to collect GPS locations (±19.9m from our field trials, Appendix A) at various schedules. In 2017, locations were collected every 4 hours and 15 minutes for 24 tags. In 2018 locations were collected every hour between 6:30am and 10:30pm and once at 12am and then again at 4am for 21 tags. The total sample included 45 turkeys: 24 adults, 20 juveniles, 22 males, and 23 females.

Roost trees were found during the day by ground truthing nocturnal GPS locations for each turkey and locating roosts, where it could have only been used for one night, or multiple nights. The roost tree was then confirmed by the presence of fecal dropping, or feathers around the base of the tree. Morphological measurements were collected at the tree, including tree height (m), and lowest branch to ground (m) using an electronic clinometer (model Haglof HCH, Haglof, Sweden). The trunk's diameter at breast height (1.3m) was taken using diameter tape (C.F.E. Equipment Norfolk, Virginia) and the tree species was identified. Aspect and slope were collected at sites where the roost tree was on a slope, and the aspect was taken by the direction the slope was facing, based on previous research suggesting morning sun could affect their roosting selection (Boeker and Scott 1969, Donázar and Feijoo 2002). Those same morphological measurements were taken for a non-roost tree at a systematically chosen, potentially available location, determined by going 50m north of the roost location and selecting the closest tree that was > 20cm trunk, diameter at breast height (DBH), as this was the smallest tree we had seen actively being used as a roost. Hereafter we refer to these systematically selected trees as random trees. Using ArcGIS, we determined the distances to road, water, crop, building, and livestock for each roost and random location. We used the Ontario Land Cover Database (Ontario Ministry of Natural Resources and Forestry 2014) for water and forest type, and used Land Information Ontario basemaps for roads, crops, and buildings (Provincial Mapping Unit 2017, Agriculture and Agri-Food Canada 2018, Graham 2019). Livestock locations were found and noted by driving our study area and creating a map using ArcGIS (Baici 2021).

To collect temperatures at the roost, we used 10 ibutton temperature sensors (model Maxim Integrated DS1922L, San Jose, California). Five ibuttons were placed in a coniferous roost tree (eastern white cedar, *Thuja occidentalis*), and 5 ibuttons were placed in a deciduous roost tree (Sugar maple, *Acer saccharum*). The ibuttons were placed in locations within the tree to mimic locations where the turkeys might perch within the roost. One was placed at the lowest branch close to the trunk, one in the middle of the tree close to the trunk, the third closest to the top of the tree and the trunk, and the fourth and fifth were placed at the farthest point on the eastern and western facing branches respectively. The ibuttons were installed in July of 2018 and were collected in February of 2019, taking temperature data every hour for 212 days, at a schedule of collecting temperature data every hour. The ibutton data was averaged between the 5 ibuttons placed in each tree, and then filtered down to its night time (10pm-5am) temperature data. Ambient temperature was taken from the Trent University weather station as it was the closest weather station to our study site (Canada 2019). A Kruskal-Wallis test was used to test for temperature differences between the coniferous and deciduous tree during the winter and summer months.

We divided the year into two seasons, winter and summer, where winter occurred between November 1st and April 30th, and summer between May 1st to October 31st. The seasons were divided in this way to include the majority of low temperatures in the winter and the high temperatures in the summer, similar to the study done in Quebec by Lavoie et.al.(2017). This division also aligns with turkey behaviour where birds flock up in large groups beginning in November, and then begin to separate out into smaller groups for breeding by May. Roosts were categorized as a winter roost if 90% or more of the total GPS locations (pooled across all birds) occurred during the months of November – April. The same rule was applied to categorizing summer roosts for points at roosts between the months of May – October.

A binomial logistic regression, performed in RStudio v 1.2.1 (RStudio Team 2018) was used to test for differences between characteristics of roost trees and random trees. We evaluated coefficients of the global model to test our hypotheses and to gain insight into selected roost characteristics. The Kruskal Wallis test was used in order discover statistical significance of roosts in relation to season, and then the Wilcoxon tests were used to compare roost characteristics between each season. The Kruskal Wallis one way analysis of variance was used to determine statistical significance in the ibutton temperature data.

2.3 RESULTS

A total of 48 roosts were located and sampled over the 2-year study period. Eleven species of trees were used as roost sites, including American beech (*Fagus grandifolia)*, American elm (*Ulnus americana*), Black ash (*Fraxinus nigra*), Basswood (*Tilia americana*), Black locust (*Robinia pseudoacacia*), Eastern white cedar (*Thuja occidentalis*), Large tooth aspen (*Populus* *grandidentata*), Norway maple (*Acer platanoides*), Manitoba maple (*Acer negundo*), Sugar maple (*Acer saccharum*), and Trembling aspen (*Populus tremuloides*). In total, 51% of the roosts were used year-round, 17% of the roost sites were used only in winter and 46% of roosts were used only in summer.

Mean roost tree heights were significantly taller than randomly selected trees (Table 1). The mean DBH of roost trees was also larger than the random trees. Closest branch to the ground, aspect, slope, distance to water, to road, to closest crop, to buildings, and to livestock did not differ significantly (all $P>0.1$) between roost trees and the random trees (Table 1).

Table 1. Comparison of 10 characteristics of the Eastern wild turkey roost trees (n=48) and random trees (n=48) in Peterborough, Ontario, as determined from a multivariate binomial logistic regression.

Characteristic	Roost		Random		Z Value	P-Value	Coefficient	S.E
	Mean	S.E	Mean	S.E				
Height (m)	21.4	0.8	18.2	0.8	1.996	0.04	0.11	0.05
DBH (cm)	58.1	5.5	38.7	3.1	3.320	0.001	0.04	0.01
Closest Branch to Ground (m)	5.0	0.5	3.6	0.4	1.234	0.217	0.11	0.09
Aspect (°)	80.8	18.5	53.2	15.5	-0.749	0.454	-0.002	0.003
Slope (%)	-7.6	1.6	-5.0	1.4	-1.174	0.240	-0.05	0.04
Distance to Water (m)	66.2	11.3	72.0	11.8	-0.237	0.813	-0.001	0.003
Distance to Road (m)	184.0	20.3	194.1	18.5	0.499	0.618	0.001	0.002
Tree Type (Coniferous 1, Deciduous 0)	0.2	0.06	0.4	0.07	-0.874	0.382	-0.54	0.62
Distance to Crop (m)	264.8	28.1	363.6	128.1	-0.496	0.620	-0.0002	0.0005
Distance to Buildings (m)	252.3	16.2	265.6	18	-0.910	0.362	-0.002	0.002
Distance to Livestock (m)	845.1	102.3	917.8	99.1	0.388	0.698	0.0001	0.0004

During summer, we observed temperature differences between coniferous and deciduous trees and ambient temperature (Table 2). In particular, it appeared that temperatures in deciduous roosts were higher than in either coniferous trees or ambient temperature. There was a significant difference between all groups, ambient temperature was cooler than the temperatures found at the deciduous site and coniferous site (Dunn test, z-value=5.04 and 2.65 respectively, both P<0.005, n = 882), and the coniferous site was cooler than the deciduous site (Dunn test, z-value = 2.39, P<0.01, n = 882). There was a significant difference between temperature at the different trees and ambient temperature during the summer (Kruskal Wallis comparison of rank means, df = 2, chi-squared = 25.39, P<0.0001). There was no significant effect of location on temperature during the winter months (Kruskal Wallis comparison of means, df = 2, chi-squared =0.19, P=0.9).

Table 2. Comparison of ibutton temperature data (°C) located in a deciduous tree, coniferous tree, and ambient temperature data from weather station close to sampled trees in Peterborough, Ontario. Data are expressed as means, and inter-quartile ranges (IQR). Comparisons were done using the Kruskal-Wallis one way analysis of variance. Temperature data came from July 2018 to February 2019.

