Large Mammal Movement: Differences in Primary and Branch Logging Road Use in Algonquin Provincial Park, Ontario

by

Hillary Roulston

A thesis
presented to the University of Waterloo
in fulfillment of the
thesis requirement for the degree of
Master of Environmental Studies
in
Environment and Resource Studies

Waterloo, Ontario Canada, 2013

AUTHOR'S DECLARATION

I hereby declare that I am the sole author of this thesis. This is a true copy of the thesis, including any required final revisions, as accepted by my examiners.

I understand that my thesis may be made electronically available to the public.

ABSTRACT

There is an expansive network of roads in Algonquin Provincial Park (APP) to facilitate forestry resource extraction. This leaves a research need for examining how the logging road network in APP affects the large mammals, and what local-level and landscape-level variables influence that use. Local-level data was collected directly at observation points, and landscape-level data was produced from ArcGIS for 40km^2, 80km^2, and 130km^2 buffer areas. The objective of my study was to look at the use of primary and branch logging roads by five large mammal species in APP, and determine if landscape-level variables had an influence on the level of movement and utilization. The five species included moose, white-tailed deer, American black bear, eastern wolf and coyote. My null hypothesis (H_0) states that there will be no difference in large mammal use between the primary and branch logging roads within APP and that local- and landscape-level variables will have no influence on them; my alternative hypothesis (H_1) states that there will be less large mammal activity on the primary logging roads, more large mammal movement on the branch logging roads and local- and landscape-level variables will influence this use. Tracking was done by vehicle on six transects across the park for three repeated surveys where species identification and local-level variables were recorded. Landscape-level variables were acquired through GIS analysis in the lab. Based on the results from the local-level data, branch and primary logging road use differed in composition, though no significance was found between the use by large mammals for these two types of road. Through generalized linear models, specific combinations of landscape-level variables did influence large mammal movement on the primary and branch logging roads within three habitat range scales (130km^2, 80km^2, and 40km^2). The most significance was seen at the buffer of 40km^2 on the branch logging roads, with the variables road density ($p < 0.01$), percent forest cover ($p = 0.04$) and topographic ruggedness ($p < 0.01$) all having a strong impact on large mammal movement. The only significant findings for primary logging roads were also at the 40km^2 scale with percent forest cover ($p = 0.03$) and percent water cover ($p = 0.02$) having an impact on large mammal movement. Overall, the landscape variables had greater influence on branch logging roads that may be explained by the quality of the surrounding habitat, as well as greater influence at smaller buffer scales. Further research and monitoring of the large mammals in APP is recommended to expand on this preliminary study. Greater understanding of the local- and landscape-level variables at differing habitat ranges will assist in understanding these large mammal movements and provide data to base logging road management on. As large mammals are wide-ranging species, my study informs APP that their logging road network does not seem to hinder the movements of this group of animals. Overall, the large mammals in APP did not have any significant difference in their use of primary and branch logging roads of APP. Further research has the potential to give greater understanding of the impacts of the logging road network on the five large mammal species studied in APP. There is also the potential for useful management strategies to emerge for large mammals in this park, and how to incorporate human activities within their habitat while maintaining sustainable populations.

ACKNOWLEDGEMENTS

I thank my advisor Dr. Steve Murphy for guidance and assistance throughout this whole process. Thank you for the constant encouragement and faith in my ability to work through this Masters. Algonquin Provincial Park, Ontario Parks, for allowing me and trusting me to conduct my field research within the bounds of the park. Brad Steinberg, Ontario Ministry of Natural Resources Biologist, for helping me initiate this project. It would not have happened without your input. Jennifer Hoare, Park Biologist, Ontario Parks, Algonquin Provincial Park, for coming in part way though the process, and providing you thoughts and assistance to make this a great study, with beneficial outcomes. Dr. Brad Fedy, PhD. University of Waterloo, for his assistance and encouragement through the tougher statistical tests and models. To the University of Waterloo for their ongoing support, and allowing me to conduct my research to the fullest extent. I would also like to show my appreciation for the love and support that Robert Main and my family have shown me throughout this whole process, I could not have done it without you guys!

Table of Contents

1.0 INTRODUCTION

As wildlife connectivity potentially decreases with the growing road network, there is a greater need for habitat protection through parks and wildlife reserves. Many protected areas are the only suitable habitat left for some species of wildlife, becoming an important location for species preservation (Minor & Lookingbill, 2010; Naughton-Treves et al., 2005). For Ontario Provincial Parks, the Provincial Park and Conservation Reserves Act mandates that ecological integrity is the main value for their parks, and that research, protection, education and recreation are the four main objectives of Ontario provincial parks (Algonquin Provincial Park Management Plan, 1998; Provincial Parks and Conservation Reserves Act, 2006) (Figure 1). The Acts first objective states:

"To permanently protect representative ecosystems, biodiversity and provincially significant elements of Ontario's natural and cultural heritage and to manage these areas to ensure that ecological integrity is maintained." (Provincial Parks and Conservation Reserves Act, 2006, c. 12, s. 2 (1).)

Figure 1. The landscape of Algonquin Provincial Park. Photo credit Hillary Roulston.

Part of the issue with wildlife management on a global scale is the loss of habitat connectivity, or increasing fragmentation of the natural landscape species rely on (Baggio et al., 2011; Buchmann et al., 2013; Colchero et al., 2010; Kaphegyi et al., 2013; Morellet et al., 2011). Connectivity is often key, especially for wide-ranging species such as large mammals, whose metapopulations require movement between core areas of habitat for survival (Alexander & Waters, 2000; Corlatti et al., 2009; Kindall & van Manen, 2007; Lewis et al., 2011; Luque et al., 2012; Woodriffe & Ginsberg, 1998). The issue that is being looked at in my research is whether APP can provide well-connected habitat for the large mammals of the area, as the logging road network is extensive within this protected area boundary (Algonquin Provincial Park Management Plan Amendment, 2013).

Logging roads can be examined within the framework of "road ecology", and how roads are playing a role in fragmenting habitat worldwide (Alexander & Waters, 2000; Beier et al. 2008; Clevenger et al., 2001a; Colchero et al., 2010; Ford et al., 2009; Northrup et al., 2012; Shepard et al., 2007). Road ecology is the study of roads and their interactions with the surrounding environment, from wildlife to vegetation, sedimentation to chemical runoff (Forman et al., 2003). Roads have been around for millennia, but their increase in density has emerged as a means for greater access for the growing human population. From this expansion in the road network, road ecology developed as a way to study the effects of roads on the surrounding environment, as they are now a prominent and influential feature on the landscape (Corlatti et al., 2009; Forman et al., 2003; Glista et al., 2009; Hochrein, 2008; Liviatis & Tash, 2008; Trombulak & Frissell, 2000).

Road ecology within APP is a point of interest since the park contains an extensive logging road network (Algonquin Provincial Park Management Plan, 1998; Roger et al., 2012; Selva et al., 2011). As the persistence of large mammals in this park is important to the overall ecosystem integrity, as well as the social and economic components of APP, there is a desire to have a greater understanding of how the logging roads in the park influence the movement and connectivity of these populations. Five large mammals are studied in order to determine what local- and landscape-level variables influence their use of both the primary and branch logging roads in APP.

1.1 Road Ecology and Fragmentation

Habitat fragmentation is increasing globally as human development, including the road network, increases (Bissonette & Adair, 2008; Shepard et al., 2008). It is estimated that one third to one half of the worlds landmass is already impacted by human activities with little evidence of that slowing down or stopping (Bissonette & Adair, 2008). This fragmentation can factor into species loss if it is severe enough and dissect critical habitats into smaller patches (Alexander & Waters, 2000; Frair et al., 2008; Heilman et al., 2002; Shepard et al., 2008). Fragmentation is also one of the most important factors in native species loss and extinction (Corlatti et al., 2009). When trying to ensure the persistence and existence of the charismatic mammals of APP, such as moose (*Alces alces*) and eastern wolves (*Canis lupus lycaon*), consideration needs to be taken of the logging road network and its potential effects on those species (Grilo et al., 2008). Roads have had increasing impacts on the ecosystems because of their increase in number, density, and greater spread into previously untouched areas (Forman et al., 2003; Litvaitis & Tash, 2008). In North America where the vast majority of land is within 1km of a road, this is a pertinent issue as there are a wide range of ecological effects that roads have on the ecosystems and species that live in them, well beyond the actual footprint the roads cover (Bissonette & Adair, 2008; Litvaitis & Tash, 2008; Roger et al., 2011).

A mitigation measure for reducing this form of habitat fragmentation is to construct wildlife-crossing structures such as over-passes or underpasses, in order to provide some form of connectivity to the wildlife in a particular location (Corlatti et al., 2009). It is difficult to determine the effectiveness of these structures, and recommendations take the form of continued research to determine if populations are being sustained at an indefinite survival rate. In the study by Olsson et al. (2008), the authors looked at overpass use by moose and roe deer (*Capreolus capreolus*). Their results found that use was different for the two species, that traffic volume affected their use of the overpass, and that having fencing along the sides of the highway assisted in filtering the wildlife to the overpass. There was also a noted time lag in overpass use as the two ungulates became accustomed to its presence. Overall, habitat fragmentation caused by roads is greater in areas with large highways with high volumes of traffic compared to the logging roads of APP, but it is understood that density of the road network plays a strong role in determining how fragmented a landscape truly is for a group of species and not just the road width and traffic volume as the only influencing variables (Forman et al., 2003).

Within APP, there is a vast network of roads. These roads exist for the purpose of forestry resource extraction and to a much lesser extent, to facilitate recreation. Many thousands of kilometers of logging roads are within the park that have the potential to pose as a threat to the large mammals living there. This is the only exception for an Ontario Provincial Park that allows logging to occur within the boundaries of a protected area (Algonquin Provincial Park Management Plan, 1998). As logging is an on-going practice within this park, the primary logging roads are active at all times, while branch level logging roads are reopened during extraction and frequently blocked when complete (Algonquin Provincial Park Management Plan Amendment, 2013). There is also year-to-year movement of where the forest resource extraction takes place, in order to minimize impact on the environment. This exception to the rule for Ontario Provincial Parks creates a unique system to study how logging roads may affect large mammals.

With the logging roads creating fragmentation of APP forest, and the added fragmentation of the logging itself, the large mammal community in APP may be impacted in some way. When a native forest, such as APPs becomes increasingly fragmented there is a change from an internally driven system to an externally driven one (Heilman et al., 2002). There is also natural fragmentation in this system as the landscape is covered with open water lakes, rivers and streams, as well as the natural topography of the landscape (Algonquin Provincial Park Management Plan, 1998). Consideration for both types of fragmentation will assist in our understanding of suitable habitat for the large mammals in the park and if they utilize the logging roads for movement.

Road networks have large impacts on the fragmentation of a landscape and the wildlife populations (Frair et al., 2008; Grilo et al., 2008; Ritters & Wickham, 2003). These impacts include both direct and indirect, and both positive and negative effects on wildlife (Baggio et al., 2011; Lesmerises et al., 2012). These impacts include pollution of sound, air, and light, wildlife-vehicle collisions, fragmentation, and alteration of ecosystems functioning, such as water flow patterns, water quality and availability of suitable habitat (Bissonette & Adair, 2008; Clevenger & Sawaya, 2010; Forman et al., 2003). From research observing the effects of road networks on wildlife worldwide, there are indications of correlations between species abundance and road density (Frair et al., 2008). By focusing my study on the logging roads of APP, I have chosen to examine a road ecology system that has been researched very little, in order to increase our understanding of road ecology in many different ecosystems.

Looking into the direct negative impacts of roads would include the dangers they pose for individuals trying to cross roads. Factors that play into wildlife-vehicle collision rates are traffic volume, vehicle speed, driver awareness, animal speed, roadside vegetation, time of day or year, habitat juxtaposition, landscape integrity, animal abundance, and road width (Forman et al., 2003; Litvaitis & Tash, 2008; Olsson et al., 2008). Within APP wildlife mortality is a greater concern on the highway 60 corridor that runs 56km through the park, and less so on the logging roads where traffic volume is low (Algonquin Provincial Park Management Plan, 1998). Ways to reduce wildlife-vehicle collisions from occurring is to implement fencing along highways, which often works best in conjunction with crossing structures, as well as the implementation of driver cautionary signs, slower speed limits and other human or animal behaviour-changing device (Forman et al., 2003). Previous research has found that large mammals tend to be particularly vulnerable to roads as their home ranges tend to be large (Forman, 2010; Forman et al., 2003; Kusak et al., 2009; Nicholson & van Manen, 2009).

Roads also have negative consequences on many species of wildlife through noise pollution, light disturbance and emissions pollution, potentially causing indirect harm to the health and well being of animal and plant species living in affected areas (Forman et al., 2003). Highways will have higher levels of these types of disturbances since the traffic volume is generally higher and streetlights are placed more frequently on these roads (Cserkesz et al., 2013; Leblond et al., 2013). On the other hand, the logging roads in APP have almost no streetlights present (some at the entrances off Highway 60) and the traffic volume tends to be low as the forest industry, park staff and other authorized vehicles are the only permitted vehicles on these roads. Noise pollution may be a strong deterrent for the large mammals of APP where forest extraction is currently taking place due to the heavy machinery and trucking present in those areas. As APP is large, and the area in which logging takes place is minimal, it is expected that these species have the ability to move away from these areas of disturbance into other areas of suitable habitat (Algonquin Provincial Park Management Plan, 1998; Clevenger et al., 2001b).

Conversely, road networks may have a positive influence on some species (Forman et al, 2003). It may provide relief from predation for prey species when their predators will not approach areas with roads, such as deer species that can escape predation by wolves (*Canis lupus*), bears (*Ursus sp.*), or other predators by foraging there (Bowman et al., 2010; Clevenger et al., 2001a). Roads may also provide easy passage and access to new habitats and act as travelling corridors for large-ranging species, such as those movements observed of wolves and moose (Bowman et al., 2010; Lebel et al., 2012; Lesmerises et al., 2012). Highways, country roads and logging roads may also provide the necessary edge habitat or forage material required for some niche species (Beyer et al., 2013). Specifically one can look at the berry growth on the edges of roads that attracts American black bears (*Ursus americanus*) and grizzly bears (*Ursus arctos*)

(Clevenger et al., 2002; Northrup et al., 2012). Greater deciduous growth is also found in recently logged areas and along roadsides, providing an abundance of desirable forage for herbivores, in turn attracting predators to those areas to hunt their prey with greater probability of success. As moose and white-tailed deer (*Odocoilieus virginianus*) move to these foraging locations, wolves also migrate to these areas as their prey are in higher densities (Bowman et al., 2010; Nikula et al., 2004).

My research specifically examines the use and effects of primary and branch logging roads on the large mammals of APP. Primary logging roads are wider than branch logging roads, and tend to have higher maintenance, as they are kept functional at all times (Algonquin Provincial Park Management Plan, 1998). Most research studying mammals and roads examine the effects highways and areas with high road densities, or logging roads within the boreal forest (Alexander & Waters, 2000; Ascensao et al., 2013; Beckmann et al., 2010; Bowman et al., 2010; Clevenger et al., 2001b; Grilo et al., 2008; Gurratxaga et al., 2010; Kusak et al., 2009; Olsson et al., 2008). The logging roads in APP are unique as they are within the Great Lakes-St. Lawrence forest region within a protected area (Algonquin Provincial Park Management Plan, 1998). This research hopes to fill some gaps in logging road ecology in a more mixed forest, and by examining not only a single species of large mammal, but by looking at both carnivore and herbivore species. This is important because high priority in protected areas goes to conservation and preservation of their wildlife and maintaining ecological integrity (Algonquin Provincial Park Management Plan, 1998; Ontario Parks, 2013; Parks Canada, 2013).

Secondly, APP allows resource extraction in two ways, through logging and hunting, which makes it a fairly unique protected area that still requires sustainable populations of their large, charismatic animals. It should be noted that hunting is permitted by the Algonquins of Ontario on the east side of the park and by the public in the townships of Burton, Clyde, and Eyre, therefore restricting the impact to the large mammals in the park (Hunting Regulations 2013-2014). This leaves the potential impact of logging roads, so gaining greater knowledge of how their large mammals react to primary and branch logging roads, park managers will have a better understanding of their ecosystem and how to balance between habitat suitability, wildlife protection, providing great visitor experience, and sustainable resource extraction.

1.2 Habitat Connectivity and Wildlife Ecology

Habitat connectivity is important for population survival, as genetic diversity is important to any species of plant or animal (Corlatti et al., 2009; Luque et al., 2012). This is particularly important for species that have large home-range requirements, longer dispersal distances, and widespread populations that require new genetic input from time-to-time. Connectivity is especially important in the world today, since habitat fragmentation is a prevalent issue as discussed in the previous section (Caro et al., 2009; Chetkiewicz and Boyce, 2009). By promoting and maintaining connectivity, there is a better chance for higher biodiversity and resilience in a given ecosystem (Baggio et al., 2011; Minor & Lookingbill, 2010). Accompanying this will be a higher tolerance and elasticity to changing dynamics and disturbances, therefore allowing greater species persistence over the long term, and perhaps a better chance at adaptation and survival under the influences of current and future challenges (Molles & Cahill, 2008; Worboys et al., 2010).

Many types of connectivity enhancements have been used and established all around the world (Clevenger et al., 2002; Forman et al., 2003; Glista et al., 2009; Kaphegyi et al., 2013; Mata et al., 2008). Some are large, expensive, dramatic undertakings such as wildlife overpasses built over large highways to protect both wildlife and humans from vehicle collisions. Underpasses are another method for reducing road impacts on wildlife that tend to be less expensive and useful to a wide range of species. They may also consist of culverts laid under the road or a bridged river valley, leaving it open to wildlife movement. Another tool used to guide wildlife to suitable crossing areas is fencing, which has been shown to provide greater safety to both humans and large mammals along highways in North America and Europe (Ascensao et al., 2013; Clevenger et al., 2001a; Leblond et al., 2007; McCollister & van Manen, 2010). On a smaller scale, vegetation changes such as cutbacks or restoration can be used to assist mammal crossing on smaller, less-used roads by providing areas of preferred habitat, and encouraging crossing at those locations (Forman et al., 2003; Grilo et al., 2008; Witt et al., 2012). One other tool that can assist in safer crossing for species is the use of signs as warnings to drivers on the roads (Forman, 2010; Sherwood et al., 2002). Most often it is suggested that signs be used in conjunction with other methods of road connectivity. In fact, using multiple methods of providing connectivity for wildlife and increasing safety for vehicle drivers may be the most beneficial in the long run for high-use roads (Forman et al., 2003).

One initiative that has emerged in the last decade is the Algonquin to Adirondacks connectivity plan (A to A, 2012). The goal of this endeavor is to provide connectivity between these two core habitat areas to improve the conservation of North American wildlife. This is a similar idea to the Yellowstone to Yukon Conservation Initiative that strives to provide large, landscape-level connectivity by creating viable corridors between two distant protected areas (Y2Y, 2013). It was due to our greater understanding of the importance of habitat at a larger scale that these initiatives, and others on smaller scales were initiated.

Figure 2. Moose in its summer aquatic habitat, Algonquin Provincial Park. Photo credit Hillary Rouslton.

To examine APP at the landscape level, I specifically chose road density as a landscape variable as many large mammals react to this measure of human impact (Beyer et al., 2013; Bowman et al., 2010; Fahrig & Rytwinski, 2009; Forman et al., 2003; Lugo

& Gucinski, 2000). Besides road density my study will also look at how forest coverage factors into the predictability of large mammal presence on the primary and branch logging roads of APP. I would expect that areas with larger contiguous forest would have more evidence of mammal presence, as many species prefer the safety and resources heavy forest cover can provide (Bowman et al., 2010; Kaphegyi et al., 2013; Kindall & van Manen, 2007; Lewis et al., 2011). Water cover is also examined, and may influence the presence of species on the roads as it may increase access to water as a necessary element of survival, including moose, which prefer aquatic habitats during the summer (Puttock et al., 1996) (Figure 2). Topographic ruggedness index (TRI) is the last landscape-level feature to be looked at, and as roads are constructed based on topography, there may be a correlation between road location and topography, as well as predicting that the wildlife may also utilize those areas as the topography allows for easier movement (Acevedo et al., 2011; Lesmerises et al., 2012; Roger et al., 2012).

Figure 3. Moose along highway 60 in Algonquin Provincial Park. Photo credit Hillary Roulston.

To take the concept of ecology to a narrower scale then that of community ecology or landscape-level ecology I focus into the concept of individual species ecology. Specifically, my current study focuses on the presence of large mammals on APP primary and branch logging roads. A total of five large mammal species were observed in the study and included: American black bear (*Ursus americanus*), coyote (*Canis latrans*), moose (*Alces alces*) pictured above in Figures 2 and 3, white-tailed deer (*Odocoileus virginianus*), and eastern wolf (*Canis lupus lycaon*). By knowing habitat selection characteristics for each species and a grasp on their movement behaviour an overall understanding of why they use or would not use the primary and branch logging roads of APP could be determined (Williams et al., 2011). A landscape-level approach to conservation and restoration has become key to a better understanding of large mammal ecology. Although my current study is working within the bounds of a protected area, it is important to know that there are many different designated areas for different uses within this park through park zoning as discussed in further detail in Section 3.1, making landscape scale data important for this analysis (MacPherson & Bright, 2011).