Season	Coniferous				Deciduous				Ambient				P-Value
	n	mean	SE	IQR	*n*	mean	SE	IQR	*n*	mean	SE	IQR	
Winter	815	-5.3	0.09	9.8	815	-5.4	0.09	9.8	815	-5.4	0.09	9.9	0.91
Summer	882	13.9	0.09	11.3	882	14.5	0.09	11.4	882	13.2	0.09	10.7	0.000003

Distances between roosts and buildings, road, and crop differed among seasons (Table 5). Roosts were on average, more than 100m closer to buildings in the winter compared to roosts used year-round or roosts used in the summer (Pairwise Wilcoxon test, p<0.01). Winter roosts were farther away from crops compared to year round roosts (Pairwise Wilcox test, p=0.01). Summer roosts were closer to roads than the roosts in the winter and the roosts used year round

(Pairwise Wilcoxon test, p=0.01). There was no difference between roosts in the winter and the roosts used year-round in distance to roads.

Table 3. Comparison of 10 characteristics of the eastern wild turkey summer roost (n=18) winter roosts (n=9), and roosts used year round (n=21) in Peterborough, Ontario, as determined from Kruskal-Wallis rank sum test.

Characteristic	Summer (N=18)		All year round (N=21)		Winter (N=9)		P-Value
	Mean	Std. Error	Mean	Std. Error	Mean	Std. Error	
Distance to Buildings (m)	**258.3**	**29.0**	**302.0**	**23.4**	**150.8**	**26.0**	**0.002**
Distance to Road (m)	**143.0**	**36.3**	**218.0**	**25.1**	**235.2**	**33.7**	**0.008**
Distance to Crop (m)	**262.4**	**55.2**	**179.0**	**33.4**	**395.2**	**63.7**	**0.045**
Distance to Water (m)	41.9	14.4	84.6	20.3	71.9	20.3	0.092
Tree Type (Deciduous 0 Coniferous 1)	0.3	0.1	0.1	0.1	0.3	0.2	0.229
Closest Branch to the Ground (m)	4.7	0.9	5.6	0.7	4.1	1.1	0.351
DBH (cm)	61.8	7.8	49.2	6.0	71.6	20.8	0.510
Distance to Livestock (m)	908.4	163.0	970.0	164.2	591.5	155.7	0.674
Height (m)	21.2	0.2	21.1	0.9	22.0	2.3	0.921
Slope(%)	-7.4	2.6	-6.8	2.3	-9.9	5.0	0.944
Aspect(°)	81.7	28.3	80.1	29.9	80.7	45.7	0.974

2.4 DISCUSSION

Wild turkey roosts in our study area were selected for tree height and tree DBH. Compared to random trees, roosts were taller, and had a larger DBH. We also found that there were some microclimate differences between types of trees, but it was not what we expected. It was the summer temperatures that showed a difference between the coniferous, deciduous tree, and ambient temperature, when we predicted that trees might be selected for thermoregulatory advantage for winter roosts, in particular. The seasonal differences continued when we looked at the type of roosts selected during each season and where these roosts were located in proximity to resources. In particular, winter roosts were closer to buildings, but farther from roads and crops than summer or year-round roosts. Overall, the height and DBH finding suggests anti-predator benefits of the roost, whereas proximity to buildings in winter might be associated with resource acquisition because of supplemental food available via bird feeders or livestock operations. This represents only weak evidence supporting the Two Strategies hypothesis however, where the strategies are predator avoidance and resource acquisition.

Similar to other studies in parts of the turkeys range, (Boeker and Scott 1969, Kilpatrick et al. 1988, Rumble 1992), the turkeys selected roosts that were larger in diameter and taller. The selection of trees based on these characteristics help to highlight the importance of communal roosting in turkeys. These larger trees would also then support large groups and the social interaction that occurs while roosting. The height that they are selecting for relates to the ability of that roost tree to defend them from ground predators (Beauchamp 1999). Future research could look into the hierarchy of the perch locations within a roost, and how that selection is made. In support of the Two Strategies Hypothesis, if higher up in the roost is beneficial for an individual for predator avoidance, at some point a decision is made by an individual to claim that perch, fight for it, or submit and let another turkey take that prime perch location.

We found some interesting differences between seasons, specifically when looking at the microclimate properties of the roosts. Previous research suggests coniferous roosts are selected based their ability to shelter from the weather better than deciduous trees which drop all their leaves and are more exposed to the elements (Schmitz 1991). However, the ibutton data collected showed no significant difference in temperature at the roost tree in the winter. One element that was not recorded by the ibuttons was wind speed, which might have shown a difference between the coniferous and deciduous roost sites. Wind in combination with temperature affect the operative cooling of an organism, which likely plays an important role in their energy balance in the winter (Bakken 1976). The turkeys may be favouring the coniferous sites because of the shelter they receive from wind, rather than temperature. The ibutton data did not show significant temperature differences between tree type in the winter, but it did however show a significant difference between the temperatures found at the coniferous roost tree and the deciduous roost tree during the summer months.

Our winter roosts sites were significantly closer to buildings than roost sites selected during the summer. This underscores the reliance that wild turkeys may have on humans during winter, and how we may be playing an important role in their survival during the harsh temperatures of the winter. With lower temperatures comes snow, and turkeys have been shown to be limited by snow depth in terms of their ability to forage for resources (Lavoie et al. 2017). If their roost sites are closer to buildings, and therefore humans, it is likely they are getting some sort of supplemental food sources, and the cost of acquiring that food source is much lower than naturally foraging through deep snow. The turkey's ability to survive winter will likely increase if their selection of winter roost site is closer to supplemental food sources, and therefore closely tied to the presence of humans.

If it matters more where they roost in the summer to avoid overheating, expanding farther north may show that the cold winter weather may not be the critical factor keeping them from expanding their range. There may be other variables that are limiting their northern expansion, and we may also see their southern range move north to escape the heat. A study modelling 50 bird species' heat balance, showed the likelihood of southern range declines driven by climate changes, specifically water requirements for evaporative cooling, exacerbated in larger bodied birds (Riddell et al. 2019). Wild turkeys may be more concerned about heat stress in the summer, rather than heat loss in the winter in relation to their selection of roosting sites. The winter roosting sites are possibly being selected for other properties not related to thermoregulation, and therefore there may be a stronger driver in the selection process of roost sites throughout the season.

The wild turkey is not only a game species in Ontario, but they are also a successful reintroduction story. The results found could help to inform management decisions for population sustainability in Ontario, as well as inform other provinces thinking of reintroducing the species. Preserving stands with large coniferous and deciduous trees will be important for roosting habitat as wild turkeys switch tree types throughout the year (see Chapter 3) and the roost tree selection may be linked to microclimate temperatures at the roost tree itself. In our study area, the results showed a link between humans and wild turkey, with a more direct link in the winter where they may be relying on waste grain and livestock for supplemental food resources. As our climate changes and we see a northern expansion of many species, using this information may also help to predict where we will see wild turkeys selecting favorable roosting habitat as their range expands.

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CHAPTER 3: THE ROOSTING NETWORK OF A WILD TURKEY POPULATION

ABSTRACT

Male wild turkeys roost communally year-round, while females do not roost during their nesting period. Individuals switch roosts throughout the year, implying that there may be a network of roosts that turkeys rely on. Using network analysis as a tool, we were able to assess the structure of the network of the roosts, with the roost trees being the nodes in the system, linked by the individual turkeys switching between roosts. Using GPS tagged wild turkeys (n = 45), we located 323 roosts over a 2-year study period in the Peterborough County area. Using the roosts and movements between roosts, we were able to build the network and evaluate the structure of the network. The structure of the roost network closely resembled a scale-free network, where the degree distribution follows a power-law formula. Our network highlighted the disproportionate importance of a few hub roosts (n = 4), such that a few roosts were used much more frequently than a larger number of satellite roosts (n = 319) in the system. Hub roosts were farther from buildings, water, likely to be deciduous trees, and close to livestock, and roads. Hub roosts were also used more frequently in winter. These hub roosts are critical for management and conservation purposes as these disproportionately used roosts may only make up a small number of the total roosts, but are extremely valuable to the species.