Suitable habitat for these mammals generally involves the best forage available to them while taking into consideration predation, anthropogenic disturbances and ease of movement (Beyer et al., 2013; Boan et al., 2011; Bowman et al., 2010; Lebel et al., 2012; Masse & Cote, 2012; Nikula et al., 2004; Puttock et al., 1996). Each species has requirements for survival, which generally dictate movement and habitat use. The following table (Table 1) summarizes key characteristics of the large mammals from this research by describing how they are affected by different types of disturbances and habitat features.

Table 1. Outline of the five studied mammals and the different variables that have some potential influence on them, based on previous literature. (+) This symbol indicates a positive correlation, (-) this a negative correlation, and (=) this indicates a neutral correlation. Note that road density is an issue of higher traffic levels and human encounters, rather than causing hunting increases in these studies.

Species	Important Variables	Description	Sources
American Black Bear (*Ursus americanus*)	Road density (-)	Greater road cover, less likely to see bear movement.	Cushman & Lewis, 2010; Trombulak & Frissell, 2000
	Road use levels (-)	More traffic causes bears to stay further away.	Cushman & Lewis, 2010
	Forest cover (+)	Greater forest cover promotes suitable bear habitat.	Cushman & Lewis, 2010; Frary et al., 2011; Kindall & Van Manen, 2007; Long et al., 2011
	Marsh habitat (+)	Suitable bear habitat when marsh is present.	Jones & Pelton, 2003
	Human development (-/+)	Anthropogenic development causes bears to move away from the area, though campgrounds may have an opposite effect.	Cushman & Lewis, 2010; Long et al., 2011; Government of New Brunswick, n.d.
Coyote (*Canis latrans*)	Human disturbed areas (=)	Areas with human disturbance may deter use by coyotes.	Boisjoly et al., 2010; Kays et al., 2010
	Wolf extirpation (+)	When wolves are not present, coyotes can move into that niche and find suitable habitat and prey.	Boisjoly et al., 2010; Kays et al., 2010
	Logged landscapes (+)	Recently logged areas promote young herbaceous growth, which draws prey in, a food source to the coyote.	Boisjoly et al., 2010
Eastern Wolf (*Canis lupus lycaon*)	Road density (-/+)	Wolves will utilize roads for ease of passage, but they may also avoid them, especially if traffic levels are high.	Bowman et al., 2010; Carroll et al., 2003; Carroll et al., 2006; Houle et al., 2010; Mech, 1995; Mladenoff et al., 1995; Trombulak & Frissell, 2000
	Human development (-)	Wolves tend to avoid areas with higher human development.	Argue et al., 2008; Carroll et al., 2006; Musiani et al., 2010; Oakleaf et al., 2006
	Prey density (+)	Wolves will migrate towards areas where their prey density is highest.	Carroll et al., 2003; Cook et al., 1999; Forbes & Theberge, 1996; Laviviere et al., 2000; Lesmerises et al., 2012; Mladenoff et al., 1995; Musiani et al., 2010; Oakleaf et al.,

			2006; Vucetich et al., 1997
	Linear structures for movement (+)	Wolves may utilize road and streams for ease of movement while foraging.	Bowman et al., 2010; Houle et al., 2010; Latham et al., 2011; Lebel et al., 2012; Lesmerises et al., 2012; McLoughlin et al., 2011; Patterson et al., 2004
	Forest percent cover (+)	Greater forest cover provides protection and cover for wolves.	Carroll et al., 2003; Oakleaf et al., 2006
	Deciduous forest (+)	Attracts common wolf prey, such as deer.	Bowman et al., 2010; Musiani et al., 2010
	Coniferous forest (+)	Provides appropriate habitat for wolf dens and rendezvous sites.	Kolenesky & Johnston, 2010
	Mixed forest (+)	Mixed forest provides habitat for both wolves and for their prey.	Kolenesky & Johnston, 2010
	Logged landscapes (+)	Opens the forest canopy to allow new growth, which encourages deer and moose to forage there, attracting wolves to the area.	Bowman et al., 2010
	Steep terrain (-)	Difficult to move from place to place.	Carroll et al., 2006
Moose (*Alces alces*)	Early successional species (+)	Provides great forage material.	Boan et al., 2011; Bowman et al., 2010; Puttock et al., 1996
	Deciduous forest (+)	Provides shelter, protection and forage material.	Boan et al., 2011; Bowman et al., 2010
	Anthropogenic disturbance (-)	Moose tend to avoid areas with higher human disturbance.	Bowman et al., 2010
	Road density (-)	Areas of high road density are generally avoided by moose.	Bowman et al., 2010; Houle et al., 2010
	Logged landscapes (+)	Recently logged areas provide great forage from the new growth of vegetation.	Boan et al., 2011; Houle et al., 2010; Latham et al., 2011; Lesmerises et al., 2012
	Roadside vegetation (+)	Often young, herbaceous growth provide moose with good forage.	Finnegan et al., 2012; McLoughlin et al., 2011
White-Tailed Deer (*Odocoileus virginianus*)	Early successional species (+)	A preferred foraging vegetation of deer.	Boan et al., 2011; Bowman et al., 2010; Witt et al., 2012
	Anthropogenic development (=)	Can provide both beneficial and detrimental habitats.	Bowman et al., 2010
	Road density (-)	High levels of roads in an area tend to be avoided by deer.	Houle et al., 2010
	Deciduous forests (+)	Provides deer with appropriate habitat and forage.	Boan et al., 2011; Bowman et al., 2010
	Logged landscapes (+)	Recently logged areas encourages young vegetation, a highly sought after vegetation by deer.	Boan et al., 2011; Boisjoly et al., 2010; Witt et al., 2012

Some animal species are more adaptable to situations and new scenarios than others. White-tailed deer and coyotes are flexible and adaptive species that can live in rural and urban areas across North America. On the other hand, American black bears, eastern wolves and moose can live successfully in areas of moderate disturbance (Table 1). To further understand large mammal use of habitat, examination of home range size can provide more insight into these species' lives. The following table (Table 2) provides a summary of approximate sizes of home ranges for the five large mammals of this study. These data were collected from previous research, and potentially allow us to understand large mammal use of habitat and how far they are willing to migrate to find suitable habitat.

Table 2. Sources of reference for home-range sizes of the six large mammals studied in Algonquin Provincial Park. *Average homeranges of each species: American Black Bear (88km^2), Coyote (38km^2), Eastern Wolf (284km^2), Moose (186km^2), and White-Tailed Deer (3km^2).

Species	Home Range Size	Description	Sources
American Black Bear (*Ursus americanus*)	~100km^2	Breeding areas in Algonquin Provincial Park, Ontario.	Inglis et al., 1998
	4 – 126km^2	Female bears in Ocala National Forest, Florida.	Moyer et al., 2007
	28km^{2}Female 170km^{2}Male	Male and female ranges from North-Central, Florida.	Wooding & Hardisky, 2001
Coyote (*Canis latrans*)	Up to 26km^2	Average of resident and transient coyotes from Chicago, Illinois.	Gehrt et al., 2009
	Up to 57km^2	Coyote home-ranges from the Northern Chihuahuan Desert.	Howard & DelFrate, 1991
	Average 30km^2	Eastern coyotes from an urbanized area, Cape Cod, Mass.	Way et al., 2002
Wolf (*Canis lupus*)	Up to 500km^2	Based on a Ontario level of study.	SARA, 2013; SBAA, 2005
	Average 201km^2	From grey wolves in Poland.	Jedrzejewski et al., 2007
	Average 150km^2	Daily movement of wolves from Dalmatia, Croatia.	Kusak et al., 2005; SBAA, 2005
Moose (*Alces alces*)	3.6 – 92km^2	Based on globally ranged studies of moose from the University of Michigan.	De Bord, 2009
	13 – 26km^2	Male and female moose from Sweden.	Cederlund & Sand, 1994
	40 – 942km^2	Female moose in the Northwest Territories, Canada.	Stenhouse et al., 1995
White-Tailed Deer (*Odocoileus virginianus*)	~1km^2	Fragmented urban habitat near Chicago, Illinois.	Piccolo et al., 2000
	3 – 7km^2	Comparison between two protected areas in Florida.	Sargent & Labisky, 1995

1.3 Land Management

Following from species-specific ecology is a move into land management as another focus of this research. Understanding how ecosystems function and how the mosaic of a landscape interacts is key to knowing how to manage it (Chetkiewicz & Boyce, 2009; DeFries et al., 2007; Kindall & van Manen, 2007). There are different areas of thought for land management and where they fit in; such as natural resource extraction, conservation, and development. Over the last century greater concern for protecting land emerged, and consideration for conservation of other species emerged as well (Dearden & Rollins, 2009; Lockwood et al., 2006). At first the concept was in the form of game reserves and hunting forest for the wealthy, but as time moved forward, conservation for the preservation of life and protection from human disturbance became the main force in land management.

Land management is a tool used by humans to conserve, extract, and utilize resources. Management of natural resources has been used as a reason to protect areas of land, such as APP for forestry preservation and headwater protection (Algonquin Provincial Park Management Plan, 1998). Land management is important in many of areas, but management of the landscape within a protected area is especially of concern as a variety of activities can take place within the borders of a single space.

1.4 Protected Areas

Since the late 1800's, an understanding for protecting important and scenic pieces of land was desirable (Dearden & Rollins, 2009; Lockwood et al., 2006). It began with some of the world's most renowned parks of today, such as Yellowstone National Park in Wyoming, USA and Banff National Park in Alberta Canada. Since their inception, parks were being formed all over the world, and have been increasing ever since. This dramatic shift in land management was instigated because of our growing human population and subsequent higher use of the world's natural resources and a greater appreciation for what natural areas can represent to us as humans (D'Antonio et al., 2013; DeFries et al., 2007; Minor & Lookingbill, 2010; Naughton-Treves et al., 2005; Roever et al., 2008).

In recent years, there has been growing concern over the loss of key habitat and wildlife. Due to this concern protected areas began to be established, frequently in systematic ways, such as the National Parks Systems Plan of Canada, where at least one park is to be established in each of the 39 defined eco-regions of the country (Parks Canada, 2013). At the international level the International Union for Conservation of Nature (IUCN) has brought together the protected areas from many countries by establishing criteria for which a protected area can fit in to (IUCN, 2013; Lockwood et al., 2006). The classifications that the IUCN established include: 1a strict nature reserve, 1b wilderness area, 2 national park, 3 natural monument or feature, 4 habitat/species management area, 5 protected landscape/seascape, and 6 protected areas with sustainable use of natural resources. For Ontario Provincial Parks, they are also created to provide a system of protection by including representative ecosystems in the province, both naturally and culturally, in order to maintain biodiversity, and to provide recreation that is sustainable, compatible and ecologically sound (Provincial Parks and Conservation Reserves Act, 2006).

Protected areas have had a strong role in research that is trying to determine if there is a connection between their existence and the sustainability and conservation of the world's biodiversity (Giam et al., 2011; Naughton-Treves, 2005). The size of a protected area has an effect on the ability to conserve biodiversity, as it takes into account edge effect and the size of the core area with less human disturbance (Molles & Cahill, 2008; Smith & Smith, 2009). This is particularly key for large-ranging mammals that require large, relatively undisturbed home ranges for survival (Fahrig & Rytwinski, 2009;

Kusak et al., 2009). There is also the question of connectivity between protected areas, and a move towards networks of protected areas with corridors between them (Minor and Lookingbill, 2010).

There is an economic component with almost everything in today's society, and protected areas are no different (Dixon and Sherman, 1991). There is a large gap in adequate funding for protected areas and it has been seen in the 2012 cutbacks at the national and provincial level of parks in Canada and Ontario respectively (Ontario Parks, 2013; Parks Canada, 2013). Many parks around the world acquire a great deal of their revenue from visitor user fees, which in turn has its ramifications for the potential degradation of ecological integrity for these protected areas. For Canadian and Ontario parks, both systems have stated that ecological integrity is of highest priority to their parks, but with recreation and visitor use potentially driving the system, it may be put to the side as the more financially benefitting socio-economic aspects of visitor revenue takes the place as first priority in reality (Algonquin Provincial Park Management Plan, 1998; Dixon & Sherman, 1991).

As stated above, all aspects of protected areas are important to consider from the ecological to the social and economic. It is up to each protected area to strike a balance between these facets of park management and realize the benefits and consequences. For APP specifically, balance for ecological integrity must be met with resource extraction, recreation, and financial stability.

1.5 Land Management in Protected Areas

Land management is just as important inside protected areas as it is outside of them. Surrounding land may be important for human survival by providing the essentials for life, while protected areas provide their own set of important ecosystem services (DeFries et al., 2007). Some of the human-based services fall into areas, such as recreation, health benefits, spiritual sustenance, and a connection with nature (Gies, 2006). Algonquin Provincial Park has some of the highest visitor levels of any of the parks in Ontario and Canada, and provides many of these services people desire (Introduction to Algonquin Park, 2005). Since APP is such a large area of land with the allowance of forestry resource extraction within its boundaries, and is the host to so many visitors every year, there is a great deal of importance riding on suitable management plans to ensure its ecological persistence into the foreseeable future.

Protected areas in many places around the world have key goals and management practices in mind. Ecological integrity has become the key term for Ontario Parks with it encompassing the primary mandate of management for these parks (Ontario Parks, 2013). Connectivity, buffers around the parks and core areas protected from as much human activity as possible are frequently the model used today to provide the greatest amount of protection to these parcels of land, including APP with its zoning (Gurrutxaga et al., 2010). Algonquin Provincial Park is made up of different zones to permit certain activities in some areas and restrict them in others (Algonquin Provincial Park Management Plan, 1998). There are seven zone types across the park consisting of nature reserve, wilderness, natural environment, historical, development, access and recreation/utilization zones. Each has a purpose and a set of rules that control the use throughout the park, creating a series of management tools to assist in overall land management (Further detail within Section 3.1 Study Area, Table 4).

A tool frequently utilized in protected areas management are signs to deter or restrict access to key ecological areas in order to prevent disturbance and destruction of that habitat (Hunt & Hosegood, 2008). In the study by Hunt and Hosegood (2008), the authors examine how effective signs are in restricting the access of vehicle traffic on seasonal forest roads, much like the road use in APP, which is seasonally accessible or permanently restricted. This study found that signs were effective at reducing some vehicle use, but not all, therefore not having the desired results that would be necessary to protect critical habitat. As APP uses multiple strategies to prevent entry, such as locked gates, signs, and berms they may have greater success in keeping unwanted access out of their important habitats than other protected areas even though they contain this vast network of logging roads, which may in turn decrease the fragmenting effects of the logging roads to the large mammals there.

1.6 Logging in Protected Areas

Logging within protected areas is a controversial subject. The majority of protected areas in Canada are not subject to logging practices and other forms of resource extraction (Parks Canada, 2013; Provincial Parks and Conservation Reserves Act, 2006). In Canada, APP is one of the very few protected areas that allows logging to occur (Friends of Algonquin Park, 2013). Logging has historically been practiced in APP before it was protected by the Ontario provincial government. Though this form of resource extraction still occurs today, a great deal of change has occurred as to how it is done. About 1% of the parks forest is currently extracted each year and the majority of it is done through a selective harvest method in order to maintain a functioning ecosystem, as its intention is to mimic natural disturbance (Guitete et al., 2012; Inglis et al., 1998; Simard & Fryxell, 2003; Tozer et al., 2012).

In a study conducted in APP by Simard and Fryxell (2003), they discovered that sugar maple (*Acer saccharum*) produced more seeds in areas that had not been logged within the last 90 years. This indicates some change in forest structure, even where selective harvest is the form of forestry used. In this case the sugar maple may prefer a later successional forest than those soon after logging in an early successional state. The logging practices within the park also affect the soil nutrients by disruption and disturbance to the upper soil layers. The Simard and Fryxell (2003) study also found that in undisturbed stands of sugar maples there were higher numbers of arthropods since there was greater access to seeds for forage. In turn the deer mouse (*Peromyscus maniculatus*) that fed off of the arthropods was also more abundant in these undisturbed sites. On the other hand the eastern chipmunk (*Tamias striatus*) seemed to prefer the more recently disturbed sites as it provided them with high variation in ground vegetation for forage. In this case, the effects of logging on species in the park were both positive and negative in nature, depending on the species it affected. This can also be seen with the large mammals of APP as logging can both deter species presence, such as with

American black bears that prefer greater canopy cover, or it could create ideal habitat for other species, such as white-tailed deer and moose that forage on the young, new growth.

One aspect of logging is the need for road access into the logging sites (Figure 4). By introducing this disturbance, it does in fact fragment the landscape quite effectively and quickly as the logging moves from one site to another (Lugo & Gucinski, 2000). There is evidence in South America that as the roads are widened, it creates a barrier to large carnivore movement and increased access for more anthropogenic disturbances (Colchero et al., 2010). This may not be as pronounced in APP, since Ontario Legislation (Provincial Parks and Conservation Reserves Act, 2006) has greater enforcement over protecting the landscape than in some other countries, but the logging roads into the park do provide potential access to the public who may wish to hunt, extract resources or just visit the park in a manner that is not encouraged.

Figure 4. Primary logging road within Algonquin Provincial Park. Photo credit Hillary Roulston.

Overall, logging within a protected area, such as APP, is an uncommon practice that brings along land management issues and benefits (Algonquin Provincial Park Management Plan, 1998; Ontario Parks, 2013; Parks Canada, 2013). This research, with its focus on large mammal movement and use of the primary and branch logging roads in APP, will help to broaden the scope of understanding for road ecology at this scale and location.

1.7 Road Monitoring Studies

As was gleaned from earlier details, road ecology is a recent field of study (Fahrig & Rytwinski, 2009; Forman et al., 2003; van der Ree et a., 2011). The expanding human population drives the demand for new development, and new development cannot be achieved without the construction of roads. This is also the case when obtaining resources and having access to new resources, such as the logging practices in APP, spreading the road network further. This is not always the case though, as many of the logging roads can be reopened and utilized again every 20-30 years are forestry extraction moves within the park.

To be specific toward this particular case study, APP is one of the only protected areas in Canada to allow legal logging operations within its boarders (Friends of Algonquin Park, 2013). Logging operations require extensive road building to have access to the forests resources. In the case of this park there are the three types of logging roads that are used (primary, branch and tertiary) in order to meet the needs of forestry extraction processes (Algonquin Provincial Park Management Plan, 1998). It is the primary and branch roads that are the focus of this study making road ecology a primary point of view for observing the large mammal movement on these roads, much like these following studies.

Foote and Keeping (2007) from the University of Alberta conducted a study in the Kalahari ecosystem of Africa using mammalian tracking on 15 different transects that were between the ranges of 5-20km in length. They conducted a survey of each of these transects with a rake attached to the rear of the vehicle to erase the tracks already recorded. Each transect would then be analyzed again after 24 hours time. During their study period, 150km of road transect to a maximum of 600km was covered. They tracked on sandy roads of variable lengths in order to have high track visibility. Their vehicles were driven at approximately 10km/hour, and four trackers were within the vehicle to each have assigned tasks to carry out. This study was part of an overarching plan to enhance biodiversity monitoring in the Kalahari and gives a basis to understanding viable road-tracking methods.

D'Eon et al. (2006) is a paper that gives guidelines for winter tracking of ungulates, based in the mountainous regions of the west coast of North America. The authors refer to small transects as being <1000m in length, and larger transects for tracking ungulates as being >1000m in length. Using these standards that were created in D'Eon et al. study, the research for this study has transects that are on the larger scale, between 16 and 20 kilometers long, for monitoring the large mammals of APP.

Ward et al. (2004) gives multiple methods for tracking different groups of animals, including large mammals as their own separate group. In general, the authors give multiple reasons for why indirect tracking of these large mammals is better than direct tracking, and they include: "(1) they can be difficult to see in forest habitat, (2) aerial surveys are not suitable for all species, (3) misidentification can be common from aerial surveys, and (4) indirect studies can be conducted at any time of day and are not dependent on times when levels of animal activity is high." A less invasive way to track mammal presence is by using tracks and scat as evidence (See Figure 5). The types of transects that Ward et al. (2004) used are 100m tracks laid out and walked in both directions with markers every 20m. Each 20m section was looked at individually and any tracks or scat within those points was recorded.


Figure 5. Moose track Algonquin Provincial Park. Photo credit Hillary Roulston.

In a review paper by Fahrig and Rytwinski (2009) the authors go into a detailed summary of road ecology literature that was available to date. Road ecology had become an important topic by this time, and they were able to review 79 journal articles, record 30 species groups that were studied, and find a total of 131 individual species. They took the main results from all of these studies to provide a useful tool to the scientific community with the core concepts and findings from the library of literature on road ecology. In most of the case studies, the research examined direct and indirect impacts of roads on wildlife species, but many did not take the perspective of landscape ecology, or approach animal and road encounters on logging roads.

Overall, road ecology is growing, and specifically looking into a logging road network within a protected area is a gap in the research that needs to be addressed. For this, my research will begin to fill this gap with the large mammals of APP and how they relate to the primary and branch logging roads.

1.8 Hypotheses

My null hypothesis (H_0) states that there will be no difference in large mammal use between the primary and branch logging roads within Algonquin Provincial Park and that local- and landscape-level variables will have no influence on them. My alternative hypothesis (H_1) states that there will be less large mammal activity on the primary logging roads in Algonquin Provincial Park, and more large mammal movement on the branch logging roads and local- and landscape-level variables will influence this use. The literature examining this or a similar question tend to lean towards the alternative hypothesis, that lower-use roads see greater use and crossing frequencies than larger highways do, so in this case it is expected that the primary logging roads will have less wildlife use, as traffic levels are slightly higher (Beyer et al., 2013; Forman et al., 2003; Leblond et al., 2013; Northrup et al., 2012).

1.9 Purpose, Objectives and Relevance of This Study

The overall purpose of this study is to determine how large-sized mammals utilize APP logging roads, and what variables may factor into these movements. There is also further examination for distinction between two layers of logging roads within the park, primary logging roads or branch logging roads and how local- and landscape-level variables may influence large mammal presence. Primary logging roads are no wider than 13.7m, tend to be well maintained, have gravel as their main aggregate, and have regular grading of their surfaces (Algonquin Provincial Park Management Plan, 1998). Branch logging roads are built no wider than 9.1m, overall tend to be smaller in width than primary logging roads. Some maintenance does occur on active logging roads, that includes grading and gravel input. The level of road use by large mammals is determined by total number of individual evidence located on the two logging road types and if difference in use is significant or not.

The two main objectives of this study are as follows: (1) to determine if there is a difference between primary and branch logging road use by large mammals based on their distinct features and surrounding habitat characteristics, and (2) to determine what local-level features and landscape-level features influence logging road use by large mammals in APP.

Connectivity of habitat for wildlife species, particularly those that have wide-ranging territories, is important for their survival (Alexander & Waters, 2000; Bowman et al., 2010; Colchero et al., 2010; Garcia-Rangel & Pettorelli, 2013; Grilo et al., 2011; Kaphegyi et al., 2013; Kusak et al., 2009; Lesmerises et al., 2012; Lewis et al., 2011; Long et al., 2011; Nicholson & van Manen, 2009; Woodroffe & Ginsberg, 1998). This creates a relevant area of research to examine the connectivity of large mammals in APP, and how the logging roads may or may not be hindering their movements and overall population stability.

There is a strong need for studies to be conducted on logging roads that do not focus within the boreal forest, with further intent to study how they effect mammalian species movement and survival. A great deal of recent literature is available on highway mitigation strategies for many groups of wildlife, including mammals, reptiles, birds, amphibians and invertebrates (Acevedo et al., 2011; Buchmann et al., 2013; Fahrig & Rytwinski, 2009; Forman et al., 2003). There has also been forest roads research, but these studies tend to focus on the impacts of the roads on wildlife populations in the boreal forest or in mountainous terrain (Lesmerises et al., 2012; Lewis et al., 2011; Madej, 2001). This leaves a key gap in our knowledge on the effects of logging roads on the mammals in the Great Lakes-St. Lawrence forest region, and how these logging roads might effect their movement and use of habitat. Research in this area will be important for filling this gap in logging road ecology for the mixed forests of APP and how potential wildlife management strategies can be created if needed for a greater understanding of their use or non-use of the primary and branch logging road network in this park.

2.0 METHODS

2.1 Study Area

My research is based in Algonquin Provincial Park, Ontario, Canada (N 45°30' W78°40'), which is a protected area 763,459 hectares in size in the central area of the province and is classified as a natural environment park under the Ontario Parks class list (Ontario Parks, 2013). This park is renowned for its vast forests and thousands of lakes that are frequently canoed. Camping, recreational activities, forestry resource extraction and hunting all take place within the park boundaries, and is thought of as a multi-use park that fits all of these uses by time and space separation (Algonquin Provincial Park Management Plan Amendment, 2013). It is the forestry activities that are of key interest to this particular study, as this activity requires a vast network of roads in order to gain access to the interior forests of the park. Many kilometers of logging road exist within APP as a reminder that forestry is an ongoing practice within this renowned protected area (Algonquin Provincial Park Management Plan, 1998) (See Figures 7-12).

The overall designation of this park by the IUCN is Category IV or a Habitat/Species Management Area (IUCN, 2013; Ontario Parks, 2013). This park is also further divided into seven zones at the provincial level, where differing activities are permitted, and one zone that is unique to APP. These zones include nature reserve, wilderness, natural environment, historical, development, access points, and recreation/utilization zones where forestry resource extraction is permitted to take place (Table 3) (Algonquin Provincial Park Management Plan Amendment, 2013).

Table 3. Proportions of zoning within Algonquin Provincial Park, showing direction of change in area from previous management plan zoning (+ increase in size, - decrease in size). Adapted from the Algonquin Provincial Park Management Plan Amendment, 2013.

Zone Type	Area (ha) 2013	Area (%) 2013	Change from 1988
Nature Reserve	51,462	6.8	+
Wilderness	104,792	13.7	+
Natural Environment	83,470	10.9	+
Historical	1,624	0.2	-
Development	22,502	3.0	-
Access	824	0.1	+
Recreation/Utilization	498,785	65.3	-
Total	**763,459**	**100**	

Each of these provincial park zones permits different levels of activities and human disturbance. Directly from the park management plan a Nature Reserve zone is: *any significant earth and life science features that require management distinct from that in adjacent zones*. This zone does not permit camping, with the exception of some interior camping, and temporary facilities for management or research may be permitted. The Wilderness zone is described as: *wilderness landscapes of appropriate size and integrity that protect significant natural and cultural features and are suitable for wilderness experiences*. The goal of this zone is to protect ecological processes as they encompass large areas of the landscape. No railways, logging, buildings or hydro lines are permitted in these areas, and any disturbances that do occur are generally natural, such as wildfire, disease, insects, windthrow and wildlife disturbance. Natural

Environment zones are: *aesthetic, natural and cultural landscapes in which there is minimum development required to support low-intensity back-country recreational activities*. These activities include horseback riding, hiking, bicycling, canoeing, fishing, backpacking, skiing, and back-country camping. The next zone, Historical: *include(s) any significant historical resources that require management distinct from that in adjacent zones*. This zone permits the continued existence of archeological and historical evidence of human cultural within the park. *Development zones provide the main access to the Park and facilities and services for a wide range of day use and camping activities*. These facilities include offices, outfitters, access points, parkway corridors, concessions, and administrative offices, as well as opportunities for day-use facilities and overnight camping. Zones in the Access area: *serve as staging areas where minimum facilities support use of Nature Reserve and Wilderness Zones and less-developed Recreation/Utilization, Natural Environment, and Historical Zones*. Last of all is the Recreation/Utilization zone that is of the greatest relevance to my research. It: *includes aesthetic landscapes in which there is minimum development required to support low-intensity recreational activities and which also provide for commercial forest management. To the greatest extent possible, they will be planned, developed and manged in accordance with the policies set out for the Natural Environment Zones*. This zone is unique to APP by allowing for forest resource extraction in low amounts. This is also the zone where hunting and trapping is permitted during specific periods of time for the Algonquins of Ontario on the east side of the park.

The forests of APP are mixed in nature and consist of species such as: sugar maple (*Acer saccharum*) (the dominant species on the west side of the park), yellow birch (*Betula alleghaniensis*), Eastern hemlock (*Tsuga canadensis*), Eastern white pine (*Pinus strobus*), red pine (*Pinus resinosa*) (both pines are the dominant species in the sandier soils of the east side of the park), American beech (*Fagus grandifolia*), and red oak (*Quercus rubra*) (Introduction to Algonquin Park, 2005). In the northern portions of the park there are spruce bogs, which consist mainly of black spruce (*Picea mariana*) and tamarack (*Larix laricina*) trees (Kershaw, 2001).

The most common large mammal species that live in the park are being studied in this project, including the American black bear, eastern wolf, moose, white-tailed deer, and the coyote. As hybridization and similarity in size occur in eastern wolves and coyotes, for the accuracy of this study both of these species will be placed together in a group labeled canine. These are the species that are expected to leave visible prints in the aggregate of the logging roads and perhaps scat or other forms of evidence of their presence as well. Since they are all in the large range of mammal size, it is also expected that their movements will be wider ranging as they generally have large home ranges and dispersal needs (See Table 3 for sources). Because of these large ranges, it is likely that they would encounter the logging roads within APP regularly. There will also be factors influencing their movements, such as if the logging road is still frequently accessed by loggers, parks employees, researchers, or the public, if it is a primary or branch logging road, and whether other local- and landscape-level variables influence large mammal presence and use of those logging roads.

These five species were also chosen for the reason of providing key information to APP for future reference and large mammal background. Many of the large mammals of the park are present and desirable for visitor viewing (Algonquin Provincial Park Management Plan, 1998). This in turn promotes park tourism and revenue for the park. While this is a good reason to monitor their species of large mammals, there is also the potential for data collection on how the species might be utilizing the park, especially under such unique circumstances as forest resource extraction that takes place in the same area. As ecological integrity and providing recreation for the public is main goals of APP, Protection of our large mammals is just one point in this complex relationship, but they are worth understanding as a stepping-stone in gathering information for this vast protected area.

2.2 Variables Measured in My Study

When reviewing previous literature of mammal tracking studies, a number of variables emerge that are useful for studying these animals presence and movement (Acevedo et al., 2011; Alexander & Waters, 2000; Bowman et al., 2010; Brady et al., 2011; Chetkiewicz & Boyce, 2009; Clevenger et al., 2001b; Cushman & Lewis, 2010; Grilo et al., 2008; Kindall & van Manen, 2007; Long et al., 2011; Roger et al., 2012). Two groups of variables were measured in this study from the local-level and the landscape-level, as both can provide important information for determining large mammal use of APP logging roads (Leblond et al., 2011; Morellet et al., 2011). Also previous literature guided my choice of transects, their lengths and how frequent observation points were made. When comparing to Ward et al. (2004), my transects were considered large in size.

The response variable for my study is the total number of individuals for each transect, calculated by examining primary and branch logging road for three repeated surveys, in order to gather information on what local-level and landscape-level variables influence movement of moose, white-tailed deer, eastern wolf, coyote, and American black bear in APP (Cushman et al., 2011; Forman, 2010; Garcia-Rangel & Pettorelli, 2013). With this as the main focus, I hope to understand more about the influences differing habitat variables can have on the large mammals of Ontario in the APP region.

Figure 6. Branch logging road in Algonquin Provincial Park. Photo credit Hillary Roulston

Local-level measurements and identification were taken for vegetation type/surrounding habitat type (coniferous forest, deciduous forest, mixed forest, meadow, water, or marsh), road width, and road type (primary or branch). Primary roads tend to be permanently in use within APP, whereas branch logging roads may be closed after logging is completed in a particular location. Other variables included road aggregate type, road grading presence, whether there was proximity to water, approximate vegetation height, some note of the primary species composition of vegetation, canopy cover presence or absence, if there were portage crossings nearby, whether hunting was permitted (east vs. west sides of the park), and if there were ditches present and their widths and depths (Figure 6). These variables were chosen from selected compilations of previous studies on what was measured, in order to grasp a strong picture of what the local habitat was like at each observation point (Alexander & Waters, 2000). Slope, though common in other studies, was not included in my research as the APP is not a mountainous area (Clevenger et al., 2002; Lesmerises et al., 2012; Roger et al., 2012).

On the landscape level of variables, measurements were taken for road density, percent forest cover, percent water cover, and topographic ruggedness index (TRI) (See Figures 7-12 for details). These four variables were chosen in order to better understanding of the overall habitat within APP, and how it may influence the movement of the five large mammals I studied. Road density has been known to influence habitat use for many large species, such as wolves, moose, and American black bears (Beyer et al., 2013; Bowman et al., 2010; Chetkiewicz & Boyce, 2009; Lewis et al., 2011). Canopy cover and percentage forest cover can explain presence of some large species, such as bear species who prefer cover as suitable habitat (Chetkiewicz & Boyce, 2009; Kaphegyi et al., 2013; Kindall & van Manen, 2007; Lewis et al., 2011; Mitchell & Powell, 2003). Water cover percentage is important to understand how much area it is covering as it factors in to natural fragmentation of the landscape, and species such as the moose use areas of water as an important habitat during the summer season, which may in turn explain greater use on some road areas (McLoughlin et al., 2011; Nikula et al., 2004; Puttock et al., 1996). Lastly, topographic ruggedness index (TRI) was utilized to see how it might influence the movement patterns of the large species of APP. As it is a commonly recorded variable within previous studies to ascertain if channels of movement exist, it was thought to be important as it may influence actual logging road placement, and therefore correlate with the ease of movement of the wildlife as well (Chetkiewicz & Boyce, 2009).

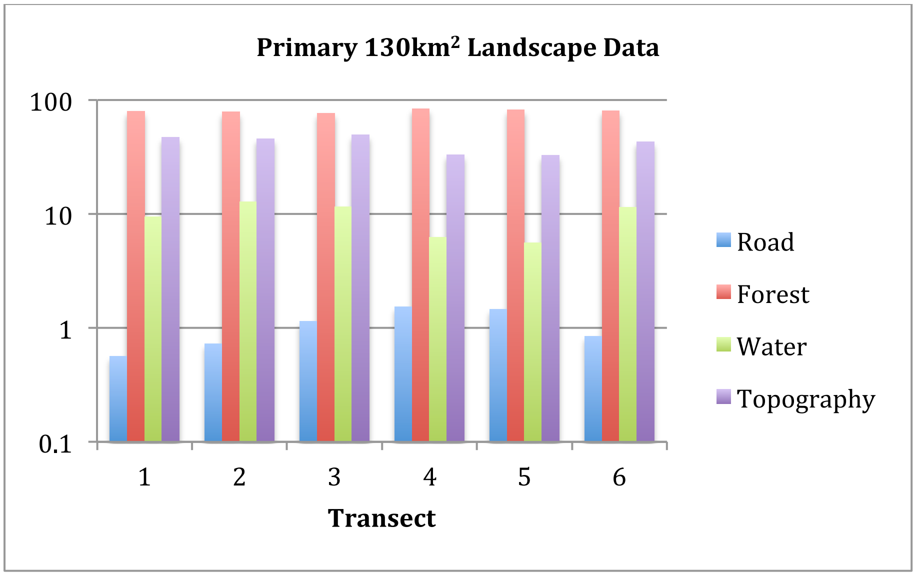


Figure 7. Raw landscape-level data for largest habitat buffer on primary logging roads in APP. Road = road density (km/km^2), Forest = % forest cover, Water = % water cover, and Topography = mean topographical ruggedness.

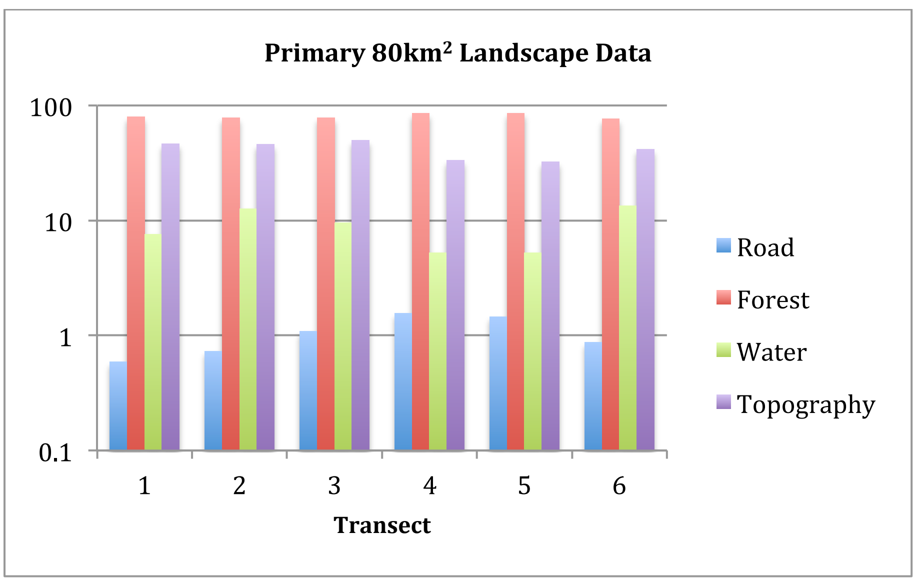


Figure 8. Raw landscape-level data for mid-sized habitat buffer on primary logging roads in APP. Road = road density (km/km^2), Forest = % forest cover, Water = % water cover, and Topography = mean topographical ruggedness.

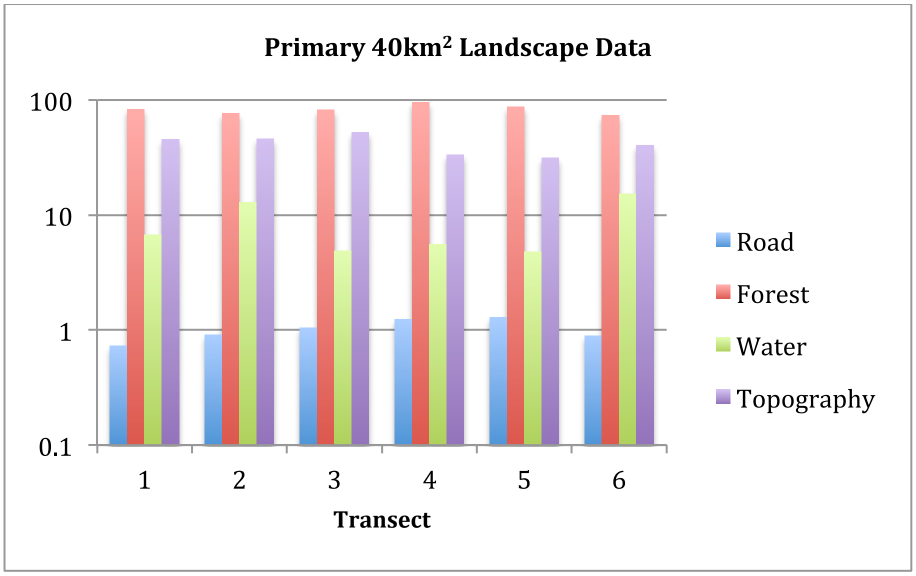


Figure 9. Raw landscape-level data for smallest habitat buffer on primary logging roads in APP. Road = road density (km/km^2), Forest = % forest cover, Water = % water cover, and Topography = mean topographical ruggedness.

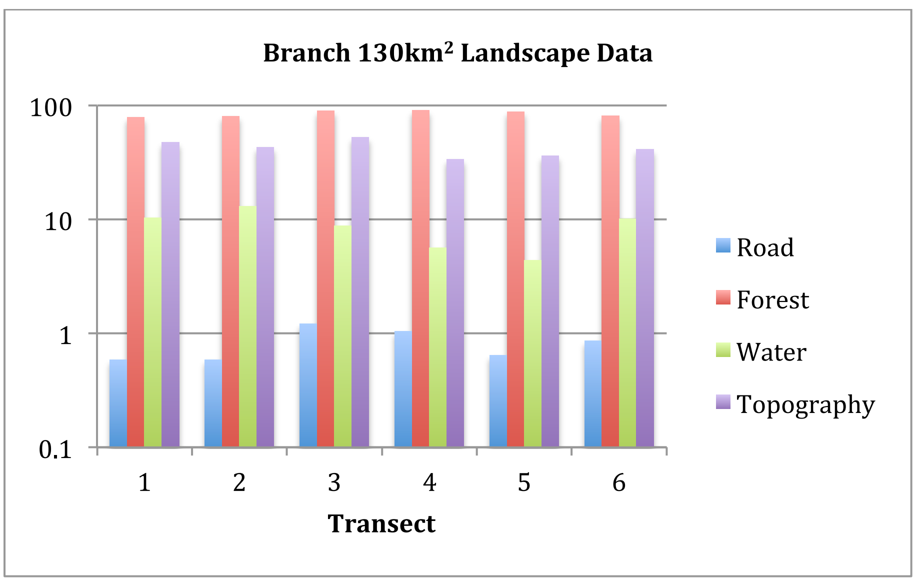


Figure 10. Raw landscape-level data for largest habitat buffer on branch logging roads in APP. Road = road density (km/km^2), Forest = % forest cover, Water = % water cover, and Topography = mean topographical ruggedness.

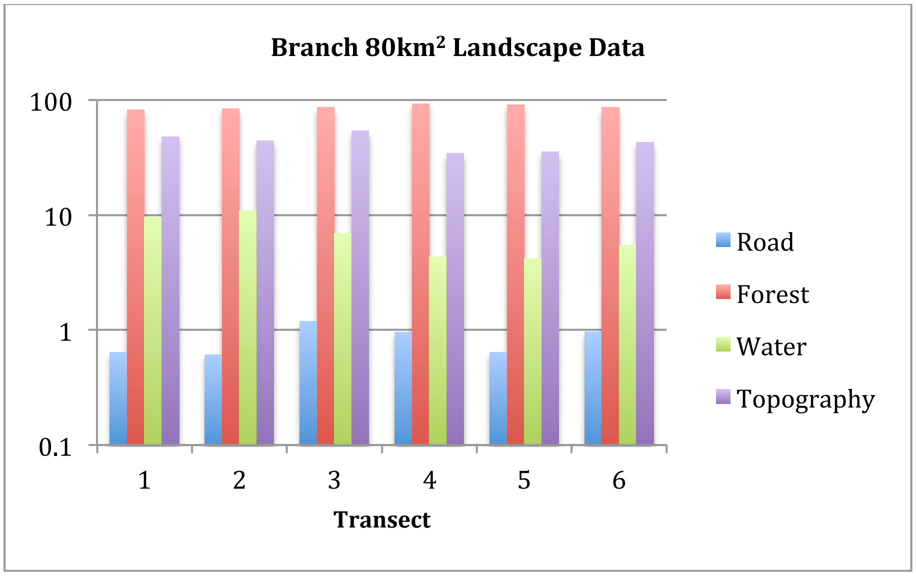


Figure 11. Raw landscape-level data for mid-sized habitat buffer on branch logging roads in APP. Road = road density (km/km^2), Forest = % forest cover, Water = % water cover, and Topography = mean topographical ruggedness.