3.1 INTRODUCTION

Communal roosting is common across many species with many proposed benefits. Understanding the use of roosts, and the characteristics of these roosts helps in understanding the needs of a species and its relationship to the landscape. Some of the benefits of communal roosts include reduced predation risk (Finkbeiner et al. 2012), increased information about food sources (Ward and Zahavi 2008), and increased thermoregulation benefits (Beauchamp 1999). In some cases, roost sites are significant for conservation (Rehfish et al. 2003, Rhodes et al. 2006).

Wild turkeys are a flocking species that use communal roosts every night, aside from females while nesting (Nguyen et al. 2004). Past research has mainly focused on the selection of roost sites, as well as the characteristics of the roost site or tree (Boeker and Scott 1969, Kilpatrick et al. 1988, Rumble 1992, Chamberlain et al. 2000). For example, Kilpatrick et al. (1988) found that eastern wild turkeys selected roosts with a diameter at breast height (DBH) greater than 48cm, in white pine stands, and were within 40m of water during the winter. However, turkeys switch roost locations somewhat frequently, indicating that they may be using a network of roosts, though roosts tend to be thought of as stand-alone resources (Ontario Ministry of Natural Resources 2007).

Roost switching is more apparent in female wild turkeys in the brood-rearing season when roost locations must also be proximate to young flightless poults (Lutz and Crawford 1987, Chamberlain et al. 2000, Kane et al. 2007). Females will seek out specific trees based on the age and stage of their poults in terms of their ability to either be in the roost with her, or shelter at the base of the tree (Spears et al. 2007). However, both sexes will also switch roost locations throughout the year (Kilpatrick et al. 1988, Hoffman 1991), implying that there may be a network of roost locations, rather than individual roost trees constituting stand-alone resources for the wild turkeys.

Networks are made up of nodes connected by links or edges, and those nodes and links can be defined by many different things, depending on the system under consideration. Social network analysis can be used to characterize the association or interaction data between individuals in a population, and provides a description of social structure (Croft, James & Krause 2008). In such an application, the node would be an individual, and the links would be the interactions between individuals in that system. This form of network analysis also helps to describe how local processes drive group level properties in a system (Strandburg-Peshkin et al. 2013). For example, this occurs in the Paridae (blue tit (*Cyanistes caeruleus*), marsh tit (*Poecile palustris*), and great tit (*Parus major*)) who are more likely to forage in new food patches based on how socially connected they are to other individuals (Aplin et al. 2012). Networks are further understood by looking at metrics describing connectedness, closeness, and centrality of the elements within the network (Table 3).

Table 3. Glossary of frequently used terms (Croft et al. 2008).

Network Metric	Definition
Betweenness	A measure of centrality based on the shortest paths
Connectedness	The number of links that connect a focal node to other nodes in the network
Closeness	The mean shortest path between a node and all other nodes
Centrality	Where a node's position is, in relation to the structure of the network
Degree	The number of links that are connected to a node
Degree Distribution	The fraction of nodes in a network that have a given degree
Clustering coefficient	A measure of cliquishness of the network, which is the fraction of a node's immediate neighbor that are themselves neighbors
Eigenvalue centrality	Relative score assigned to nodes to assess their importance based on the connections to other nodes
Edge	The interaction between two nodes
Node	The object in the network, example, the roosts in this paper

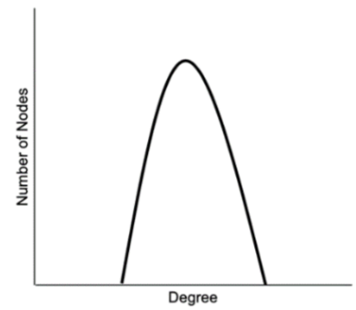
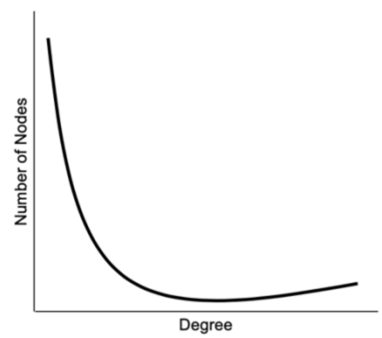
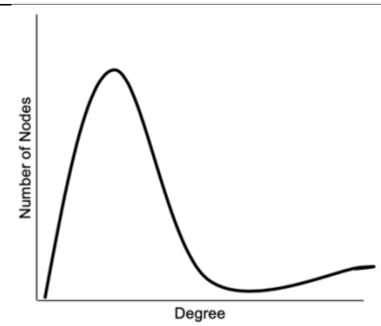
Network analysis as a tool has gained traction in wildlife management and conservation in ways such as social networks of wild songbirds and the transfer of information (Farine et al. 2015), disease spread in bighorn sheep (*Ovis canadensis*)(Cahn et al. 2011), assessing the resiliency of bald eagle (*Haliaeetus leucocephalus*) roosting network (Watts and Dyer 2018), and using social patterns with offspring in the critically endangered Indo-Pacific humpback dolphin (*Sousa chinensis*) (Dungan et al. 2016). Using networks to describe patterns can help to uncover new insights about a biological system.

The distribution of the node degree can be used to determine the structure of a network, with the node degree being the number of connections one node has to other nodes (Proulx et al. 2005). For example, scale-free networks have many nodes with few connections, and few nodes with many connections. Consequently, the nodes with many connections can be disproportionately important to flow through the network. In the context of animal conservation, identifying highly connected nodes, or hubs in the network can be an important aid in conservation planning for a species. Network hubs might be disproportionately important for conservation and could then be considered targets for protection.

The role that roosts play in the use of a broader landscape by wild turkeys is understudied, and we do not know the network structure of roosts. However, we suspect that some roosts are disproportionately important because of their characteristics, suggesting that turkey roost networks might have scale-free characteristics.

By looking at the network structure of roosts, we aim to identify patterns of association between turkeys and their roosts. Specifically, we hypothesize that a population of wild turkeys uses a network of roosts, rather than single, unconnected roost trees. If turkeys are using roost networks, we hypothesize that certain roost trees have properties that lead them to be disproportionately important to the network. In other words, we might consider some roost trees to be hub trees in a scale-free network (Table 4). Consequently, we predict that roosts are more structured than expected from a random network. Our main objectives were to test for a roost network using data from roost tree usage from a population of wild turkeys in Ontario near the northern edge of their geographic range. Our goals were to discover the structure of the roost network, to determine whether season played a role in the structure of their roosting network, and to identify the characteristics of the roost that affect their selection of roosts and importance in the network at their northern range.

Table 4. Comparison of the three major types of networks

Type of Network	Characteristic	Degree Distribution Example
Small world	Local clusters with a few connections between those large clusters. This is similar to groups of friends being connected by only one or two mutual friends.	
Scale Free	Follow the pattern of a power law degree distribution, with fewer 'hub' nodes that are highly connected, than 'satellite' nodes that have few connections. This would be similar to the network of airports around the world, with few major airports that most flights depart, or arrive to, compared to the many smaller airports with few flights in and out.	
Random	Nodes are connected randomly to each other.	

3.2 METHODS

Wild turkeys were trapped using rocket nets (Grubb 1988) between January and March of 2017 and 2018, in open fields with bait piles consisting of corn. Locations to trap were based on driving surveys of a larger study area in Peterborough County and locating flocks of wild turkeys that were fairly consistent in their daily movements and flock size. We also needed landowner permission and a safe area to operate a rocket net. Our three major trapping locations are hereafter referred to as Trent, Blezard, and Westwood, which were named based on closest landmarks or road names. Our study area consisted of mainly agricultural fields, mixed forests, wetlands, active farming properties, as well as deciduous and coniferous trees lining properties. Trapping in the winter allowed us to target larger flocks and increase our chances of putting GPS on an equal number of males and females. Capture and handling methods were in compliance with the Animal Care Committee protocols at Trent University.

To track turkey movements we used GPS transmitters (model PinPoint VHF-3600L, Ontario, Canada) weighing 85 g (<3% average weight of an adult hen, average mass = 4.3kg). Transmitters were attached using a backpack-style harness made of shock cord (Norman et al. 1997). The tags were programmed to collect GPS locations (±19.9m from our field trials, Appendix A) at various schedules. In 2017, locations were collected every 4 hours and 15 minutes for 24 tags. In 2018 locations were collected every hour between 6:30am and 10:30pm and once at 12am and then again at 4am for 21 tags. The total sample included 45 turkeys: 22 males, and 23 females.

We used RStudio v 1.2.1 (RStudio Team 2018) to select one night time location between midnight and 4am for each turkey from February 2017 to December 2018 in order to ensure both schedules of tags were included. Using Crimestat lll (Levine 2010), minimum convex polygons were created using the nearest neighbour script to create clusters. The clusters allowed us to then identify which turkey, and how many turkeys were using each cluster(roost) each night, allowing us to quantify connections among roosts. These clusters became the nodes of the network system, and the turkeys switching between roosts (nodes) on consecutive nights are the links in the network system (Figure 6).

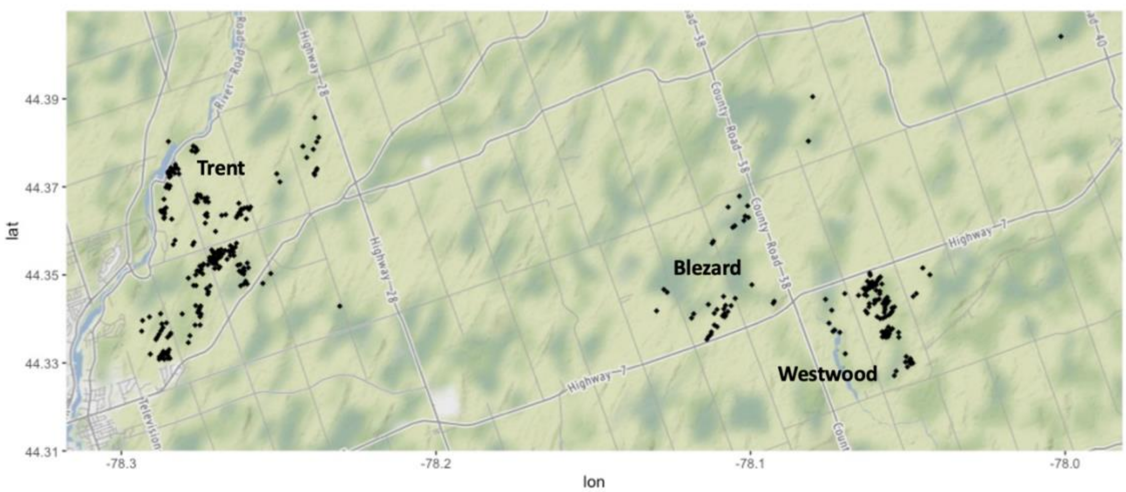


Figure 4. Locations of roost clusters that became the nodes of the roosting network.

Using Cytoscape (Shannon et al. 2003), network parameters, including degree, betweenness, closeness, eigenvalue centrality and clustering coefficient were found and assigned to each roost (node). The structure of the roost network was illustrated by producing a frequency distribution of degrees, being the probability distribution of degrees over the whole network and comparing that to a random network. The random network was created by using the same data with an application in Cytoscape (Tosadori et al. 2017).

Season was characterized by proportion of use throughout the year. If a roost was used 90% or more during the months of May – October, it was classified as a summer roost, and the same rule was applied to winter roosts during the months of November – April. Roosts that did not qualify as winter or summer roosts by this criterion were considered ‘year-round’ roosts. Separate analyses were completed for the summer network, winter network, and year-round network, as well a total annual network comparison. We used multivariate poisson logistic regression models to compare the node degree of the roost network with the spatial characteristics of the roost location to discover patterns in the disproportional frequency of roost use within the network. We gathered spatial characteristics of tree roost locations from digital map resources. We used the Ontario Land Cover Database (Ontario Ministry of Natural Resources and Forestry 2014) for water and forest type, and used Land Information Ontario basemaps for roads, crops, and buildings (Provincial Mapping Unit 2017, Agriculture and Agri-Food Canada 2018, Graham 2019). Livestock locations were found and noted by driving our study area and creating a map using ArcGIS (Baici 2021).

3.3 RESULTS

We identified 323 roosts used by 48 turkeys over the two-year study period, with roughly 5 major flocks in 3 locations. Individual turkeys used an average of 20.1 $\pm$ 0.6 (SE) roosts/year, with an average of 11 $\pm$ 0.5 roosts in the summer and an average of 9.1 $\pm$ 0.4 roosts in the winter. Males used an average of 26.3 $\pm$ 0.9 roosts a year, with females only using an average of 14.2 $\pm$ 0.6 (Wilcox Test, w = 159, P = 0.03). In the summer, males used 16.9 $\pm$ 0.8 roosts, and females used 5.4 $\pm$ 0.5 (Wilcox Test, w = 117, P = 0.001). During the winter, males used 9.4 $\pm$ 0.6 roosts, and females used 8.8 $\pm$ 0.4 roosts (Wilcox Test, w = 267.5, P = 0.7). Birds frequently moved between roosts, confirming the presence of a connected network of roost trees. We detected 3770 connections (movement of birds between roosts each night) within the roost network (Figure 5).