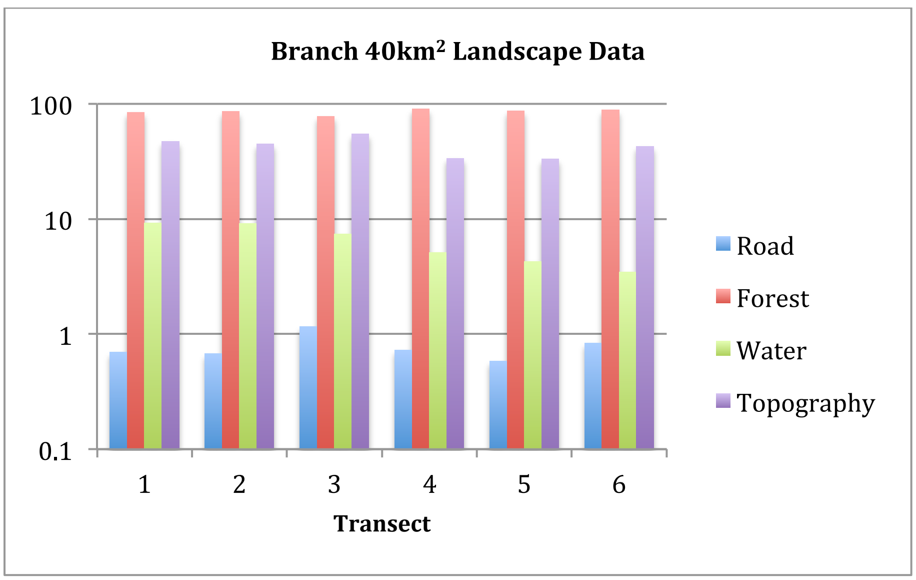


Figure 12. Raw landscape-level data for smallest habitat buffer on branch logging roads in APP. Road = road density (km/km^2), Forest = % forest cover, Water = % water cover, and Topography = mean topographical ruggedness.

The importance of both the local-level and landscape-level habitat characteristics is poorly understood, and this research hopes to provide insight into the APP habitat and how these variables affect the presence and movement of the large mammals in my study (Brady et al., 2011).

2.3 Field Methods

IR-cameras were set up at both portage crossings and in areas where there were no crossings, both on the west and east sides of APP in order to determine if there were differences in movement on the two sides of the park. Portage crossings were chosen as they are considered Areas of Concern by the park, and so have special requirements for where they cross logging roads (Algonquin Provincial Park Management Plan, 1998). Forestry resource extraction is not permitted within 60 meters of portage crossings, as a way to separate recreation from the forestry industry. The logging roads are narrowed at these locations as well with a maximum width of 6.7m (Algonquin Provincial Park Management Plan Amendment, 2013). In total, four IR-cameras were attached to nearby trees that had good visualization of the road or portage trail. This method allows data, in the form of photographs, to be collected in real time and may provide additional data on the large mammal movement characteristics in the park (Figure 13). If more crossings are made at the portage trails, as hypothesized, this may indicate to the park that narrower, canopy-covered areas may need to be provided in order to encourage more connectivity for the mammals that live there. The use of trail cameras was shown to be successful in the study by Moen (2009), where they were used to monitor large mammals and vehicle interactions throughout the study period. IR-cameras have also been used in tracking of wildlife crossing structures in recent years, and have been known to be helpful in species identification when studying animal movement (Clevenger & Sawaya, 2010; Ford et al., 2009; Forman, 2010; Kusak et al., 2009; Long et al., 2011).

Figure 13. Canine caught in IR-camera in Algonquin Provincial Park. Photo credit Hillary Roulston.

The physical field methods of observation were carried out by driving transects of the primary and branch logging roads within APP, looking for evidence of large-sized mammals through identification of tracks, scat, or any other form of evidence (road-kill, actual sightings). Six primary logging roads were picked, three on the west side where hunting is not permitted, and three on the east side where hunting is permitted to the Algonquins of Ontario. Branch logging roads were chosen off of the primary logging roads in order to establish the total road transect. This breaks down to ~10km of primary logging road being monitored for tracks, scat or other mammal evidence and ~10km of branch logging road being monitored for the same types of evidence, for a total of 20km per transect. The six transects were chosen in order to have large geographical distances between them in order to have independent observations based on habitat ranges for these species. Time and personal ability was a limiting factor to working in the field, and six transects of both primary and branch logging road types for three repeated surveys each was determined to be feasible. When comparing to other vehicle monitoring studies, groups of four seemed to be the most common number of field workers out on their transects. For my research, I was the primary field worker and I had assistance from a friend or family member on four out of six occasions.

To monitor these 20km road transects, the car was driven no more than 20km/hour in order to have time to detect scat or physical presence (Figure 14). Besides stopping for evidence of that sort, regular stops were made every kilometer along each transect to get out and look for evidence of large mammals using the road, crossing it, or to indicate if there was no evidence there at all. It was hypothesized that there would be differences in the counts of mammal evidence between these two types of logging roads, with the most frequent use on the branch logging roads, and less movement on the primary logging roads. This form of tracking has been used in previous studies, such as Varman and Sukumar (1995), D’Eon et al. (2006) and Foote and Keeping (2007).

Figure 14. Canine print on a primary logging road. Photo credit Hillary Roulston.

At the regular kilometer stops, or when scat or some other type of evidence was found along the road, local-level measurements and data were collected in order to analyze potential correlations. To begin with, the date, time, location (using a Garmin Oregon® 550 GPS), and transect number were recorded for future reference. The species of mammal was then identified and what type of evidence was recorded (i.e. Tracks or scat). To ensure accuracy in my tracking identification the length and width of tracks were recorded for the west side transects on their first survey. As eastern wolves and coyotes in APP are difficult to differentiate without genetic analysis, their tracks and scat were placed into an overarching canine category. If prints were found, the length of road they crossed was measured, to determine if the animal was crossing the road or using the road for easier travel in a lengthwise direction. A compass was used to determine the general direction of mammal movement on the logging roads, and weather conditions were also recorded for future reference. Temperature high for the day was recorded and rain and wind were also recorded as present or recent, as it may have influenced the visibility of mammal evidence.

Road characteristics were noted at observation points. The width, road aggregate, what type of logging road, and if the road was graded recently. Ditches were also examined for their presence, width and depth, to determine if it influenced large mammal movement. Vegetation characteristics were monitored at observation sites. The broad type of vegetation was recorded (i.e. Forest, meadow, marsh), the approximate height of that vegetation in meters, the type of forest if present was recorded (i.e. Coniferous, deciduous, or mixed), if canopy cover was present or not, and some of the main vegetation species/groups were identified for those present along the logging roads (i.e. Grasses, spruce, or maple). Vegetation can be a strong determinant in mammal presence if it provides desirable forage for species, such as moose, deer or bears (Beyer et al., 2013; Boan et al., 2011; Bowman et al., 2010; Clevenger et al., 2002; Kaphegyi et al., 2013; Nikula et al., 2004; Roever et al., 2008).

Other attributes that were also measured at the time were proximity to water and if there was water, what form it took (i.e. Lake, pond, river, stream), if there were trails or portage crossings present in the area, and was hunting permitted according to the location in the park (east or west side). Any further notes of interest were recorded and photos were taken as needed.

Logging was seen on transect 3 and was not present for transects 1 and 2. Both transects 1 and 2 had a full 20km of transect covered, but transect 3 was only 16km long, and so had to be shortened as the road went no further in the branch type. The west side of the park had far fewer logging roads to utilize compared to the east side, therefore restricting available transects. Transects 4, 5, and 6 were all a full 20km and also differed in their use levels. Transect 4 was a major public access point into the park and so had logging and public use. Transect 5, on the other hand, was also an access point for the public, but seemed to have very little use. No current logging activities were noted for transect 5 and many of the branch roads were blocked by berms to restrict access. The last transect, number 6, was a public access road to a point, but all of the data that was collected was beyond the public access point, and so only logging operations and parks people could access that area. Logging was currently underway in that area, though the specific branch roads I monitored were not currently being utilized. Further details on when the observations were done are found in the following Table 4.

Table 4. Details on field data collection.

Transect	Date	Time	Temp C°	Wind	# Points
1	May 23, 2012	09:24am – 03:40pm	24	Little wind	29
1	August 8, 2012	10:00am – 01:15pm	28	Light breeze	28
1	August 22, 2012	08:00am – 10:50am	20	Windy	26
2	May 24, 2012	08:23am – 01:23pm	27	Light breeze	28
2	August 8, 2012	03:10pm – 05:35pm	28	Slight wind	39
2	August 22, 2012	12:25pm – 02:05pm	22	Windy	28
3	May 25, 2012	07:50am – 10:44am	25	Light wind	24
3	August 7, 2012	02:25pm – 04:15pm	23	Light breeze	21
3	August 21, 2012	02:15pm – 03:45pm	20	Windy	23
4	June 12, 2012	11:00am – 01:55pm	22	Breezy	26
4	August 14, 2012	09:20am – 12:55pm	21	No wind	26
4	August 31, 2012	09:05am – 11:55am	22	Light wind	23
5	June 12, 2012	06:30pm – 08:17pm	19	Breezy	35
5	August 14, 2012	03:15pm – 05:15pm	24	No wind	26
5	August 31, 2012	01:35pm – 03:10pm	27	Windy	25
6	June 13, 2012	11:06am – 01:30pm	19	Light breeze	28
6	August 15, 2012	09:40am – 11:45am	16	No wind	33
6	September 1, 2012	10:00am – 12:10pm	20	Light wind	29

2.4 Lab Methods and Statistics

In order to get the raw data into a useable and understandable form, some preliminary tests were conducted based on eight steps laid out by Zuur et al. (2010). With the realization that the sample size was fairly small for this research, it had implications for the types of analysis that could be conducted, as well as an understanding that the results would be stronger if more data was available or collected.

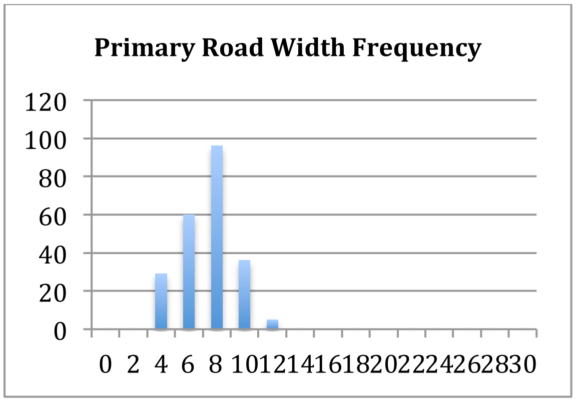
First the data was visually examined for outliers that would potentially indicate human error while taking down the information, or transferring the information into digital form. Since the data collected was based on measurements of roads and categorical in nature, outliers would be included in the model analysis as they are important in determining results.

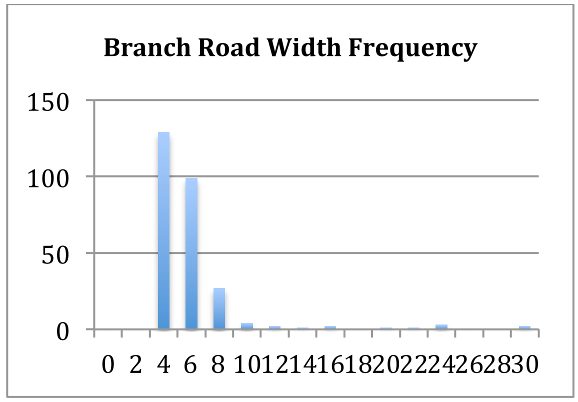
The second step that was taken was to examine if there was normality of the measured road widths. Since the rest of the data was categorical testing for normality was not necessary. For the road widths a Shapiro-Wilk normality test was used in the program R with a confidence level of 95% and a null hypothesis that the data would be normally distributed (R Core Team, 2012). In all but one case the road widths were not normally distributed based on the p-values that were below the 0.05 α value as can be seen in Table 5 below. The only road width data that was found to be normally distributed was the branch road from transect 3.

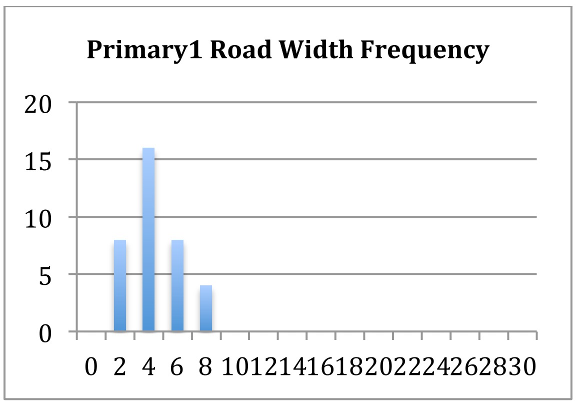
Table 5. Shapiro-Wilk test of normality for road width for 14 layouts of data. Using a confidence interval of 0.95.

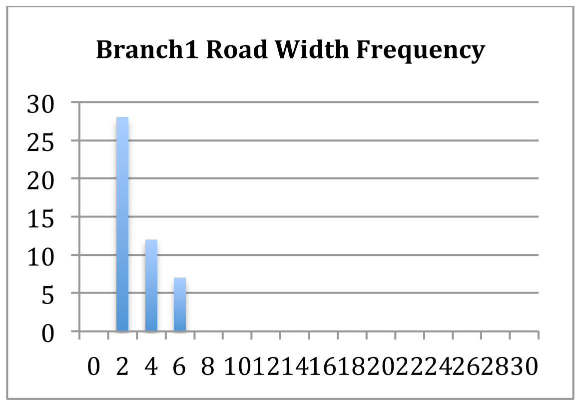
Shapiro-Wilk	p-value	α	Normal	W
Primary	<0.01	0.05	No	0.98
Branch	<0.01	0.05	No	0.54
Primary1	<0.01	0.05	No	0.90
Branch1	<0.01	0.05	No	0.78
Primary2	<0.01	0.05	No	0.88
Branch2	<0.01	0.05	No	0.40
Primary3	<0.01	0.05	No	0.90
Branch3	0.12	0.05	Yes	0.94
Primary4	<0.01	0.05	No	0.91
Branch4	<0.01	0.05	No	0.66
Primary5	0.03	0.05	No	0.94
Branch5	0.02	0.05	No	0.94
Primary6	<0.01	0.05	No	0.85
Branch6	<0.01	0.05	No	0.91

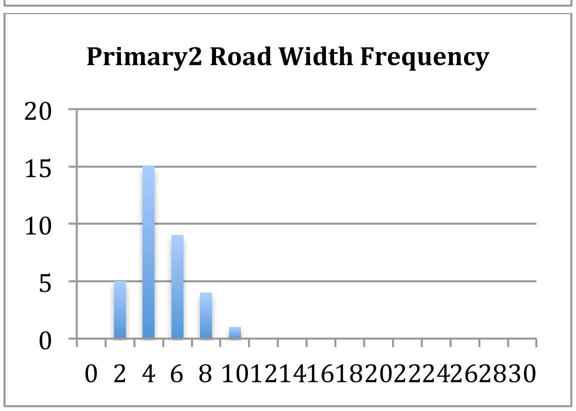
To also confirm whether the data was normally distributed or not, histograms were created in Microsoft Excel 2011 to boost the legitimacy and confidence of my results. These histograms did not refute the results from the Shapiro-Wilk normality test (Figure 15).

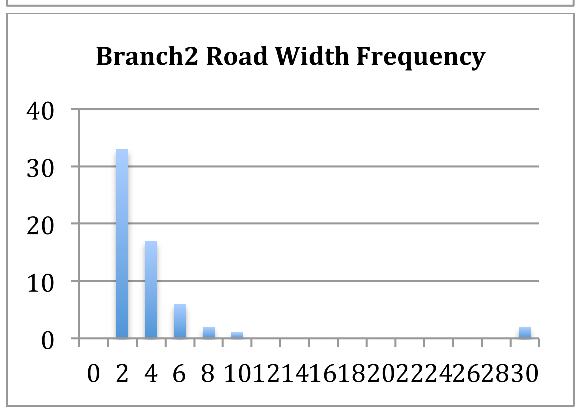

Primary Road Width Frequency
120
100
80
60
40
20
0
0 2 4 6 8 101214161820222426283 0

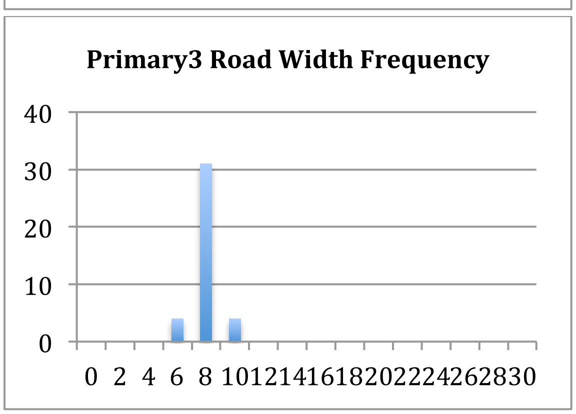

Branch Road Width Frequency
150
100
50
0
0 2 4 6 8 101214161820222426283 0

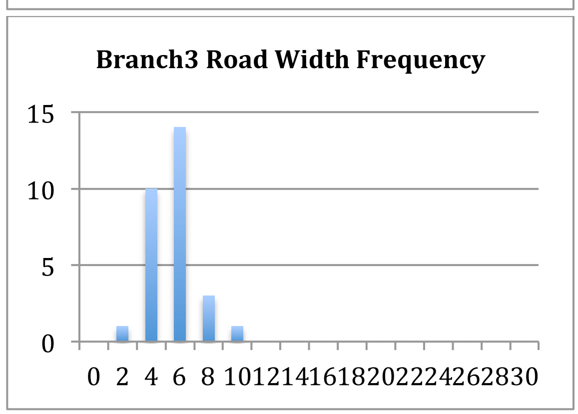

Primary1 Road Width Frequency
20
15
10
5
0
0 2 4 6 8 101214161820222426283 0


Branch1 Road Width Frequency
30
25
20
15
10
5
0
0 2 4 6 8 101214161820222426283 0


Primary2 Road Width Frequency
20
15
10
5
0
0 2 4 6 8 101214161820222426283 0


Branch2 Road Width Frequency
40
30
20
10
0
0 2 4 6 8 101214161820222426283 0


Primary3 Road Width Frequency
40
30
20
10
0
0 2 4 6 8 101214161820222426283 0


Branch3 Road Width Frequency
15
10
5
0
0 2 4 6 8 101214161820222426283 0

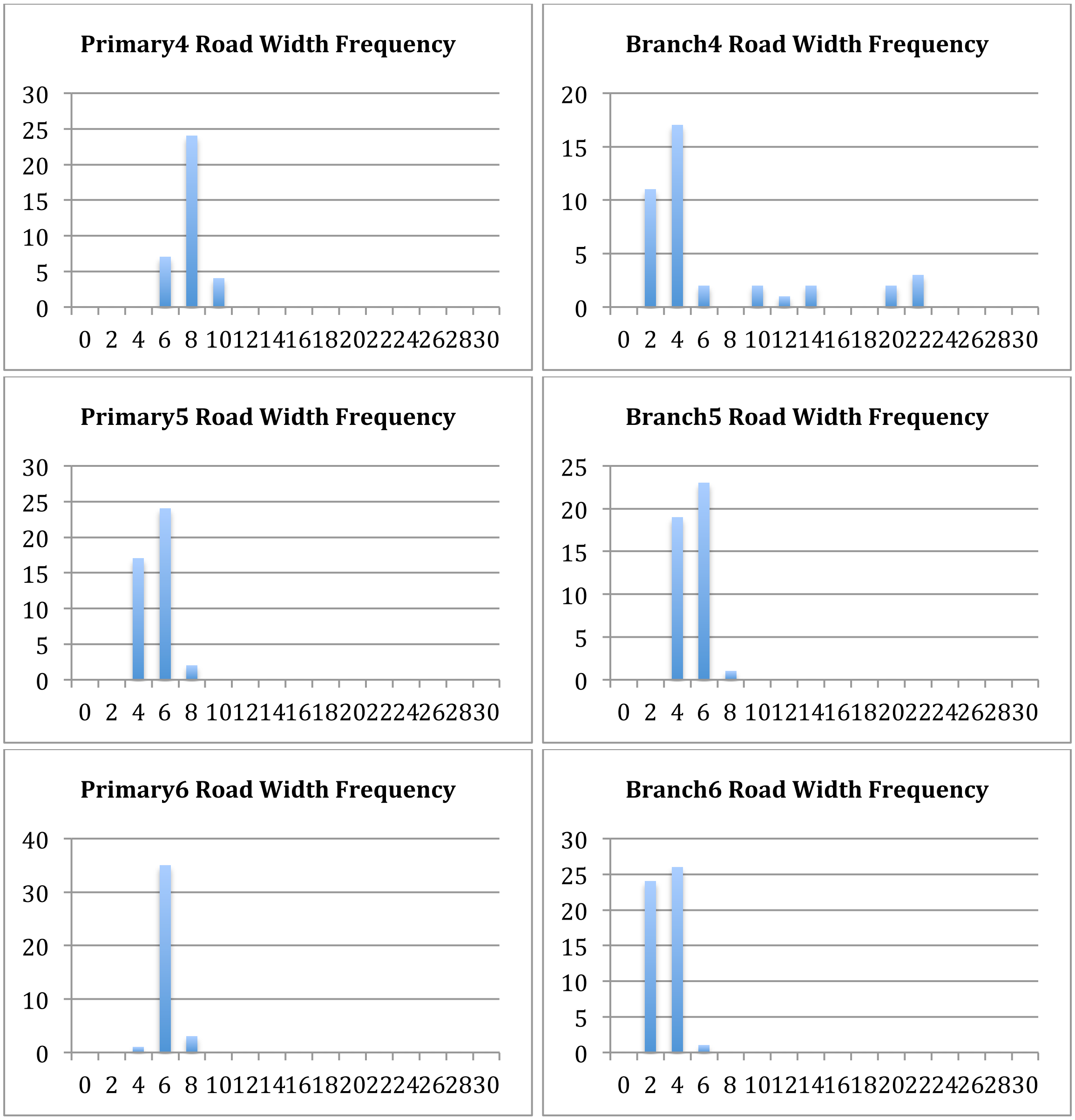


Figure 15. Histograms of road width for all six transects and primary and branch road widths. Demonstrates that the road widths were not particularly normal in distribution and did not dispute the results of the Shapiro-Wilk normality test from above. The x-axis is road width (meters), while the y-axis is frequency of observations at that road width.