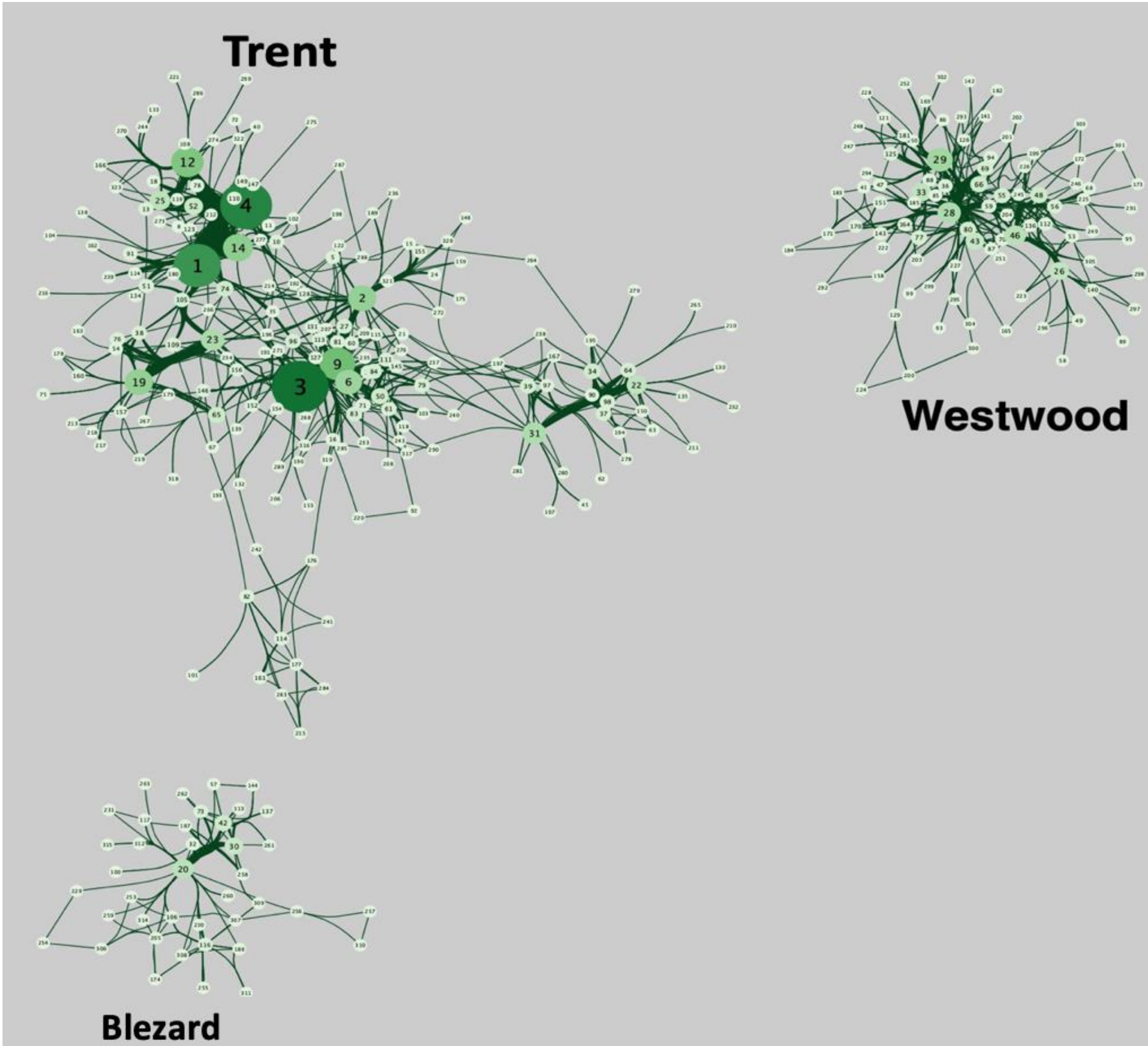


Figure 5. Network of wild turkey roosts in Peterborough, Ontario for 45 turkeys over a two-year study period. The three major clusters are named based on their trapping locations.

General structure of the roost network showed similarities to a scale-free network rather than a random network (Figure 6). The degree distribution of a scale free network follows a power-law form $P(k)=Ak^{-y}$ with k being the independent variable, and where the exponent y typically falls in the range of $2<y<3$ (Proulx et al. 2005). The exponent y for our data was -1.06, which does not fall within the typical range of a scale free network. However one study found that networks where the power law degree exponent is smaller than 2, are networks where fewer nodes are needed to change the behaviour of the entire network (Nacher and Akutsu 2012). Scale-free networks with y>2 have also been studied and their properties were described as having links that grow faster than the number of nodes in the network, but were still classified at scale-free networks (Seyed-Allaei et al. 2006).

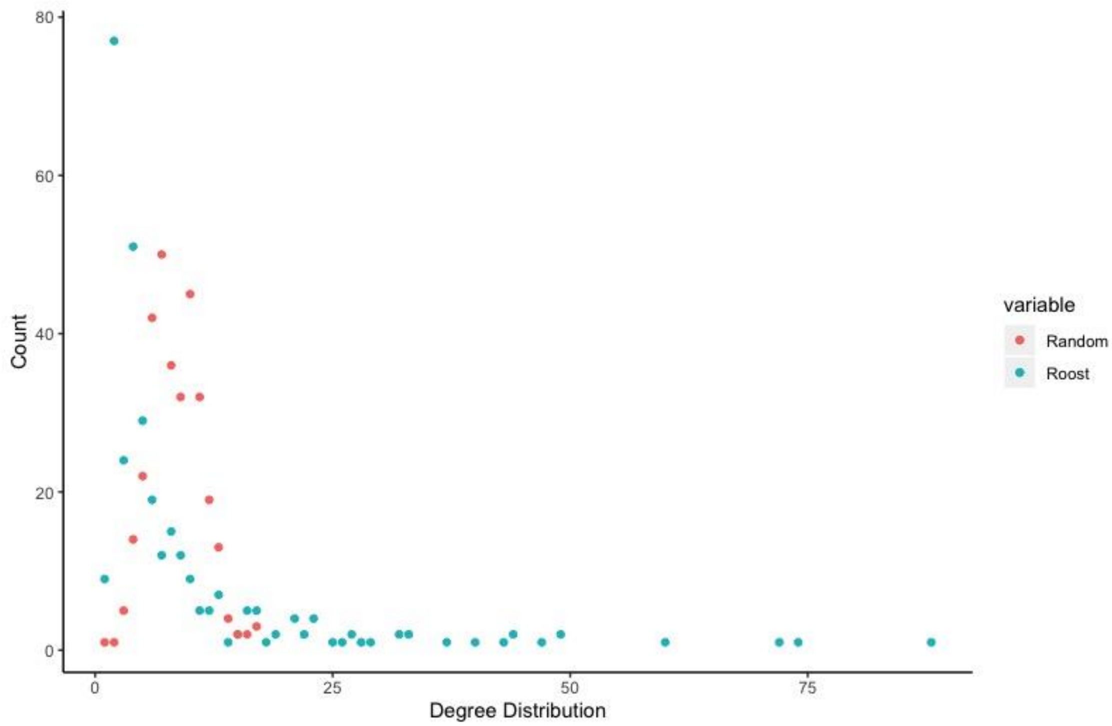


Figure 6. Degree distribution for 323 roosts against a random network.

Degree varied between 1 and 88, with more than 98% (n=319) of nodes within the network had direct connections to <15% of other roosts. Four roosts had direct connections to >18% of other roosts. One of the roosts had a direct connection to 27% of the other roosts in the network.

The network parameters showed further difference within the network (Table 5). There were 129 roosts that had a betweenness value of 0, which means they did not act as a bridge between other roosts. The roosts at the upper level of the betweenness range (0-12513.82) were also generally the roosts with the higher degree value. Eigenvalue ranged between 0-0.39, with roosts having a value >0.2 serving as hubs, making up only 1% of the entire network. The closeness values of the network indicated that some roosts were located close to the centre of the network, while others were not. The roosts that had the highest closeness values were also the roosts that were more likely to be hubs with higher centrality measures.

Table 5. Descriptive statistics for parameters measured for a wild turkey roost network in Peterborough, ON. We used wild turkeys (n=45) tracked with GPS transmitters (2017-2019) to estimate parameters (n=323).

Parameter	Median	Mean	Standard Error	Range
Degree	4	8.45	0.63	1-88
Betweenness	5.10	285.88	59.97	0-12513.82
Closeness	0.36	0.36	0	0-0.80
Eigenvalue Centrality	0.01	0.03	0	0-0.39
Clustering Coefficient	0.50	0.51	0.02	0-1

The entire roosting network as a whole showed further patterns based on the node degree (Table 6). The highest weighted nodes, or more frequently used roosts, were associated with distance to buildings (P<0.001), distance to roads (P<0.001), the tree type (P<0.001), the distance to livestock (P=0.01), distance to water (P=0.05), and season (P=0.05). These hub roosts tended to be farther from buildings, closer to roads, were likely to be deciduous, close to livestock, farther from water, and the more frequently used hubs were winter roosts.

Table 6. Summary of the strength and direction of the relationship between 7 predictor variables and the weighted degree of the network of roosts over two years, or a more heavily selected roost, as determined from an annual multivariate Poisson regression (n=323).