The next step involved an examination of the independence of observations for the response variable (number of individuals on the logging roads). For the raw data collected in this study, stops were made every kilometer along the 20km transect, unless scat was observed and then an extra observation point was made. Considering independence from point to point may be difficult as it was hard to determine if prints found from a moose at one observation point was not going to be the same moose walking on the road a kilometer further down. Due to these considerations, most data used in the generalized linear models were total counts of evidence found on the primary and branch logging roads and the numerical landscape-level data, as independence would be greater at the transect level than at the individual species level.

Both a paired t-Test and a Wilcoxon Signed-Rank Test were conducted on the totals of mammal individuals for the primary and branch logging roads to determine if there were significant differences for the use of the two road types in relation to large mammal presence. The Wilcoxon Signed-Rank Test was done to determine if the data was parametric or non-parametric. Both tests were conducted in Microsoft Excel 2011. Results of the t-Test ($p = 0.16$) and Wilcoxon Signed-Rank Test ($p = 0.46$) showing that the there is no significant difference in large mammal presence on the primary and branch logging roads of Algonquin Provincial Park at a 95% confidence interval.

Collection of the landscape-level data was conducted through ArcGIS 10.1 at the Geospatial Centre at University of Waterloo (ESRI, 2013). Three buffer scales were established around a central point in each of each of the six primary and branch logging road types consisting of areas of $130km^2$, $80km^2$ and $40km^2$. Using databases, available through the Ministry of Natural Resources and Ministry of Transportation, data were collected for the 36 buffers on road density (km/km^2), percent forest cover (%), percent water cover (%), and topographic ruggedness index (m). Road density, percent forest cover, and percent water cover was in vector format, and the topographic ruggedness data was in raster form.

The data were analyzed using generalized linear models (GLM) to determine if any statistical significance occurred between the large mammal movement on the primary and branch logging roads in APP and the four landscape-level variables. The response variable that was examined was the number of mammal individuals on the primary and branch logging roads separately, in order to determine if there were significant differences in use on these two types of roads based on the potential influence of the four landscape-level variables (road density, forest cover, water cover, and topographic ruggedness index). The GLM was chosen for its capabilities of working with non-parametric data, as well as small sample sizes, while still providing valuable results (StatSoft Electronic Statistical Textbook, 2013). The equation of the Poisson GLM is as follows:

$$\log(\mu) = \beta_0 + \beta_1\chi_i$$

Where "μ is the mean of the Poisson distributed response variable, β_0 is the intercept (constant), β_1 is the regression coefficient and χ_i is the value of a single predictor variable for observation *i*" (Quinn & Keough, 2002). Fifteen models were run for the six sets of primary and branch logging road buffers to determine best predictors of the landscape-level variables on the large mammals of APP.

3.0 RESULTS

The results of this research on the large mammal use of logging roads in APP fall into the following sections on local-level results and landscape-level results.

3.1 Tracking Results Showed No Difference in Primary and Branch Use

A total of 497 data points were collected throughout the field study period and were split fairly evenly between the west side and the east side of Algonquin Provincial Park; with the west side having 246 observation points (49.50%) and the east side having 251 observation points (50.50%). The number of points each transect had for their primary and branch road sections over the three repeated measures are listed out in the table below (Table 6).

Table 6. The number of data points collected for each pass of the six transects primary and branch road sections.

Primary Transect	Observations	Branch Transect	Observations
Transect 1	14, 11, 11	Transect 1	15, 17, 15
Transect 2	12, 11, 11	Transect 2	16, 28, 17
Transect 3	13, 12, 11	Transect 3	11, 9, 9
Transect 4	12, 12, 11	Transect 4	14, 14, 12
Transect 5	17, 14, 12	Transect 5	18, 12, 13
Transect 6	14, 12, 13	Transect 6	14, 21, 16

The results from the t-Test and Wilcoxon Signed-Rank Test both showed that there was no significant difference in use by large mammals of these two types of logging roads in APP. For the t-Test $p = 0.15$ and for the Wilcoxon signed-rank test $p = 0.46$. Both cases were not significant at the 95% confidence interval.

The most important result of the local-level fieldwork was the summaries of large mammal use on the primary and branch logging roads (Figure 16). The large mammals that were found throughout the field study period were moose, white-tailed deer, canine, and American black bear. Specific data on the numbers collected for these five species can be found in Table 1 in the Appendices. Results from the local-level data for individual observation points consisted of descriptive percentages in order to gain a better understanding of the characteristics the primary and branch road transects have. IR-cameras had little evidence on them and did not permit use of their data except as proof of logging road use by the few mammals caught on the camera.

Figure 16. American black bear walking past an IR-camera. Photo credit Hillary Roulston.

The types of evidence that were collected were in categories of tracks, scat, other (actual sightings in person), or no evidence at all (Table 7). For the primary logging road, evidence was found for the observations points as tracks (62.37%), scat (5.75%), other (0.88%), and none (30.97%). The branch road observations consisted overall of tracks (48.71%), scat (28.41%), other (0.74%) and none (22.14%). In both cases the majority of observations found were tracks and scat was found in greater frequencies on the branch logging roads.

Whether ditches were present or absent on the two types of logging road is the next local-level variable. Ditches were present on the primary logging roads 34.51% of the time and on branch logging roads 26.20% of the time. The majority of points of observation for both primary and branch logging roads had no ditches present.

Observations were also examined for canopy cover in the categories of total cover, slight cover (~50%), and no cover. For the primary logging roads 7.96% had total canopy cover, 18.58% had slight cover, and 73.45% had no canopy cover. The branch logging roads had 9.59% of their observations with total canopy cover, 22.14% slight cover, and 68.27% with no canopy cover. There was slightly higher canopy cover presence on the branch roads than on the primary roads, perhaps because overall the branch logging roads were narrower.

Further descriptive results from the combined observations of primary and branch road data looked at the most prominent vegetation. Forest was the most common vegetation for both primary (76.99%) and branch (67.53%) road types, followed by forest/lake habitat combination with primary at 7.52% and forest/open for branch at 9.59%. Overall APP is mostly made up of forest and bodies of water dispersed relatively frequently throughout the observation points and transects.

Primary and branch road proximity to water (within sight) was also determined for the observation points. Primary roads had 23.89% of its observations within proximity to water, whether that was a creek, river, lake, or other form of water, and 76.11% not within water proximity. For branch logging roads, 22.14% had proximity to water with 77.86% of the observations not in proximity to water. For both layers of logging roads, the majority of observations were not sight of water.

Table 7 shows the differences between primary and branch logging roads and the proximity of hiking trails at observation points. For both road types, most of the observations did not have trails in close proximity (85.40% primary and 87.45% branch). The second category was “other” representing things such as driveways and laneways or tertiary logging roads (9.29% primary and 10.70% branch). Last were the observations where hiking trails were present, with primary roads having 5.31% and branch roads having 1.85% of their observations with this evidence. Portage trails may also factor into the use of logging roads by large mammals in APP. Almost all observations had no portage trails present with primary having 96.44% and the branch roads having 98.52%;

leaving 3.56% of primary road observations with portage trails present and 1.48% on the branch logging roads.

Road aggregate was another consideration taken into account for the primary and branch logging roads of APP. The most common road aggregate for both the primary and branch roads were a gravel and sand mixture, with 88.50% for the primary logging roads and 65.68% for the branch logging roads. Second was gravel with 8.41% observations on the primary locations and 15.87% for the branch. In both road types sand came in as the third most common aggregate type with 2.65% on the primary logging roads, and 6.64% on the branch logging roads. The other types of aggregate that were occasionally seen were gravel pits, gravel/grass mixtures, woodchip, dirt/woodchip combinations, soil, and a rocky/compact mixture.

Table 7. The categorical results in percentages of the local-level data from the three repeated measures of the primary and branch logging roads summed together for all six transects.

Variable	Mammal Evidence (%)				Ditches (%)		Canopy Cover (%)		
	Tracks	Scat	Other	None	Present	Absent	Total	Slight	None
Primary	62.39	5.75	0.88	30.97	34.51	65.49	7.96	18.58	73.45
Branch	48.71	28.41	0.74	22.14	26.20	73.80	9.59	22.14	68.27

Variable	Vegetation (%)									
	Forest	Marsh	F/M	F/O	F/L	L/M	F/R	F/Ro	Lake	Open
Primary	76.99	2.21	4.87	3.10	7.52	0.88	0.88	1.33	0.88	1.33
Branch	67.53	1.48	6.64	9.59	4.43	2.58	0.00	0.00	0.00	7.75

Variable	Water (%)		Trails (%)			Portage Crossings (%)	
	Present	Absent	Present	Absent	Other	Present	Absent
Primary	23.89	76.11	5.31	85.40	9.29	3.56	96.44
Branch	22.14	77.86	1.85	87.45	10.70	1.48	98.52

Variable	Road Aggregate (%)								
	Gravel	Sand	G Pit	G/Grass	G/S	Wchip	Dirt/Wc	Soil	Rocky
Primary	8.41	2.65	0.00	0.00	88.50	0.00	0.44	0.00	0.00
Branch	15.87	6.64	0.74	2.21	65.68	4.80	1.11	1.11	1.85

Road width was also another important measurement taken at the local level of field analysis. The mean, median and mode were calculated for the combined data of the three repeated surveys for each transects' primary and branch roads (Table 8). Overall, the primary roads had greater widths than the branch logging roads. The ranges of road width averages were 3.87m to 8.53m across and overall averages for primary and branch widths respectively were 6.69m and 5.48m, well below maximum widths allowed by park regulations.

Table 8. The mean, median and mode of all the combined road width data for each primary and branch logging road (P = Primary logging road and B = Branch logging road).

	Transect 1		Transect 2		Transect 3		Transect 4		Transect 5		Transect 6	
Road Type	P	B	P	B	P	B	P	B	P	B	P	B
Mean	5.05	3.87	5.41	5.44	8.49	6.12	8.53	7.47	6.12	5.92	6.51	4.08
Median	5.25	3.33	4.42	3.83	8.33	6.00	8.42	4.42	6.08	5.83	6.50	4.00
Mode	4.75	4.00	4.00	3.83	8.33	6.17	8.33	4.17	5.88	5.88	6.50	3.83

On initial inspection of the photos from the IR-cameras, both of the regular, primary road positions seemed to work normally. The two IR-cameras positioned on the portage trails seemed to be slightly abnormal and inconsistent, making comparison between the results difficult. Information from these cameras was therefore considered inappropriate for use, with only the potential use to boost sightings from the local-level data and give physical proof of use for four out of the five large mammal species observed. One moose was detected in the photographs on the Transect 1 road, and there were a fair number of white-tailed deer and wolf caught on that camera as well. One black bear was found on Transect 6 along with most of the wolf movement. White-tailed deer were found on both of the cameras along Transect 1 and Transect 6. In conclusion, four out of the five large mammal species observed through tracks and scat were also photographed using the logging roads in APP.

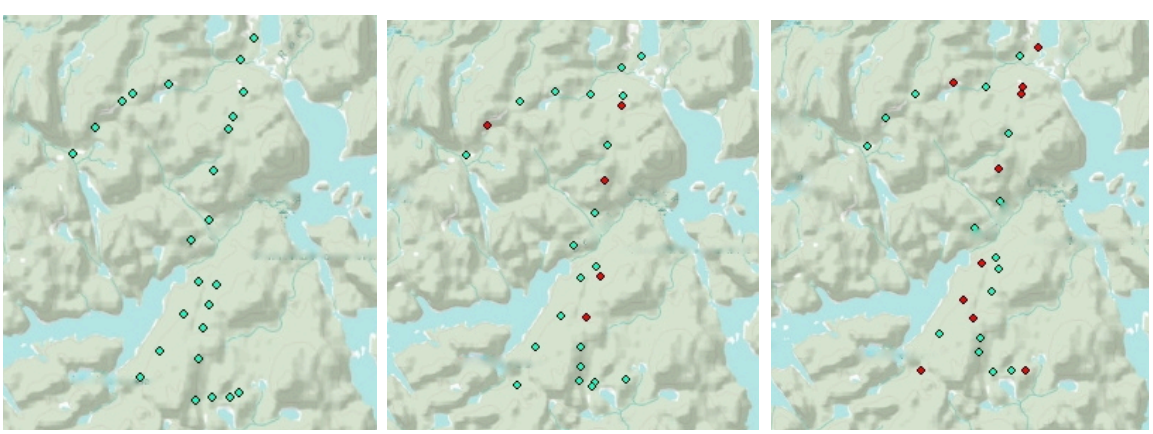
3.2 Model Results Show Greater Landscape Influence on Branch Logging Roads

The sums of individuals for each primary and branch transect sections on the three repeated observations are as follows in Table 9. Overall, 66.67% of the branch transects had greater large mammal presence than the primary transects. The total numbers of individuals was 156 for primary logging roads and 210 for branch logging roads making them 42.64% and 57.38% of the data respectively.

Table 9. Sum of individuals found for each primary and branch logging road sections of the six transects in Algonquin Provincial Park (P = primary logging road and B = branch logging road)

	Transect 1		Transect 2		Transect 3		Transect 4		Transect 5		Transect 6	
# Individuals	P	B	P	B	P	B	P	B	P	B	P	B
1	14	15	12	16	13	11	9	13	16	18	10	12
2	10	13	4	26	4	4	5	6	11	6	7	18
3	5	11	6	14	10	5	4	6	7	7	9	9
Total	29	39	22	56	27	20	18	25	34	31	26	39

The following figures are maps of the six transects for each repeated measure for large mammal presence and absence at the observation points (Figures 17-22).



a) b) c)

Figure 17. Transect 1 of large mammal presence and absence (a = first survey, b = second survey, c = third survey). The green dots indicate presences and the red dots indicate absence.

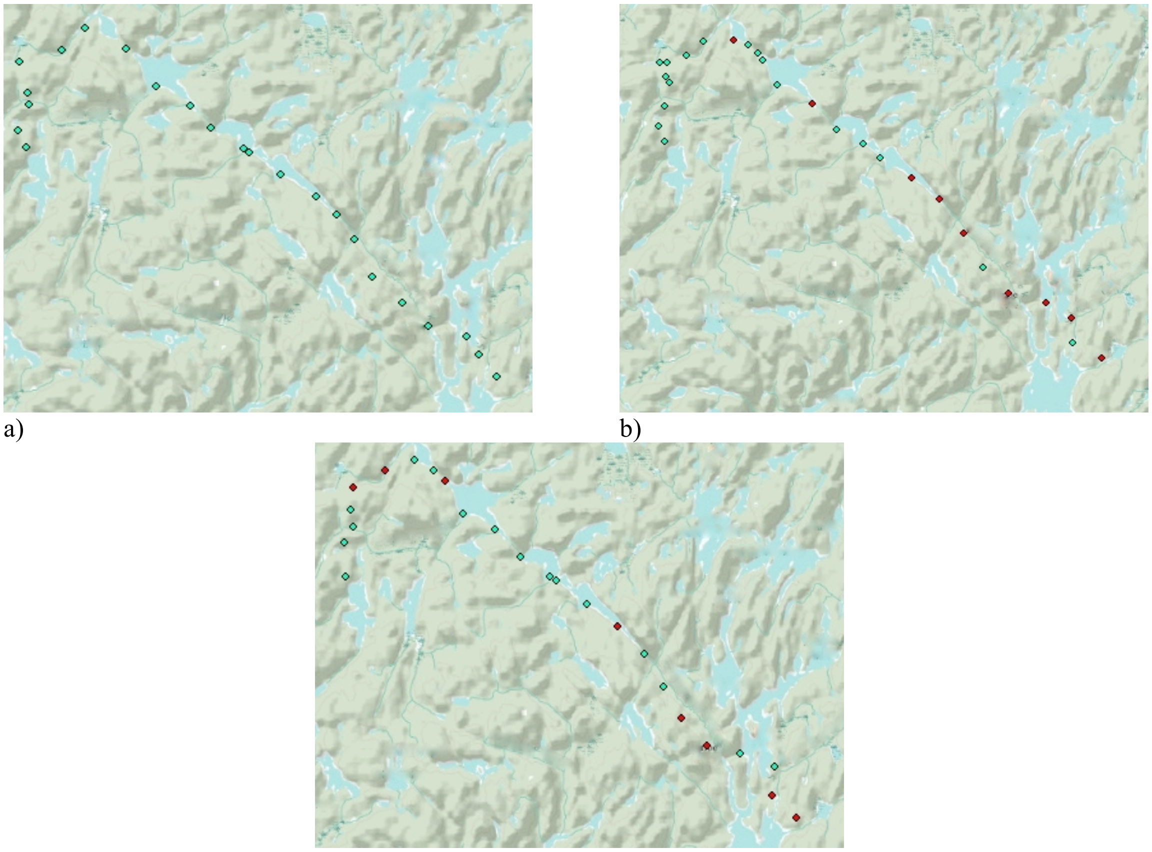
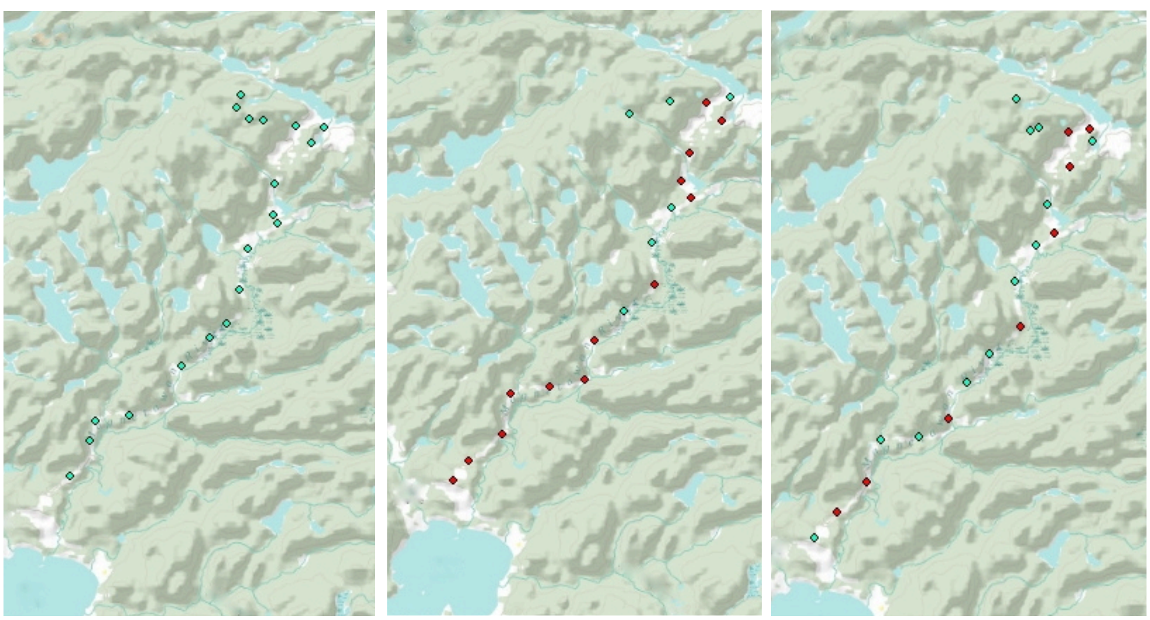
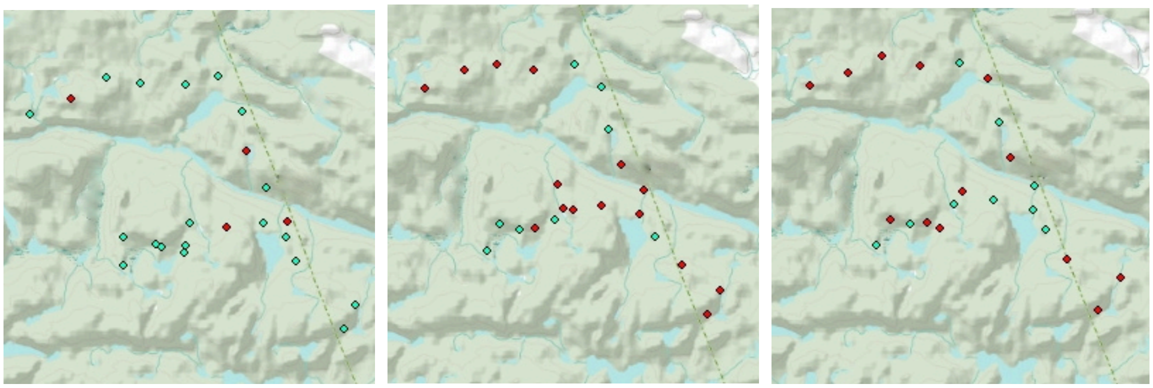