Characteristic	Estimate	Std.Error	Z Value	P Value
Distance to Building(m)	1.251e-03	1.744e-04	7.17	7.29e-13
Distance to Road(m)	-8.885e-04	1.293e-04	-6.87	6.48e-12
Tree Type (0 Coniferous/1 Deciduous)	1.522e-01	4.014e-02	3.79	0.0001
Distance to Livestock(m)	-1.710e-04	6.691e-05	-2.56	0.01
Distance to Water(m)	5.277e-04	2.761e-04	1.91	0.05
Season (0 Winter/1 Year round/2 Summer)	-4.562e-02	2.361e-02	-1.93	0.05
Distance to Crop(m)	1.957e-05	9.818e-05	0.20	0.84

There were 119 summer roost, 100 winter roosts and 104 roosts that were used year-round. On average, there were more coniferous roosts (61.3%) than deciduous roosts (38.6%). Within each season, this pattern was similar with 63% of summer roosts being coniferous, 65.4% year round roosts, and 55% winter roosts being coniferous.

The characteristics of the network of each season differed as well. The hub roosts in the summer (Table 9) were more likely to be closer to roads (P<0.001), and farther from buildings (P<0.0001). The hub roosts in the winter (Table 8) were more likely to be located farther from water (P=0.01), and crops (P<0.001), closer to roads (P<0.001), and livestock (P<0.0001). The hubs used year round (Table 7) showed a preference of locations for being close to roads (P<0.0001), crops (P<0.0001), and livestock (P<0.0001), and farther from buildings (P<0.0001).

Table 7. Summary of the strength and direction of the relationship between 6 predictor variables and the weighted degree of the network of year-round roosts over two years, or a more heavily selected roost as determined from a multivariate Poisson regression (n=104). Year-round roosts were used all year, not just in summer or winter.

Characteristic	Estimate	Std.Error	Z Value	P Value
Distance to water(m)	-0.0004	0.0004	-0.9	0.37
Distance to road(m)	-0.001	0.0002	-4.86	1.20e-06
Distance to crop(m)	-0.0005	0.0001	-3.4	0.0007
Tree type (0 Coniferous/1 Deciduous)	0.39	0.06	7.02	2.26e-12
Distance to livestock(m)	-0.0004	0.00008	-4.4	0.00001
Distance to buildings (m)	0.002	0.0003	7.21	5.75e-13

Table 8. Summary of the strength and direction of the relationship between 6 predictor variables and the weighted degree of the network of winter roosts over two years, or a more heavily selected roost as determined from a multivariate Poisson regression. (n=100)

Characteristic	Estimate	Std.Error	Z Value	P Value
Distance to water(m)	0.002	0.0006	2.45	0.01
Distance to road(m)	-0.001	0.0003	-3.26	0.001
Distance to crop(m)	0.0007	0.0003	2.76	0.005
Tree type (0 Coniferous/1 Deciduous)	0.47	0.09	5.35	8.59e-08
Distance to livestock(m)	-0.001	0.0002	-5.77	7.82e-09
Distance to buildings (m)	-0.0003	0.0004	-0.68	0.50

Table 9. Summary of the strength and direction of the relationship between 6 predictor variables and the weighted degree of the network of summer roosts over two years, or a more heavily selected roost as determined from a multivariate Poisson regression (n=119).

Characteristic	Estimate	Std.Error	Z Value	P Value
Distance to water(m)	0.00009	0.0006	0.16	0.87
Distance to road(m)	-0.0007	0.0002	-3.25	0.001
Distance to crop(m)	0.00002	0.0002	0.12	0.9
Tree type (0 Coniferous/1 Deciduous)	-0.07	0.08	-0.85	0.39
Distance to livestock(m)	0.0002	0.0001	1.53	0.12
Distance to buildings (m)	0.002	0.0003	4.85	1.24e-06

3.4 DISCUSSION

We confirmed that wild turkeys use a network of connected roost trees, rather than single, unconnected roosts. The roosting network exhibited traits of a scale-free network, one of the well-known structures of networks. One of the characteristics of a scale-free network is that a large number of nodes have a small degree (few connections to other nodes), and fewer nodes have a higher degree (more connections to other nodes) (Newman 2003). Four roosts out of the total 323 had the highest degree and were more connected than the rest of the roosts in the network.

Wild turkeys are one of many species that roost communally, and though it is well known that they switch roost locations, the roosts are mainly considered as stand-alone resources in terms of conservation and management strategies for the species . This is the first time that wild turkey roosts have been examined from a network perspective. Prior research on wild turkey roosts have used direct observation, or VHF telemetry, but with the growing use of GPS transmitters, remotely and accurately tracking their movement has opened up the possibility for more in-depth data collection.

Our network was subdivided into three distinct communities directly related to their trapping locations. Figure shows the groupings as ‘Trent’, ‘Blezard’, and ‘Westwood’. Blezard and Westwood were trapping locations in 2017, but we were unable to trap at that location in 2018, so the individuals in those communities remained the same or died off. The Blezard and Westwood flocks consisted only of males, and these flocks were roughly 17km away from the

Trent site. In our study area, the turkeys had an average home range (95% kernel density km^2) of 7.1 km^2 in the spring where we see most of their movement, and an average home range of 0.9 km^2 in the winter where they move the least (Baici 2021). Thus, it was no surprise that we did not see any travel between the three major trap sites. The turkeys small home range likely had an effect on the parameters for the network as a whole as that disconnect between the three trap sites understandably changed each nodes' metrics.

Table 10 Summary table of wild turkey roosts during summer, winter, and year round in relation to 6 variables and their node degree.

Characteristic	Summer hubs (n=119)	Year round hubs (n=103)	Winter hubs (n=100)
Distance to water	-	-	Farther
Distance to road	Closer	Closer	Closer
Distance to crop	-	Closer	Farther
Distance to livestock	-	Closer	Closer
Distance to buildings	Farther	Farther	-
Tree Type	-	Likely Deciduous	Likely Deciduous

Wild turkeys at the northern extent of their range experience harsher winters than those at lower latitudes, and with these lower temperatures comes higher rates of mortality as a result of lack of resources, and increased chance of predation. The quality of their winter habitat will affect their survival throughout the winter as well their productivity the following spring (Porter et al. 1983). The winter network highlighted their selective behaviour in relation to roost location.

Deep snow not only affects their movement, but also the availability of food. While Peterborough's average snow depth is 19cm during the winter, during our study we saw a maximum snow depth of 23cm in January of 2018 (Canada 2019). Our turkeys used fewer roosts in the winter than in the summer, aligning with the idea that they are moving around less, and therefore using fewer roosts.

The roosts used year round, which made up roughly one third of our total roosts, were found to be close to crops, and livestock. The main crops in the Peterborough area are corn, wheat, and soybeans, and are mostly harvested by the time winter comes around (Farm & Food Care Ontario 2017). What gets left behind is waste grain that the turkeys will locate and, in some places, spend most of their day scratching at the snow to forage on. A study in Massachusetts found that turkey flocks between January and March would spend half of their day in agricultural lands, with cropland having the highest use (Vander Haegen et al. 1989). Lavoie et.al found turkeys heavily relied on crops as a food resource in their northern study as well.

Water will also become a limited resources as bodies of water freeze over. The water bodies in our study area were primarily little creeks and wetlands through agricultural areas, rather than large water bodies. Winter foods may be lower in moisture content, which can make it even harder for turkeys to meet their metabolic needs for their water intake (Decker et al. 1991). Turkeys have shown preference for roost proximity to water in other parts of their range, such as Arizona and Rhode Island (Boeker and Scott 1969, Kilpatrick et al. 1988).

Summer hub roosts, and hub roosts used year-round were also found to be significantly closer to buildings than winter hubs. This could be an association to buildings that have supplemental food sources, i.e. bird feeders, manure piles, and grain silos. There may also be an indirect benefit to being close to buildings and humans, as there may be fewer predators like coyotes, as farmers tend to practice coyote management on their land.