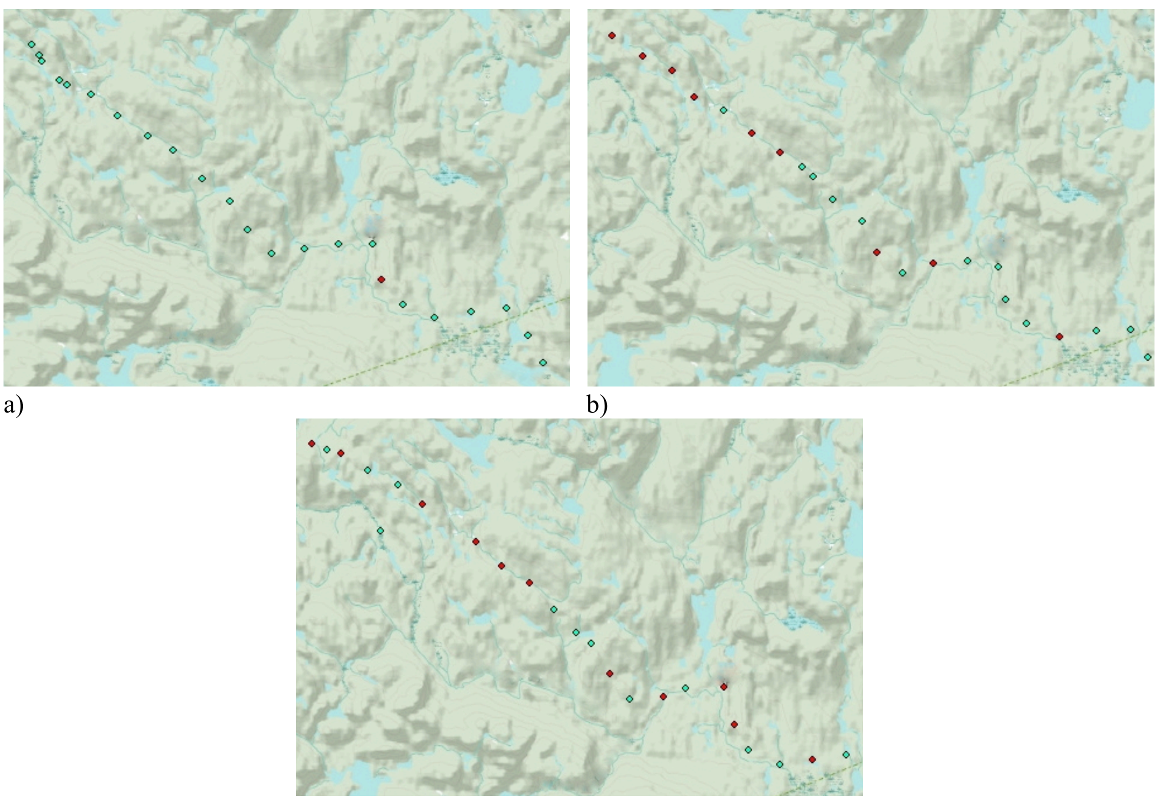
Figure 18. Three repeated measures of Transect 2 for presence and absence (a = first survey, b = second survey, c = third survey). The green dots indicate presences and the red dots indicate absence.

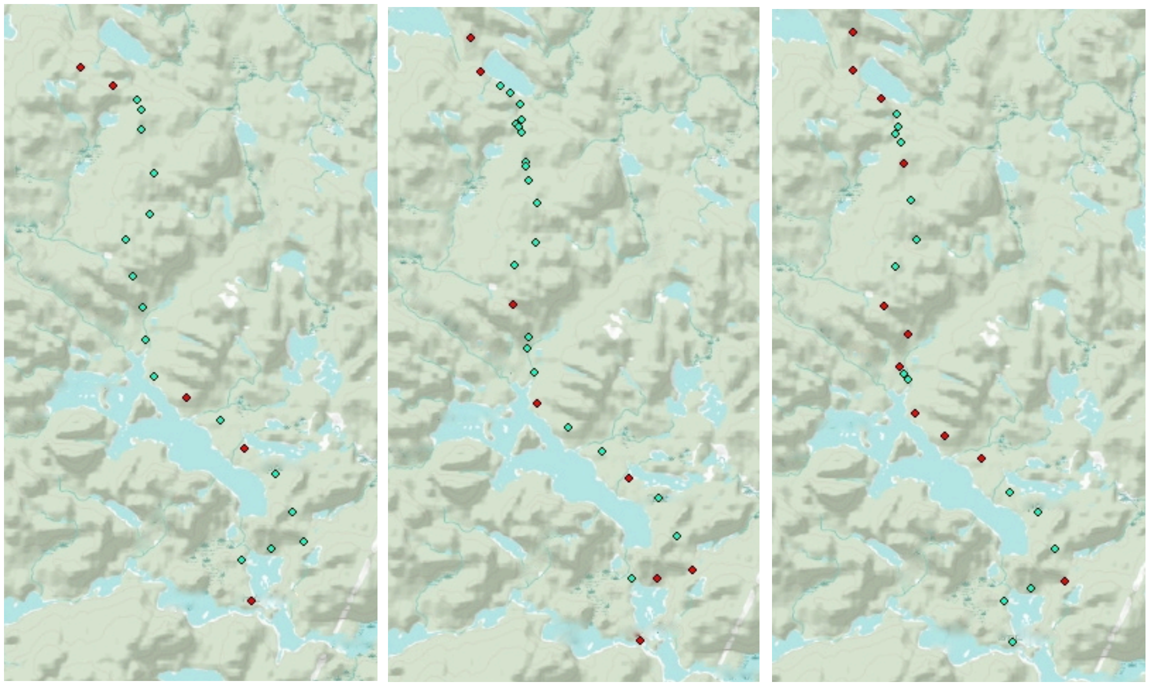


a) b) c)

Figure 19. Transect 3 of three repeated measures (a = first survey, b = second survey, c = third survey). The green dots indicate presences and the red dots indicate absence.


a) b) c)
Figure 20. Transect 4 large mammal observations (a = first survey, b = second survey, c = third survey). The green dots indicate presences and the red dots indicate absence.


a) b)
c)
Figure 21. Transect 5 large mammal presence and absence (a = first survey, b = second survey, c = third survey). The green dots indicate presences and the red dots indicate absence.



a) b) c)

Figure 22. Transect 6 presence and absence maps (a = first survey, b = second survey, c = third survey). The green dots indicate presences and the red dots indicate absence.

Previous studies have examined the effects of logging roads on large mammals, though they again tend to focus on the boreal forest with species such as caribou (*Rangifer tarandus*). For the findings of this study, overall use was fairly high and consistent across the six transects for large mammal use for each species, with an increase in use on the branch logging roads by moose, canines and American black bear (Figure 23-24). A decrease was seen moving from primary to branch observations for white-tailed deer and points where no evidence was found.

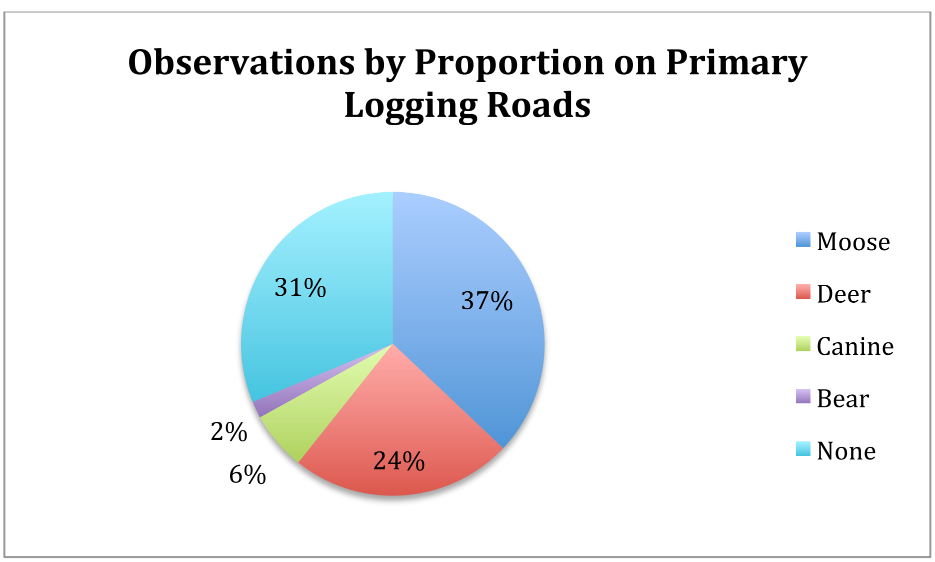


Figure 23. All three repeated observations combined for the four mammal species and those without any evidence of large mammals for the primary logging roads of Algonquin Provincial Park

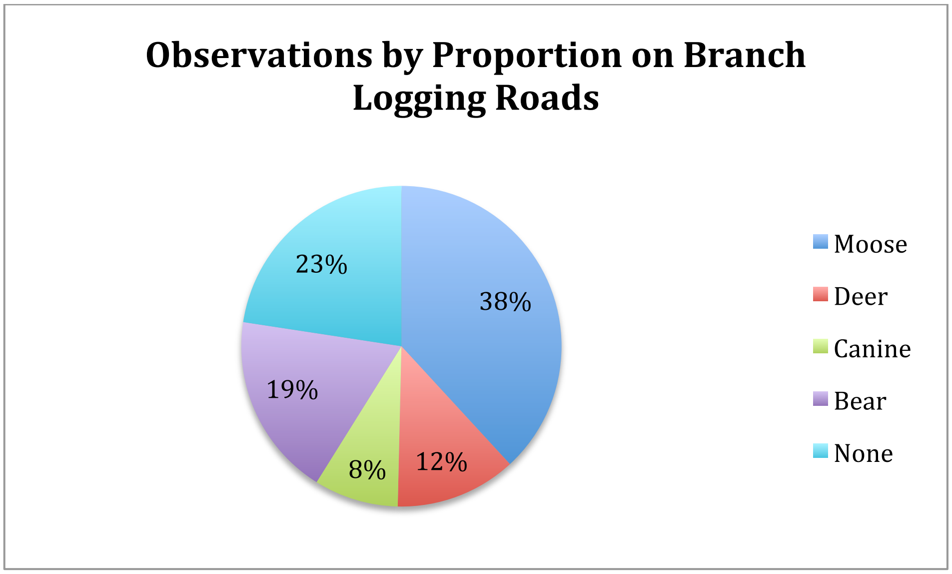


Figure 24. All three repeated observations combined for the four mammal species and those without any evidence of large mammals for the branch logging roads of Algonquin Provincial Park

The main statistical test that was conducted was looking at outputs from generalized linear models (GLMs) on landscape-level variables that were obtained through GIS data layers (See Appendix Tables 17-28). The following six tables (Tables 10-15) outline the main results retrieved from these model runs. In each case one of three buffer zones was chosen for either the primary or branch logging roads, totaling six different model sets to represent each of these parameters. The first table (Table 10) shows the results from the 130km^2 buffer zone on the primary logging roads, the next model set is primary roads at the 80km^2 buffer (Table 11), and the third model set is primary roads at the 40km^2 buffer (Table 12). The branch logging roads were also examined at these three buffer areas, making up Tables 13, 14, and 15.

For each of the six sets, 15 models were run in order to determine which model predicted the best indicators of presence for individuals of both the branch and primary logging roads in APP, and at what buffer home range. The models consisted of combinations of the four landscape-level variables from all four together, down to each of the variables modeled individually. These models can be seen in the first column of all the following GLM output tables. The four landscape variables are labeled as Road (road density), Forest (percent forest cover), Water (percent water cover), and Topography (topographic ruggedness index).

Table 10 shows the outputs for the 130km^2 buffer area on the primary logging roads. No variables in the model combinations turned out to be significant in this set of models at a 95% confidence interval. The model with the best fit is shown to have the lowest Akaike information criterion (AIC) value, which was model 1.9 with the variables Forest ($p = 0.13$) and Water ($p = 0.14$). The model that had the worst fit for the largest buffer on the primary roads was model 1.4 with the variables Road ($p = 0.76$), Water ($p = 0.23$), and Topography ($p = 0.43$). Overall, the AIC values were all very similar between the models with the greatest ΔAIC being 3.06, representing the difference between the highest and lowest model fit. No significant values were found in this model set.

Table 10. Generalized linear model results for a 130km^2 buffer on the primary logging roads with a confidence interval of 0.95.

Model/Variable	Estimate	SE	z-Score	p-Value	AIC	ΔAIC	Rank
1.9							
Forest	-0.08	0.05	-1.50	0.13	40.02	0.00	1
Water	-0.07	0.05	-1.48	0.14			
1.13							
Forest	-0.02	0.03	-0.54	0.59	40.23	0.21	2
1.14							
Water	-0.01	0.03	-0.49	0.62	40.28	0.26	3
1.12							
Road	-0.03	0.22	-0.15	0.89	40.50	0.48	4
1.15							
Topography	0.00	0.01	0.07	0.95	40.52	0.50	5
1.10							
Forest	-0.10	0.08	-1.19	0.23	41.10	1.08	6
Topography	-0.03	0.03	-1.07	0.29			
1.11							
Water	-0.07	0.06	-1.15	0.25	41.18	1.16	7
Topography	0.03	0.03	1.06	0.29			
1.2							
Road	-0.24	0.31	-0.79	0.43	41.41	1.39	8
Forest	-0.08	0.06	-1.51	0.13			
Water	-0.10	0.06	-1.67	0.09			
1.7							
Road	-0.25	0.32	-0.77	0.44	41.70	1.68	8
Water	-0.04	0.04	-0.89	0.37			
1.5							
Forest	-0.09	0.08	-1.08	0.28	42.01	1.99	10
Water	-0.07	0.06	-1.05	0.30			
Topography	-0.00	0.04	-0.12	0.91			
1.3							
Road	-0.46	0.44	-1.04	0.30	42.02	2.00	11
Forest	-0.16	0.10	-1.57	0.12			
Topography	-0.07	0.05	-1.48	0.14			
1.6							
Road	0.05	0.27	0.20	0.85	42.19	2.17	12
Forest	-0.02	0.04	-0.57	0.57			
1.8							
Road	-0.05	0.36	-0.15	0.88	42.50	2.48	13
Topography	-0.00	0.02	-0.07	0.94			
1.1							
Road	-0.53	0.44	-1.19	0.23			
Forest	-0.17	0.11	-1.58	0.11	42.56	2.54	14
Water	-0.07	0.06	-1.21	0.23			
Topography	-0.05	0.05	-0.93	0.35			
1.4							
Road	-0.11	0.35	-0.31	0.76	43.08	3.06	15
Water	-0.07	0.06	-1.19	0.23			
Topography	0.02	0.03	0.79	0.43			

The 15 series model run for the 80km^2 buffer on the primary logging roads are shown in the following table. The model with the best fit in this set was model 2.14 with the only variable as Water (p = 0.65). Model 2.1, which contained all four variable was the model with the worst fit. It had a ΔAIC value of 5.41, and variables of Road (p = 0.59), Forest (p = 0.76), Water (p = 0.55), and Topography (p = 0.73). This level of buffer zone also had very little difference between the model's fits, making little variability in determining what landscape variables were most important for predicting mammal presence on these six primary logging roads. There was also no significant influence of any of the landscape variables on large mammal movement on the primary logging roads at 80km^2.

Table 11. Generalized linear model results for an 80km^2 buffer on the primary logging roads with a confidence interval of 0.95.

Model/Variable	Estimate	SE	z-Score	p-Value	AIC	ΔAIC	Rank
2.14							
Water	-0.01	0.02	-0.46	0.65	40.31	0	1
2.12							
Road	-0.04	0.22	-0.20	0.84	40.48	0.17	2
2.13							
Forest	0.00	0.02	0.20	0.84	40.48	0.17	2
2.15							
Topography	-0.00	0.01	-0.03	0.98	40.52	0.21	4
2.7							
Road	-0.20	0.29	-0.69	0.49	41.84	1.53	5
Water	-0.03	0.03	-0.80	0.42			
2.9							
Forest	-0.03	0.05	-0.50	0.61	42.06	1.75	6
Water	-0.04	0.06	-0.65	0.52			
2.6							
Road	-0.24	0.37	-0.63	0.53	42.09	1.78	7
Forest	0.02	0.04	0.62	0.53			
2.11							
Water	-0.02	0.03	-0.56	0.58	42.20	1.89	8
Topography	0.01	0.02	0.33	0.74			
2.8							
Road	-0.14	0.37	-0.37	0.71	42.38	2.07	9
Topography	-0.01	0.02	-0.31	0.75			
2.10							
Forest	0.01	0.04	0.33	0.74	42.41	2.1	10
Topography	0.01	0.02	0.27	0.79			
2.4							
Road	-0.24	0.391883	-0.62	0.53	43.81	3.50	11
Water	-0.03	0.033748	-0.75	0.45			
Topography	-0.00	0.020934	-0.17	0.87			
2.2							
Road	-0.18	0.38465	-0.47	0.64	43.84	3.53	12
Forest	-0.00	0.06828	-0.07	0.94			
Water	-0.03	0.05976	-0.51	0.61			
2.5							
Forest	-0.05	0.104919	-0.43	0.67	44.01	3.70	13
Water	-0.05	0.078899	-0.62	0.53			
Topography	-0.01	0.030968	-0.21	0.83			
2.3							
Road	-0.23	0.40453	-0.56	0.57	44.09	3.78	14

Forest	0.03	0.04672	0.53	0.59			
Topography	0.00	0.02516	0.05	0.96			
2.1							
Road	-0.22	0.40041	-0.54	0.59			
Forest	-0.03272	0.10654	-0.31	0.76	45.72	5.41	15
Water	-0.04682	0.07772	-0.60	0.55			
Topography	-0.01097	0.03207	-0.34	0.73			

For the smallest buffer area on the primary roads the model with the best fit was model 3.5, with variables Forest (p = 0.03), Water (p = 0.02), and Topography (p = 0.10). In this case, both the Forest and Water variables showed significance in their influence of determining mammal presence on the primary logging roads at a $40km^2$ buffer. The model with the worst fit was 3.3 (Road (p = 0.82), Forest (p = 0.52), and Topography (p = 0.80) and had a ΔAIC value of 5.27, again showing little overall difference between this set of models. There was also one other model that showed some significant p-values, which was model 3.1 that includes all four variables, with Forest (p = 0.03) and Water (p = 0.02) again being the two variables with significant values.

Table 12. Generalized linear model results for a $40km^2$ buffer on the primary logging roads with a confidence interval of 0.95.

Model/Variable	Estimate	SE	z-Score	p-Value	AIC	ΔAIC	Rank
3.5							
Forest	-0.06	0.03	-2.23	**0.03**	38.80	0	1
Water	-0.09	0.04	-2.29	**0.02**			
Topography	-0.02	0.01	-1.65	0.10			
3.9							
Forest	-0.03	0.02	-1.60	0.11	39.42	0.62	2
Water	-0.05	0.03	-1.70	0.09			
3.14							
Water	-0.01	0.02	-0.63	0.53	40.12	1.32	3
3.13							
Forest	-0.01	0.01	-0.47	0.64	40.30	1.5	4
3.15							
Topography	-0.00	0.01	-0.11	0.91	40.51	1.71	5
3.1							
Road	-0.33	0.63	-0.53	0.60			
Forest	-0.06	0.03	-2.22	**0.03**	40.52	1.72	6
Water	-0.10	0.04	-2.33	**0.02**			
Topography	-0.03	0.02	-1.63	0.10			
3.12							
Road	-0.01	0.40	-0.02	0.99	40.52	1.72	6
3.2							
Road	0.26	0.54	0.48	0.63	41.19	2.39	8
Forest	-0.04	0.02	-1.63	0.10			
Water	-0.05	0.03	-1.72	0.09			
3.7							
Road	-0.18	0.46	-0.40	0.69	41.96	3.16	9
Water	-0.02	0.02	-0.75	0.46			
3.10							
Forest	-0.01	0.01	-0.62	0.53	42.12	3.32	10
Topography	-0.01	0.01	-0.42	0.67			
3.11							
Water	-0.01	0.02	-0.62	0.53	42.12	3.32	10

Topography	-0.00	0.01	-0.01	0.99			
3.6							
Road	0.23	0.56	0.41	0.69	42.14	3.34	12
Forest	-0.01	0.02	-0.62	0.54			
3.8							
Road	-0.06	0.54	-0.12	0.90	42.50	3.7	13
Topography	-0.00	0.01	-0.16	0.87			
3.4							
Road	-0.36	0.63	-0.57	0.57	43.80	5	14
Water	-0.02	0.02	-0.83	0.41			
Topography	-0.01	0.02	-0.40	0.69			
3.3							
Road	0.15	0.64	0.23	0.82	44.07	5.27	15
Forest	-0.01	0.02	-0.65	0.52			
Topography	-0.00	0.01	-0.25	0.80			

For Table 13, the model with the best fit for determining mammal presence on the branch logging roads in APP at the 130km^2 buffer was model 4.4. This model contained the variables Road ($p = 0.05$), Water ($p = 0.01$), and Topography ($p = 0.16$), which found the first two to be significant. There was a great deal of significance in many of the models for this buffer area on the branch roads, as can be seen in the table below. Model 4.15 had the worst fit in this case, with Topography ($p = 0.88$) being its only variable and a ΔAIC value of 18.52.