In all seasons, hub roosts were found to be significantly closer to roads than the less frequently used, satellite roosts. This is interesting as roads introduce a higher chance of getting hit by vehicles, though it is not usually associated as a high risk factor for mortality in wild turkeys (Macdonald et al. 2016). Turkeys spook easily when up in the roost (personal observation), and being close to roads where there will inevitably be more activity than deep in the woods, increases the chances of them getting flushed and having to search for a new roost location in the middle of the night, which increases their risk of predation as well.

Winter hub roosts in our area tended to be closer to land that had livestock. The practice of spreading manure and the presence of persistent waste grain is likely providing substantial supplemental winter food sources in our study area. In a previous study conducted in Mississippi, corn was deemed an important winter food resource especially during severe winter conditions (Porter et al. 1980). The dispersion of agricultural land near roosting habitat shows that close association with food resources. The proximity of resources to suitable hub roost sites is also important in order to reduce the energy costs of travelling through deep persistent snow. That link between agriculture and winter survival doesn't necessarily mean they are only surviving because of the supplemental food, but if there were multiple severe winters in a row, the populations roosting closer to farming properties would likely have a higher chance of survival.

The collection of roosts in our study area near the northern extent of the turkey range have yet to be examined from a network perspective until now. Previous work on wild turkey roosts have relied on direct observations or conventional telemetry but have never had a sample size large enough to construct networks. GPS transmitters have opened up the ability to sample wild turkey roosts at a finer scale as they are better at capturing their movements between, and at the roosts. The result of the network created suggests a pattern of a scale free network of roosts, highlighting certain hub roosts within the network that play an important role in their survival on the landscape. These findings have conservation implications for the selective management of these roost sites, with special note to be taken on the changes in seasonal properties of these roost sites. In general, scale free network are more robust against random attacks because of the higher number of nodes in the system that are less frequented by individuals in a population. However, the loss of one of the hub roosts would likely have much higher cost to the network as a whole, as well as the population because of their important proximity to food and water resources. In our study area at the northern edge of their range, a loss of a hub roost during the winter months where conditions are already harsh, could have an even more significant impact on the survival of a population. In Ontario, the greatest cause of mortality is emaciation, mainly occurring in the winter and spring when they have less access to food sources (Macdonald et al. 2016). Identifying these hub roosts and prioritizing them for long term protection would be essential for the wild turkey's sustainability as a population.

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CHAPTER 4: GENERAL DISCUSSION

The objective of my study was to explore the roosting behaviour of wild turkeys and link that to social and survival strategies at their northern range edge. The wild turkeys in my study area showed preference for taller and larger trees, similar to what is seen in other parts of their range as well. Seasonally they showed preferences for roosts closer to water, crops, and livestock in the winter, and in the summer their hub roosts were close to water, and buildings. The seasonal differences in roost selection, highlighted the added pressures these turkeys undergo living in a northern climate, and their resiliency to thrive in harsh conditions. As a reintroduced species, they seem to be modifying their behaviour, where large agricultural areas and human development is much greater than during presettlement times when turkeys were common.

When looking at the fine scale results from Chapter 2, there were some similarities in seasonal characteristics of roosts with what was found in Chapter 3 with the larger scale analysis. The larger scale analysis using the network of roosts helped to highlight the proportion of roost use, compared to the second chapter which put all the roosts I had collected data from on the same level, when in reality, some of those roosts might have only been used a few nights, but were still being compared to random locations. With the use of GPS tags, I was able to show how often turkeys switch their roost, and how many they use in a year, variables in roost behaviour of wild turkeys that have not previously been assessed. Season does play a role in their roost selection, but it might not be the fine scale attributes of the roost that they select, but more the landscape level attributes that are more important in their seasonal selection of roosts.

Turkeys are limited when it comes to snow depth (Porter et al. 1980, Kane et al. 2007, Lavoie et al. 2017). The turkeys that I studied are at the northern part of their range and therefore experience harsh winters like deep snow, causing them to use more energy to find food and water. Their home range shrinks significantly in the winter (Niedzielski and Bowman 2016), and it makes sense that turkeys select roosts that are closer to their resources in winter to minimize energy expenditure walking around in deep snow looking for food. Turkeys might also have difficulties finding food in deep snow, increasing reliance on anthropogenic food sources. Turkeys will lower their metabolic rate in poor winter conditions, and will do so by restricting their range and foraging activity when supplemental food is available (Coup and Pekins 1999). Two radio-tracked turkeys were perfect examples of this. A landowner in the study area had large bird feeders that were filled regularly and consistently during the winter, and those turkeys roosted about 200m away from this bird feeder all winter long.

Communal roosting in turkeys may not be directly related to thermoregulation properties as I had originally hypothesized. As the Peterborough County study area was near the northern range edge, and knowing the challenges that winter brings to survival, I thought that thermoregulatory benefits would be the primary motivation for communal roosting in turkeys. However, the ibutton data showed that there was little difference in temperatures during the winter between deciduous and coniferous roosts, and against the ambient temperature. This however did not account for huddling behaviour that can happen at roosts that might make more of a difference in body temperature regulation on cold nights than the roost tree itself. The ibutton data did show that there was a difference in temperatures during the summer months between deciduous and coniferous. Birds are not able to sweat, so this may show that staying cool in the summer is more of a concern than staying warm in the winter.

There are many other possibilities for communal roosting in wild turkeys. I found evidence consistent with the Two Strategies Hypothesis. Grouping up at night with a flock ensures that when turkeys wake, they can follow those individuals who know the locations of food. Flocking up, and following or leading individuals to a roost plays a role in their social structure, as there is still a question about how they organize themselves in the roost. From direct observation of watching a flock arrive at a roost, I saw the first few individuals take themselves up to the top of the tree, and the rest of the flock followed behind, but slowly filling up the tree from the top down. It could be hypothesized that higher ranking individuals who lead the way to food, also lead the way to the roost and get to the roost first and get the ‘best’ spots in the roost. Perhaps their reward for sharing the food resources is getting the prime spots in the roost. A study on the Andean Condor (*Vulture gryphus*), which is a large communally roosting species like the wild turkey, suggested that they encounter different selective pressures because of their body sizes, specifically where they are able to take off and land, which constrains the suitability of available roosts (Donázar and Feijoo 2002).

In horizontally structured roosts, such as those of red-winged blackbirds (*Agelaius phoeniceus*) the dominant individuals are able to obtain positions that are both protected from predators and micro-climatically superior (Weatherhead and Hoysak 1984). A study of long-tailed tits (*Aegithalos caudatus*) also showed that birds that occupied the outer positions were of lower dominance status than those occupying inner positions, and that these lower dominance status birds actively competed for the inner positions. The outcome of that competition was determined to some extent by the individuals status within the flock's dominance hierarchy (McGowan et al. 2006). Dominance status, or likely dominance related to age and sex, can also influence roost position in a similar manner seen in bronze manikins, *Lonchura cucullata* (Calf et al. 2002), starling, *Sturnus vulgaris* (Summers et al. 1987, Feare et al. 1995), rooks, *Corvus frugilegus* (Swingland 1977), red-winged black birds, *Agelaius phoeniceus* (Weatherhead and Hoysak 1984) and bald eagles, *Haliaeetus leaucocephalus* (Adams et al. 2000). In future studies, looking more into the wild turkey dominance structure may help to shed additional light on their roost site selection.

With other provinces like Newfoundland and Saskatchewan planning hunts on wild turkeys, the results of my study may help to guide them better as my work suggests that the selection of roosts might be an important social process. Other studies have also suggested similar results that agricultural areas had a positive effect on survival of the wild turkey (Porter et al. 1980, Vander Haegen et al. 1989, Restani et al. 2009).