Table 13. Generalized linear model results for a 130km^2 buffer on the branch logging roads with a confidence interval of 0.95.

Model/Variable	Estimate	SE	z-Score	p-Value	AIC	ΔAIC	Rank
4.4							
Road	-0.72	0.36	-1.98	**0.05**	40.31	0	1
Water	0.09	0.03	2.73	**0.01**			
Topography	-0.02	0.02	-1.42	0.16			
4.7							
Road	-0.90	0.33	-2.72	**0.01**	40.35	0.04	2
Water	0.06	0.02	2.34	**0.02**			
4.2							
Road	-1.02	0.46	-2.24	**0.03**	42.20	1.89	3
Forest	0.01	0.03	0.38	0.71			
Water	0.07	0.04	1.74	0.08			
4.11							
Water	0.12	0.03	4.34	**0.00**	42.24	1.93	4
Topography	-0.03	0.01	-2.34	**0.02**			
4.5							
Forest	-0.03	0.02	-1.40	0.16	42.26	1.95	5
Water	0.07	0.04	1.75	0.08			
Topography	-0.03	0.01	-2.16	**0.03**			
4.1							
Road	-0.70	0.50	-1.39	0.16			
Forest	-0.00	0.03	-0.05	0.96	42.30	1.99	6
Water	0.08	0.04	2.03	**0.04**			
Topography	-0.02	0.02	-1.37	0.17			
4.6							
Road	-0.71	0.42	-1.69	0.09	43.17	2.86	7
Forest	-0.03	0.02	-1.69	0.09			
4.10							

Forest	-0.07	0.02	-4.00	**0.00**	43.31	3	8
Topography	-0.02	0.02	-1.60	0.11			
4.13							
Forest	-0.06	0.01	-3.79	**0.00**	44.03	3.72	9
4.12							
Road	-1.16	0.31	-3.70	**0.00**	44.10	3.79	10
4.3							
Road	-0.48	0.48	-0.99	0.32	44.32	4.01	11
Forest	-0.05	0.03	-1.90	0.06			
Topography	-0.01	0.02	-0.92	0.36			
4.9							
Forest	-0.04	0.02	-1.69	0.09	45.20	4.89	12
Water	0.04	0.04	0.91	0.36			
4.8							
Road	-1.17	0.31	-3.75	**0.00**	45.91	5.6	13
Topography	0.01	0.01	0.43	0.67			
4.14							
Water	0.09	0.02	3.52	**0.00**	46.09	5.78	14
4.15							
Topography	-0.00	0.01	-0.15	0.88	58.83	18.52	15

For the model set with a buffer area of $80km^2$ on the branch roads, the following table outlines the rankings of those models of those near the top with better fit than those closer to the bottom. The model with the best fit was 5.10 and contained the variables Forest ($p < 0.01$) and Topography ($p < 0.01$). Again, like the previous set of models, many of the p-values were significant for many of the models. The model with the worst fit was model 5.15, with a similar result as the previous table with the p-value for the variable Topography being 0.94 and the ΔAIC value of 18.04.

Table 14. Generalized linear model results for a $80km^2$ buffer on the branch logging roads with a confidence interval of 0.95.

Model/Variable	Estimate	SE	z-Score	p-Value	AIC	ΔAIC	Rank
5.10							
Forest	-0.13	0.03	-4.28	**0.00**	40.80	0	1
Topography	-0.06	0.02	-3.10	**0.00**			
5.5							
Forest	-0.10	0.05	-1.96	**0.05**	42.37	1.57	2
Water	0.04	0.06	0.66	0.51			
Topography	-0.06	0.02	-2.81	**0.00**			
5.3							
Road	0.11	0.61	0.18	0.86	42.77	1.97	3
Forest	-0.14	0.05	-2.61	**0.01**			
Topography	-0.07	0.03	-2.06	**0.04**			
5.1							
Road	0.33	0.69	0.48	0.63			
Forest	-0.12	0.06	-1.95	0.05	44.13	3.33	4
Water	0.05	0.06	0.80	0.42			
Topography	-0.07	0.03	-2.15	**0.03**			
5.11							
Water	0.13	0.03	4.15	**0.00**	44.22	3.42	5
Topography	-0.03	0.01	-2.27	**0.02**			
5.7							
Road	-0.82	0.38	-2.13	**0.03**	45.02	4.22	6
Water	0.06	0.03	1.89	0.06			

5.6							
Road	-0.94	0.36	-2.64	**0.01**	45.09	4.29	7
Forest	-0.04	0.02	-1.86	0.06			
5.4							
Road	-0.35	0.58	-0.61	0.54	45.84	5.04	8
Water	0.10	0.05	1.96	0.05			
Topography	-0.02	0.02	-1.09	0.28			
5.12							
Road	-1.16	0.34	-3.39	**0.00**	46.69	5.89	9
5.2							
Road	-0.85	0.39	-2.18	**0.03**	46.83	6.03	10
Forest	-0.02	0.04	-0.44	0.66			
Water	0.03	0.06	0.52	0.61			
5.8							
Road	-1.24	0.35	-3.58	**0.00**	47.68	6.88	11
Topography	0.01	0.01	1.00	0.32			
5.14							
Water	0.09	0.03	3.36	**0.00**	47.71	6.91	12
5.9							
Forest	0.00	0.04	0.05	0.96	49.71	8.91	13
Water	0.09	0.05	1.65	0.10			
5.13							
Forest	-0.05	0.02	-2.85	**0.00**	50.42	9.62	14
5.15							
Topography	-0.00	0.01	-0.07	0.94	58.84	18.04	15

For the smallest buffer area on the branch roads the model set was best represented by model 6.3 with the variables Road ($p < 0.01$), Forest ($p = 0.04$), and Topography ($p < 0.01$) represented. Again the model demonstrating the worst fit was a model with only Topography ($p = 0.93$) represented (model 6.15). The difference between the lowest and highest AIC values in this set was ΔAIC 15.28 showing a slight drop from sets 4 and 5. A high amount of significance is seen in this GLM set with over 50% (21/32) of the results showing significant values, much like the previous two sets all on the branch logging roads.

Table 15. Generalized linear model results for a 40km^2 buffer on the branch logging roads with a confidence interval of 0.95.

Model/Variable	Estimate	SE	z-Score	p-Value	AIC	ΔAIC	Rank
6.3							
Road	-2.05	0.58	-3.52	**0.00**	43.56	0	1
Forest	0.08	0.04	2.06	**0.04**			
Topography	0.07	0.02	3.34	**0.00**			
6.1							
Road	-2.38	0.94	-2.53	**0.01**			
Forest	0.08	0.04	1.86	0.06	45.35	1.79	2
Water	-0.03	0.06	-0.46	0.65			
Topography	0.08	0.03	2.84	**0.00**			
6.8							
Road	-2.17	0.57	-3.81	**0.00**	45.88	2.32	3
Topography	0.04	0.01	2.84	**0.00**			
6.4							
Road	-2.86	0.92	-3.12	**0.00**	46.92	3.36	4
Water	-0.06	0.06	-0.99	0.32			
Topography	0.06	0.03	2.22	**0.03**			

6.7							
Road	-1.07	0.42	-2.55	**0.01**	50.06	6.5	5
Water	0.06	0.03	2.01	**0.05**			
6.5							
Forest	0.11	0.04	2.64	**0.01**	50.12	6.56	6
Water	0.09	0.04	2.47	**0.01**			
Topography	0.03	0.02	1.52	0.13			
6.9							
Forest	0.06	0.02	2.50	**0.01**	50.44	6.88	7
Water	0.11	0.04	3.03	**0.00**			
6.2							
Road	-0.67	0.65	-1.04	0.30	51.38	7.82	8
Forest	0.03	0.04	0.82	0.41			
Water	0.08	0.04	1.98	**0.05**			
6.12							
Road	-1.05	0.42	-2.49	**0.01**	52.08	8.52	9
6.6							
Road	-1.32	0.53	-2.47	**0.01**	53.42	9.86	10
Forest	-0.02	0.03	-0.81	0.42			
6.10							
Forest	0.09	0.04	2.52	**0.01**	54.33	10.77	11
Topography	0.05	0.02	2.24	**0.03**			
6.14							
Water	0.06	0.03	1.90	0.06	55.22	11.66	12
6.11							
Water	0.09	0.04	2.31	**0.02**	55.39	11.83	13
Topography	-0.02	0.01	-1.34	0.18			
6.13							
Forest	0.02	0.02	1.11	0.27	57.59	14.03	14
6.15							
Topography	0.00	0.01	0.09	0.93	58.84	15.28	15

Table 16 outlines the six models with the best fit for each primary and branch logging road buffer area. For the primary logging roads, significant findings were found only for the model focused on a buffer area of $40km^2$. Both percent forest cover and percent water cover were found to influence large mammal movement at that buffer. All three buffer layers on the branch logging roads had significant findings for their models of best fit. At $130km^2$, road density and percent water cover were influential, at $80km^2$ percent forest cover and topographic ruggedness had strong influence, and for the $40km^2$ buffer, road density, percent forest cover and topographic ruggedness all had significant effects on the large mammal movement on APP branch roads (Figure 25 shows the surroundings of a primary logging road).

Table 16. Best-fit GLM models for all scenarios.

Buffer Area	Model	p-Value	AIC	ΔAIC
Primary 130km^2	7.9			
	Forest	0.13	40.02	0
	Water	0.14		
Primary 80km^2	8.14			
	Water	0.65	40.31	0
Primary 40km^2	9.5			
	Forest	**0.03**	38.80	0
	Water	**0.02**		
	Topography	0.10		
Branch 130km^2	10.4			
	Road	**0.05**	40.31	0
	Water	**0.01**		
	Topography	0.16		
Branch 80km^2	11.10			
	Forest	**0.00**	40.80	0
	Topography	**0.00**		
Branch 40km^2	12.3			
	Road	**0.00**	43.56	0
	Forest	**0.04**		
	Topography	**0.00**		

Figure 25. Prints down a primary logging road. Photo credit Hillary Roulston.

4.0 DISCUSSION

Road ecology based on logging roads within protected areas has had very little research at this time (Forman et al., 2003). This makes my current research, an analysis of movement of large mammals on APP logging roads, a preliminary examination of this ecosystem in this way.

Many studies look into the ecology and behaviour around roads at the individual species level (Clevenger et al., 2002; Kaczensky et al., 2011; Kaphegyi et al., 2013; Kindall & van Manen, 2007; Koh et al., 2010; Schrecengost et al., 2009; Way et al., 2004). There is also literature on the broader ecosystems and group of species approach, much like my study, but it has not been done within APP with consideration of logging roads (Alexander & Waters, 2000; Boan et al., 2011; Bowman et al., 2010; Kusak et al., 2009; Lebel et al., 2012; Lesmerises et al., 2012; Shepard et al., 2007; Trombulak & Frissell, 2000). North American studies that have examined logging roads tend to focus within the Canadian boreal forest where moose, deer, caribou, wolves, coyotes and wolverines (*Gulo gulo*) are of interest (Boan et al., 2011; Boisjoly et al., 2010; Bowman et al., 2010; Simard & Fryxell, 2003; Thompson et al., 1989). Generally past studies were conducted using methods of greater expense to monitor wildlife movement, such as aerial survey, GPS collars, and radio collars (Aebischer et al., 1993). The methods utilized in my research may be more cost effective for monitoring large mammals within a large study area.

Road ecology is a recent field of study that has large gaps in its information as we slowly gather more data and relevant research. Consideration of logging roads is a rare topic that has seen little research and reflection at this time. There are also few studies that examine affects of roads within protected areas and how they might relate to species within that area and surrounding landscape features (Alexander & Waters, 2000; Ascensao et al., 2013; Beckmann et al., 2010; Bowman et al., 2010; Clevenger et al., 2001b; Grilo et al., 2008; Gurratxaga et al., 2010; Kusak et al., 2009; Olsson et al., 2008). My study tries to address this gap by opening up a discourse on the potential impacts and use of the primary and branch logging roads in APP. Finding that the large mammals were using the roads, to what degree is unknown, helps us determine that there is road use at low levels of traffic and human disturbance. Other data mostly focuses on highways with high traffic speeds and volumes, that do not help us determine how logging roads, side roads and laneways may influence large mammal use in these areas.

The gap in literature focusing on large mammals leaves an opening in the knowledge we have about landscape-level and local-level effects on these animals when considering logging roads in the Great Lakes-St. Lawrence forest region and protected areas. Large mammals have been tracked and studied in relation to roads, though they generally focus on road crossing structures and monitoring connectivity across large highways (Acevedo et al., 2011; Buchmann et al., 2013; Fahrig & Rytwinski, 2009; Forman et al., 2003). The authors of these studies have found many differing results to mammal road-use and differences tend to show up based on the species, time of year, traffic volumes, road density, and surrounding vegetation and cover (Chetkiewicz & Boyce, 2009; Clevenger et al., 2001b; Clevenger et al., 2002; Cushman & Lewis, 2010;

Forman & Alexander, 1998; Grilo et al., 2008; Kindall & van Manen, 2007; Long et al., 2011; Mitchell & Powell, 2003; Roger et al., 2012).

Though the actions of logging are important to consider, the main driver of this study is the network of logging roads within APP, consisting of primary, branch and tertiary types. For my research alone, I examined only the movement of large mammals on the primary and branch logging road types, leaving room for future research to look deeper into the tertiary logging road type and possibly Highway 60 that runs through the southern portion of the park.

The species that I focus my research on are important to the APP ecosystem. Moose, white-tailed deer, black bear, eastern wolf, and coyote all play roles within this environment from social, economic, and of course environmental aspects (Algonquin Provincial Park Management Plan, 1998). Socially, these animals are charismatic and draw the attention and admiration of many people from all around the world. They encourage conservation practices and lend to the understanding of how humans can impact the wildlife of the world, due to their large presences and large ranges of movement. There is also a strong relationship between hunters and many large mammal species. Hunting is a seasonally permitted activity for the Algonquins of Ontario on the east side of the park and in the specific townships of Bruton, Clyde and Eyre for the public (Algonquin Provincial Park Management Plan, 1998; Hunting Regulations 2013-2014, 2013).

Large mammals are also important from an economic standpoint, especially within a protected areas setting, as they bring visitors into these parks (Acevedo et al., 2011; Dixon & Sherman, 1991; Quinn et al., 2013). For APP, many people come to visit with hopes of encountering moose, wolves, American black bears, and other species of wildlife (Friends of Algonquin Park, 2013). Wolf howls have become a regular activity that the public can participate in, and highway sightings of moose are frequent and often sought after by tourists, giving the park a wilderness appeal that many people desire.

Environmentally the large mammals of APP provide key ecosystem processes. Ungulates, as herbivores, maintain vegetation stands and structure, though as their populations increase dramatically, particularly with white-tailed deer, this foraging may cause dramatic changes in the vegetative structure (Koh et al., 2010). The large carnivores of the park are important for maintaining healthy ungulate populations and proportionate trophic levels in order to have an overall balanced ecosystem (Aspi et al., 2009; Chavez & Gese, 2006; Cook et al., 1999; Forbes & Theberge, 1996; Kunkel et al., 2004). Ecosystems where wolves have been extirpated (which has been much of North America) have shown imbalances between species, with very high numbers of herbivores, causing perhaps unwanted changes in that ecosystem due to their strong influences as a species (Carroll et al., 2006; Licht et al., 2010). This all factors back in to the mammals of APP, and how their populations can help maintain an ecosystem with ecological integrity and overall habitat health, since this is an important factor in Ontario Parks legislation (Ontario Parks, 2013).

When reflecting back on Table 1 (Page 11), we were able to determine that the American black bear did seem to avoid the primary roads more than the branch, and this may have been mostly due to the presence of desirable forage material along those roads. There was also higher forest cover on the branch roads and they were further from human development and the populated area surrounding the park. Coyotes and eastern wolves seemed to travel the two types of logging roads fairly similarly, and were potentially using them as travel corridors, though that cannot be confirmed with this data. As use of all types of forest are beneficial to the canines of the park, they had ample habitat of all types within this protected area. Both moose and white-tailed deer would find forage vegetation in abundance between the deciduous growth, roadside vegetation, and in newly logged areas. Overall, these mammals may be relatively accustomed to the human presence in APP and may feel little fear from utilizing the logging roads in the park, though data is insufficient at the moment to determine that as a fact.

Trying to understand how local-level and landscape-level variables are important to the large mammals of this park, along with how logging roads, as a specific anthropogenic impact, affect these animals is poorly understood, and so becomes the main point of my research (Brady et al., 2011). Many studies covered different sets of variables to what my current research handled (Acevedo et al., 2011; Bowman et al., 2010; Brady et al., 2011; Chetkiewicz & Boyce, 2009; Clevenger et al., 2002; Cushman & Lewis, 2010). Some included variables such as food resources, more encompassing land cover, and the overarching impact of human presence, whereas my study only observed road density as a form of human impact, and some landscape variables including topographic ruggedness, percent forest cover and percent water cover (Chetkiewicz & Boyce, 2009). For the fieldwork, results were of greater importance in a general descriptive manner. Tracks were by far the most common type of indicator for mammal presence and scat was more common on branch logging roads, perhaps indicating greater presence there, or indicating that evidence of mammals lasts longer on these less human-traveled corridors.

Besides the direct impacts and influences of the logging roads themselves, we must also examine what the variables are telling us from both the local- and landscape-level. One of the key elements of my research was the utilization of both local-level variables from the field and landscape-level variables from ArcGIS lab work. Using geospatial analysis has become an increasingly popular method for analyzing wildlife movement and modeling with landscape variables over large scales (Alexander & Waters, 2000; Boan et al., 2011; Clevenger et al., 2002; Kaphegyi et al., 2013; Shanley et al., 2013). This has also become a prevalent method within the context of road ecology since this tool can calculate and utilize data of our vast road networks. For this study I used ArcGIS 10.1 to calculate statistics on road density, percent forest cover, percent water cover, and topographic ruggedness. From the landscape data outputs I was able to use generalized linear models (GLMs) to determine if there was significant influence for predicting large mammal presence on APP logging roads. Previous research used variables similar to mine, as well as others to help predict crossing patterns with surrounding landscape features, which may further determine the placement of wildlife crossing structures (Acevedo et al., 2011; Chetkiewicz & Boyce, 2009; Cserkesz et al., 2013; Cushman & Lewis, 2010; Grilo et al., 2008; Long et al., 2011; Roger et al., 2012).

For four out of six GLM sets percent water cover was one of the more important landscape variables to predict large mammal presence on the primary and branch logging roads (Table 16). All three buffer perimeters on the primary logging roads had percent water cover as a part of their models of best fit, as well as percent forest cover for the 130km^2 and 40km^2 buffers and topographic ruggedness for the 40km^2 primary road buffer. For the branch logging roads the most common landscape variable playing an important role in determining presence was topographic ruggedness as it showed up in all three buffer layer models of best fit. Percent forest cover showed up in the 80km^2 and 40km^2 models, the road density variable was found to be influential in the 130km^2 and 40km^2 buffer zones, and percent water cover was important to the 130km^2 model of best fit. These results seem to show that differences in buffer area, or home range, play different roles on what landscape-level variables are important to large mammal movement on the logging roads of APP. There also seems to be a distinction between the models for the primary and branch logging roads, perhaps indicating that there is a difference between the use of these logging roads that could be explained by these landscape features. It is also important to note that significant results were found in the models of all the branch buffer areas, but only in the 40km^2 buffer for the primary logging roads. It must also be taken into consideration that local-level variables may also play a part in the habitat selection by these species, though it is difficult to determine this from the data that were collected in this study, as they are mostly categorical in nature. Some of this has been answered in the literature, though not for all large mammals at this point.

Figure 26. Vegetation surrounding a primary logging road. Photo credit Hillary Roulston.

The landscape variables all have implications for APP, and may be important for future management changes in logging road construction or decommissioning. The percent water cover variable may indicate the need of these large mammals for this life-giving resource, and their position relative to logging roads may be important. With the data I have collected at this point I am uncertain whether having logging road access close to water is beneficial or detrimental to large mammals, other than they seem to be more likely to use roads where water is fairly close. Percentage of forest cover may be beneficial to many species that prefer this habitat, such as bears and wolves, and may also determine foraging material for ungulates. This may also determine where logging practices may move to next to remove their next timber source. Road density is often a limiting factor to large mammals at certain thresholds, so it would be beneficial for the logging roads to remain below the lowest possible road density threshold that would produce negative affects on any of these species. Lastly topography is important to consider as roads are generally built on land that has easily accessible topography, and large mammals may do the same when they travel, leaving these areas as potential travel corridors for both humans and wildlife that need to be taken into consideration when building them.