As a reintroduced species, it is generally accepted that the wild turkey is doing well following restoration to Ontario. The wild turkey population started from approximately 4400 trapped and transferred individuals, and has since grown to an estimated number of 70,000 as of 2007 (Ontario Ministry of Natural Resources 2007). Understanding what has allowed them to thrive in an environment that has changed since the species was extirpated over 100 years ago, will further guide management decisions in Ontario, as well as in other provinces hoping to introduce them. Some may be more invested in this species for hunting and game purpose, but what I find even more interesting is that as a reintroduced species, they are a conservation success story. Unlike most species who are unfortunately negatively impacted by our presence, wild turkeys seem to be taking advantage of us and are thriving because of it.

RECOMMENDATIONS FOR FUTURE STUDY

One of the major barriers of this project was working on privately-owned land, which meant requiring cooperation of landowners. Some large flocks and well used roosting sites were not accessible to us as landowners denied us access to their properties. Since wild turkeys tend to live close to agricultural properties, this may be a barrier for future studies that might not change. Expanding the network of roosts with longer study periods would help to support my findings and likely discover more patterns. Trapping different flocks in other areas of the study area so the flocks did not seem so disjointed, would also help to get an even bigger picture of the roost network at a larger scale as well. Our network showed three major clusters, not connected by any individuals moving between those clusters. If we had more trap sites between those clusters we may have seen more movements between flocks by individuals, and therefore more movements within the total network.

When looking at the microclimate characteristic of the roost tree, future studies could factor in wind strength/direction in relation to roost choice. I would also recommend having more ibuttons in more trees so the sample size could be larger. I attempted to use trap cameras to try to observe behaviour at the roost, however placing cameras in the correct position to try to capture all the movements and interactions proved difficult. Perhaps in future studies, using better camera set ups, or observing the roosts and the positioning of birds in the roosts directly from blinds, would be very interesting for the purpose of exploring the positions of individuals of different age and sex classes in the flocks and understandings their interactions and any potential hierarchies during roost formation.

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Appendix A. GPS Error Plots

Field trials to calculate GPS error consisted of leaving 2 GPS tags located in areas similar to where wild turkeys would be found throughout the day, specifically an open field and then in a forested location. We then collected 125 fixes from the field GPS, and 94 fixes from the forest GPS over 6 weeks. These locations were then compared to the actual location of the GPS to calculate an average error estimate for the GPS tags in ArcMap10 (ESRI® ArcMap™10.0) by creating error plots (Figure A1 and Figure A2). We then calculated the average distance from the GPS locations to the true location to get the mean distance error. The mean distance error of the transmitter placed in the forest was 72.46m, and the open field was 2.44 m.

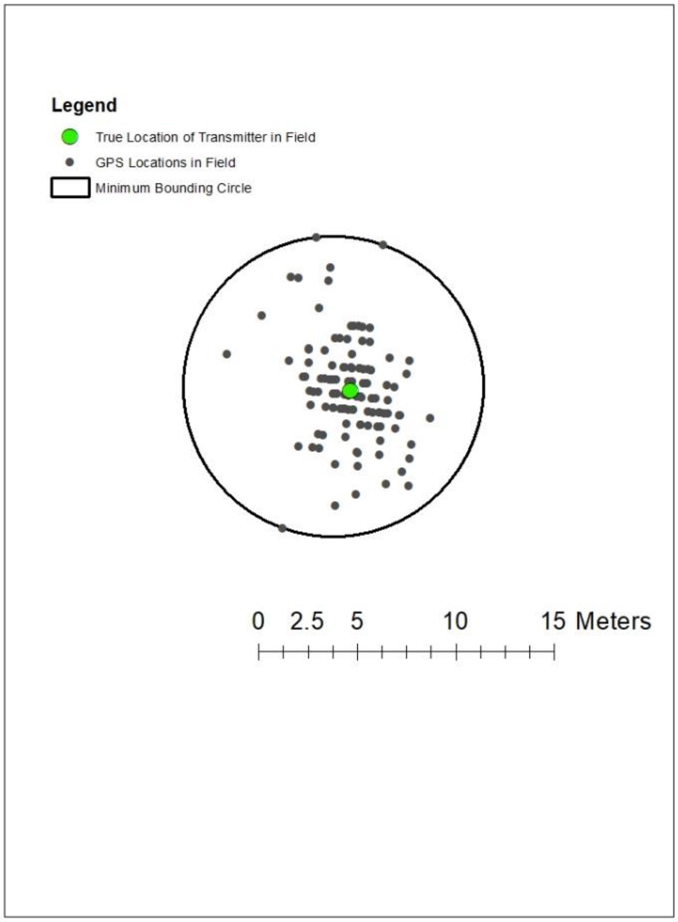

Figure A1 GPS error plot for the transmitter in an open field

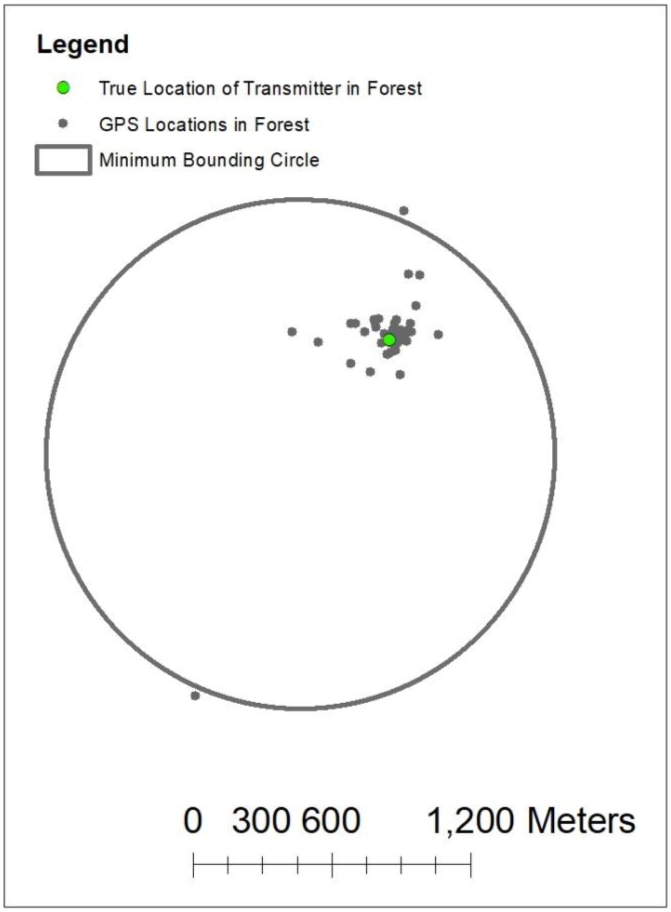

Figure A2 GPS error plot for the transmitter in the forest

Appendix B. Correlation matrix for roost tree variables

Variable	1	2	3	4	5	6	7	8	9	10	11
1. Distance to Buildings(m)	1.00										
2. Distance to Road(m)	0.34	1.00									
3. Distance to Crop(m)	-0.014	-0.47	1.00								
4. Distance to Water(m)	0.067	0.016	0.02	1.00							
5. Tree Type (Deciduous 0 Coniferous 1)	0.0001	-0.009	0.20	-0.066	1.00						
6. Closest Branch to the Ground(m)	0.37	0.32	-0.07	-0.12	-0.41	1.00					
7. DBH(cm)	-0.20	-0.23	-0.06	-0.14	-0.14	-0.26	1.00				
8. Distance to Livestock(m)	0.12	0.37	-0.35	0.13	-0.11	0.069	-0.18	1.00			
9. Height (m)	0.10	0.012	0.038	0.015	-0.24	0.27	0.016	-0.02	1.00		
10. Slope(%)	-0.10	-0.28	-0.051	0.019	-0.16	-0.11	0.23	-0.085	-0.11	1.00	
11. Aspect(°)	0.12	0.089	0.18	-0.13	0.19	0.30	-0.17	-0.0006	0.21	-0.80	1.00