The findings from my research conclude that logging roads may have some influence on the large mammal movement within the park, though it is still uncertain to what extent, and if there is a greater difference between primary and branch logging road use than what can be observed at this point in time (Figure 26). There is evidence to suggest that many of the large mammal species find little hindrance in utilizing the logging roads as tracks and scat were found regularly on both types of logging roads, though no comparison has been made with the interior of the park. Branch logging roads did tend to show more evidence of use than the primary logging roads. This may be due to confounding factors such as higher road use by vehicles and compaction from this use making mammal evidence harder to see. The results from the t-Test and Wilcoxon Signed-Rank Test both showed that there was no significant difference in use by large mammals of these two types of logging roads with the data that have been collected.

Other studies have found that the vegetation near logging roads can be highly desirable to herbivores as forage, and roads can also permit the ease of movement for predators (Alexander & Waters, 2000; Boan et al., 2011; Bowman et al., 2010; Forman, 2003; Lebel et al., 2012; Lesmerises et al., 2012). From this research, it is not surprising to see that within a protected area, such as APP where quality habitat is abundant (Algonquin Provincial Park Management Plan, 1998), that these mammals are using the logging roads to move around in order to optimize their survival.

Over the years of research on road ecology, large mammals, particularly carnivores, have been thought to be especially vulnerable to the growing road network around the world (Alexander & Waters, 2000; Fahrig & Rytwinski, 2009; Forman et al., 2003; Kusak et al., 2009; Nicholson & van Manen, 2009). Some of this is due to their large size, and therefore large habitat requirements that are necessary for their foraging behaviour and dispersal movements. For this study, I examined the use on primary and branch logging roads, to see if the logging road network was causing a barrier to the large mammal populations of the park. As evidence of logging road use was relatively consistent over the three repeated measures on both types of road, I determined that these roads may not cause a barrier for moose, white-tailed deer, black bear, eastern wolf and coyote with the data on hand. Further research would be necessary to determine if this is actually the case by radio-collaring individuals, or testing genetic samples, in order to determine if connectivity is currently being upheld in APP on the logging roads and within the interior of the park.

From the results collected and the maps of presence and absence at observation points (Figures 17-22), it can be noted that there seems to be no strong indication of any particular area where the logging roads are creating a barrier to the large mammals of APP. Though this is only a small preliminary study to try to understand a dynamic and complex ecosystem. All transects, even transect 3, which was just outside the boundary of the park, showed presence of many of the five species that I observed on both their primary and branch logging roads. There may be some difference between these two types of logging road use, but no significance was found at this point. As I recommend below, more data should be collected in order to have a greater sample size in order to be more confident in this result that there is no significant difference between primary and branch logging road use.

Most studies focus on the fragmentation effects of highways, and higher used paved roads, and found that they acted as barriers or dangers to wildlife populations in many cases (Forman et al., 2003; Kusak et al., 2009; Lewis et al., 2011; Nicholson & van Manen, 2009). Comparison with these studies is difficult because of these basic differences between road types and location. Even if studies of road ecology took place within a protected area, they tended to focus on a highways that run through them and not potential logging roads, such as in Banff National Park, British Columbia, Canada; Olympic National Park in Washington, USA; Parc de la Gaspesie in Quebec, Canada; and Great Smokey Mountain National Park in Tennessee, USA (Clevenger et al., 2002; Forman et al., 2003). These studies also tend to look for features that may explain higher use areas as tools for placing mitigation measures from road fragmentation (Clevenger et al., 2002; Corlatti et al., 2009; Olsson et al., 2008). These authors hope to find areas where crossing is highest in order to give easily understood and conclusive results to transportation departments and governments so underpasses, overpasses, or other crossing structures can be constructed and retrofitted into key wildlife corridors.

Algonquin Provincial Park connectivity for large mammals did not seem hindered based on the results from this preliminary study of their movement. Logging roads within the park are narrow, unpaved, and with low vehicle use levels, perhaps posing as a non-threatening source to wildlife movement compared to highways and other public-use roads (Algonquin Provincial Park Management Plan, 1998). Tracks and scat were regularly seen on both types of road, and there was no significant difference in use between the two for movement use, based on the t-Test and the Wilcoxon Signed-Rank Test. Habitat fragmentation and connectivity are related, and the fragmentation caused by the logging road network within this particular protected area does not seem to cause issues for connectivity at the landscape level for the five large mammals observed, as their use of these logging roads for their movement was frequent and consistent across the summer season (Forman et al., 2003). It is the protected areas around the world that are holding reserves of these populations, and so with connectivity still strong for large mammals in APP, there is a hopeful future for the species that reside there (Kaczensky et al., 2011; Minor & Lookingbill, 2010; Naughton-Treves et al., 2005).

Logging roads can have effects on their surrounding habitat just like any other type of road, though the effects may be different and the negative effects may not be seen to the extent that they are on large, paved highways (Forman et al., 2003). When logging occurs, there tends to be a surge of deciduous growth, even if the originally logged forest had greater coniferous species to begin with (Bowman et al., 2010; Jones et al., 2011; Lesmerises et al., 2012; Masse & Cote, 2012). The young, new growth promoted by the canopy openings at logging sites and the roads attract large herbivores to these areas of preferred forage material (Inglis et al., 1998). The roadsides along many of the logging roads, predominantly the branch roads, were highly populated with raspberry and/or blackberry bushes, making those areas a strong attraction to the American black bears of the park, as can be seen in other studies of black bear, grizzly bear, and the European brown bear where berries were a strong influence of road use (Clevenger et al., 2002; Roever et al., 2008). When this type of vegetation draws these species in to those areas, the predators of those species often follow, in this case potential prey for the American black bear, eastern wolf and coyote (Boan et al., 2011; Bowman et al., 2010; Lebel et al., 2012). There may also be a relationship between the canopy cover and greater branch road movement, as generally canopy cover was greater on those logging roads compared to the primary roads. Road width is perhaps another strong factor in determining large mammal movement. Branch roads were narrower than their primary counterparts overall, with the mean values of road width being 6.7m for primary and 5.5m for branch.

The positive influence of forestry roads mentioned in previous research was also evident in this case study. Tracks and scat indicate use of these roads as travel corridors, and surrounding vegetation as potential forage material, especially with the American black bears and the berries growing there during the month of June. Strong presence of deciduous vegetation and herbaceous undergrowth had the potential to be highly utilized by moose and white-tailed deer, perhaps explaining their high frequencies of tracks and scat on both the primary and branch logging roads in APP.

Though there are positive influences of logging roads on large mammal habitat within protected areas, there are also negative influences. One of the main issues with having a road network within a protected area is greater access to remote regions by humans (Forman, 2010; Forman et al., 2003; Lebel et al., 2012; Roever et al., 2008; Shanley et al., 2013; Sherwood et al., 2002). With the extent of the logging road network in APP, it creates difficulty for limiting access to humans. This may have its implications on the protection of sensitive habitats and values within the park. Where logging is currently taking place, the noise impact may deter the large mammals from those areas for a time (Forman et al., 2003). At this time there were a few areas where logging was currently taking place in the vicinity of my research, though no data was specifically collected with this in mind. As this is the case I would recommend that future research would examine this potential impact in greater detail.

Through observation on site, it was noted that the majority of tracks were running parallel with the roads and fewer crossed perpendicular. There could be a strong systemic bias in this, in that it is easier to spot tracks running with the logging roads than the smaller chance of stopping in areas where the mammals are crossing the road perpendicularly. Since there were fairly high levels of movement parallel to the road, it makes for an interesting claim that the mammals were utilizing the roads as a way to ease their movements, though my data is insufficient for actually determining this.

Using GIS data analysis within my work, I feel that there is a better grasp of understanding the movement of the large mammals in this protected area through the generalized linear models (GLMs). By seeking out these variables and identifying their potential significance at different scales of habitat it will hopefully be simpler in the future to add or subtract other landscape variables to these models. Future studies should take this research as a preliminary start to describing movement on primary and branch logging roads by large mammals in APP, and use the results to direct what steps should be taken next in the world of wildlife ecology and protection.

4.1 Recommendations and Further Research

An understanding at a group of species level may be very informative, but it may also be wise to consider the movement of large mammals on the primary and branch logging roads within APP at the individual species level. Their individual requirements and how they interact on with the local- and landscape-level variables may be beneficial for finding models that are more precise for each species. While individual analysis of a species could be overall more ecologically informative, it may not be as economically beneficial.

A second recommendation would be to add more transects and/or lengthen the current transects to incorporate more road length. This could be done to gain a better grasp on answering the research questions of how the large mammals utilize either type of logging road, and how those differ according to the different local- and landscape-level variables.

Another interesting way to extend this research would be to conduct field research at other times of the year, and not just from late spring to the end of summer (McLoughlin et al., 2011). Extension into the autumn and winter seasons could be very useful in determining if primary and branch logging road use differs depending on the time of year. This may factor in the rut in the autumn for the ungulates, the migration of white-tailed deer into their winter-feeding grounds, and how the predators move in accordance to the movements of their prey. Wildlife movement may also be influenced by the hunting season and by seasonality in the forest resource extraction industry as well.

A fourth recommendation I would suggest is the continuation of this study of tracking the large mammals within APP at least at the minimum, which I consider to be the methods of this current study. Preferably, more of the recommendations brought up in this section could be added to the study in order to provide useful data in the future. Year-to-year comparison would also be ideal, if this research could maintain a long-term presence within the APP so that not only spatial data could be collected, but temporal data could be as well. That data could then be analyzed for changes in logging road use and help determine other influencing habitat affects (Thompson et al., 1989).

Adaptations to the variables of this study are also a recommendation I would make. Perhaps the inclusion of more landscape-level data would be helpful, such a distance to nearest road, where current logging practices are taking place, or distance to nearest human development structure. This could add to the complexity, and perhaps our overall understanding of how these landscape-level variables play a role in explaining large mammal movement in APP. If more researchers were available, there could also be better coverage of the local-level data, and more accuracy in those measurements. Greater species identification of the vegetation and their heights would be useful as a better indicator of ungulate forage material. And as stated above, more time and distance could be added to the transects in order to collect more observations, therefore increasing the accuracy of the results obtained.

To ensure a more pronounced independence between observations, it may be in the better interest of this study to recommend having set observation points that are checked regularly (Long et al., 2011). Independence when tracking on roads may be difficult to determine since many of these large mammals can move along these corridors for long distances (Burdett et al., 2007; Fahrig & Rytwinski, 2009; Howard & DelFrate, 1991; Inglis et al., 1998; Kusak et al., 2005; Sargent & Labisky, 1995; Stenhouse et al., 1995; Wooding & Hardisky, 2001). If observation points were given at specific locations at set distances from each other down a road corridor, the resulting data may be more accurate in telling the researcher how the wildlife are actually utilizing the branch and primary logging roads in APP without potentially repeating counts.

Overall monitoring could be enhanced with the addition of more IR-cameras or video cameras set up in distinct locations. This could allow for better coverage and consistency between observation points, regardless of time of day, weather, or other factors that may influence human monitoring and tracking. More cameras could benefit the overall research collection by providing more data.

Another interesting point that could not be covered well in this study was looking at the impacts of hunting on the large mammal populations in the park (Sargent and Labisky, 1995). Hunting is only permitted seasonally on the east side of the park by the Algonquins of Ontario as well as in Clyde, Bruton and Eyre by the public, therefore potentially influencing different behaviour from those mammals, compared to those on the west side of the park (Hunting Regulations 2013-2014, 2013). To look at this, data collection would need to be extended into the hunting season (autumn) and look at the use of logging roads at that time and contrast it to the logging road movement at other times of the year. This would be a recommendation that could be of interest to APP for monitoring their wildlife and the hunting agreement within their protected area.

Further examination into the effects of ditches on logging road movement is something that may also interest the park. This recommendation is made as a means to look at how ditches, as a ubiquitous road planning structure, may affect the wildlife in the park, and if there is a threshold of depth and width that may deter wildlife from crossing the roads (Forman et al., 2003). Again, not a whole lot is known about this, and there may in fact be little to no effect, since many of the mammals seem to use the length of the primary and branch logging roads, instead of just crossing perpendicular to it. There is also a majority of observations without ditches, perhaps mitigating any effects ditches would have elsewhere along the length of logging road (Table 7).

There is also always the potential to examine other groups of species and their use of logging roads in APP, as well as adding more specific vegetation data. This might include things like hemlock (*Tsuga sp.*) that were a very common tree in the past in APP, and have since been extracted from the park (Algonquin Provincial Park Management Plan, 1998). Replanting of this species has been difficult as the seedlings are excellent forage for the ungulates in the park, and are stunted in their growth. Expansion of the research question to include more species might increase our understanding of the APP ecosystem, and more of its complex workings.

Comparison may also be possible between data on the logging roads in APP and outside of this particular protected area. Some of the roads surrounding the park are highway, county roads and lower-use local roads (Ministry of Transportation, 2013). If monitoring could also consider this larger scale, greater understanding of APP large mammals may occur. This might mean a threshold for traffic volume could be established for these populations, or understanding of how they utilize the protected area compared to outside the park may be beneficial to species management.

4.2 Management Strategies

The results from my research, on the large mammal movement in APP with regards to the primary and branch logging roads, found that they do utilize the logging roads, though to what extent is uncertain with the data at hand. Due to this result, current large mammal management practices could be sustained, which is to say no active management at this time, as their populations could be utilizing the logging roads to their benefit.

Currently, wildlife-crossing structures, such as overpasses and underpasses, are not necessary for the persistence of the large mammals of APP on logging roads. Fencing is also not required to prevent logging road use, as traffic volumes are low enough to not be a threat. As the logging roads have lower speed limits the traffic that is on these roads is slower than what is seen on Highway 60, again reducing the chance and impact of a collision. No road kill was observed during the duration of my study, so I do not believe the primary and branch logging roads are causing high levels of wildlife mortality for the large mammals of the park.

As my monitoring was not conducted during the hunting season, I do not have management strategies for large mammal management at that time. As recommended in the previous section, future research should track during this season to see if there is less use of the logging roads at that time. Forest resource extraction may also influence the movement and use of logging roads by these species, but perhaps only where it is currently being practiced (Algonquin Provincial Park Management Plan, 1998; Inglis et al., 1998). This may only cause temporary disturbances at small spatial scales.

We must remember how specific this study is within the topic of road ecology. Road ecology is the study of roads and their affects on the environment (Forman, 2003). This can look at water sedimentation to invasive species movement, from wildlife crossing structures to songbird survival. And within this topic my research delves into large mammals in APP, related to logging road movement, to determine what form of relationship is there. As forestry is important to this subject of logging roads, my research has hopefully informed towards some useful future management practices, such as continued monitoring, watching road densities and where water is present in relation to those roads. Generally, continued research and monitoring should occur to determine if there is change in logging road use by the moose, white-tailed deer, eastern wolf, coyote, and American black bear in APP, and from that determine if greater changes need to be made for the management of these species as this is only one aspect of a much larger ecological picture.

4.3 Final Words

My research has shown that large mammals in APP do use primary and branch logging roads, though the difference between road use and interior use cannot be determined at this time (Figure 27). Local-level variables assisted in describing the observation points and providing greater information on what APP is comprised of along its logging roads. On the other hand, the landscape-level variables were very useful in helping predict what influences they have on primary and branch logging road use by the large mammal species of this protected area through generalized linear models. From the information that was gathered, further research is the highest recommendation I would make, as more data on the movements of these species can only boost the confidence of how best to allow large mammal persistence into the foreseeable future.

Figure 27. White-tailed deer and fawn caught in IR-camera. Photo credit Hillary Roulston.

5.0 REFERNECES

A to A. (2012). *Algonquin to Adirondacks Conservation Association*. http://www.a2alink.org/

Acevedo, P., Farfan, M., Marquez, A., Delibes-Mateos, M., Real, R., and Vargas, J. (2011). Past, present and future of wild ungulates in relation to changes in land use. *Landscape Ecology*. 26: 19-31.

Aebischer, N., Robertson, P., and Kenward, R. (1993). Compositional analysis of habitat use from animal radio-tracking data. *Ecological Society of America*. 74: 1313-1325.

Alexander, S. and Waters, N. (2000). The effects of highway transportation corridors on wildlife: A case study of Banff National Park. *Transportation Research Part C*. 8: 307-320.

Algonquin Provincial Park Management Plan. (1998). *Ontario Parks*. http://www.algonquinpark.on.ca/pdf/management_plan.pdf

Algonquin Provincial Park Management Plan Amendment. (2013). *Ontatio Parks*. http://www.mnr.gov.on.ca/stdprodconsume/groups/lr/@mnr/@parks/documents/document/stdprod_108938.pdf

Argue, A., Mills, K. and Patterson, B. (2008). Behavioural response of eastern wolves (*Canis lycaon*) to disturbance at homesties and its effects on pup survival. *Canadian Journal of Zoology*. 86: 400-406.

Ascensao, F., Clevenger, A., Santos-Reis, M., Urbano, P., and Jackson, N. (2013). Wildlife-vehicle collision mitigation: Is partial fencing the answer? An agent-based model approach. *Ecological Modeliing*. 257: 36-43.

Aspi, J., Roininen, E., Kiskila, J., Ruokonen, M., Kojola, I., Bljudnik, L., Danilov, P., Heikkinen, S. and Pulliainen, E. (2009). Genetic structure of the northwestern Russian wolf populations and gene flow between Russia and Finland. *Conservation Genetics*. 10: 815-826.

Baggio, J., Salau, K., Janssen, M., Schoon, M., and Bodin, O. (2011). Landscape connectivity and predator-prey population dynamics. *Landscape Ecology*. 26: 33-45.

Beckmann, J., Clevenger, A., Huijser, M., and Hilty, J. (Eds.). (2010). *Safe Passages: Highways, Wildlife, and Habitat Connectivity*. Washington DC: Island Press.

Beier, P., Majka, D., and Spencer, W. (2008). Forks in the road: Choices in procedures for designing wildland linkages. *Conservation Biology*. 22(4): 836-851.

Beyer, H., Ung, R., Murray, D., and Fortin, M. (2013). Functional responses, seasonal variation and thresholds in behavioural responses of moose to road density. *Journal of Applied Ecology*. 50: 286-294.

Bissonette, J., and Adair, W. (2008). Restoring habitat permeability to roaded landscapes with isometrically-scaled wildlife crossings. *Biological Conservation*. 141:482-288.

Boan, J., McLaren, B., and Malcolm, J. (2011). Influence of post-harvest silviculture on understory vegetation: Implications for forage in a mulit-ungulate system. *Forest Ecology and Management*. 262: 1704-1712.

Boisjoly, D., Ouellet, J., and Courtois, R. (2010). Coyote habitat selection and management implications for the Gaspesie caribou. *Journal of Wildlife Management*. 74: 3-11.

Bowman, J., Ray, J., Magoun, A., Johnson, D., and Dawson, F. (2010). Roads, logging, and the large-mammal community of an eastern Canadian boreal forest. *Canadian Journal of Zoology*. 88: 454-467.

Brady, M., McAlpine, C., Possingham, H., Miller, C., and Baxter, G. (2011). Matrix is important for mammals in landscapes with small amounts of native forest habitat. *Landscape Ecology*. 26: 617-628.

Buchmann, C., Schurr, F., Nathan, R., and Jeltsch, F. (2013). Habitat loss and fragmentation affecting mammal and bird communities-The role of interspecific competition and individual space use. *Ecological Informatics*. 14: 90-98.

Burdett, C., Moen, R., Niemi, G., and Mech, L. (2007). Defining space use and movements of Canada lynx with global positioning system telemetry. *Journal of Mammalogy*. 88: 457-467.

Caro, T., Jones, T., and Davenport, T. (2009). Realities of documenting wildlife corridors in tropical countries. *Biological Conservation*. 142: 2807-2811.

Carroll, C., Phillips, M., Lopez-Gonzalez, C. and Schumaker, N. (2006). Defining recovery goals and strategies for endangered species: The wolf as a case study. *BioScience*. 56 (1): 25-37.

Carroll, C., Phillips, M., Schmaker, N., and Smith, D. (2003). Impacts of landscape change on wolf restoration success: Planning a reintroduction program based on static and dynamic spatial models. *Conservation Biology*. 17: 536-548.

Cederlund, G. and Sand, H. (1994). Home-range size in relation to age and sex in moose. *Journal of Mammalogy*. 75: 1005-1012.

Chavez, A. and Gese, E. (2006). Landscape use and movements of wolves in relation to livestock in a wildland-agriculture matrix. *Journal of Wildlife Management*. 70 (4): 1079-1086.

Chetkiewicz, C. and Boyce, M. (2009). Use of resource selection functions to identify conservation corridors. *Journal of Applied Ecology*. 46: 1036-1047.

Clevenger, A., Chruszcz, B., and Gunson, K. (2001a). Drainage culverts as habitat linkages and factors affecting passage by mammals. *Journal of Applied Ecology*. 38: 1340-1349.

Clevenger, A., Chruszcz, B., and Gunson, K. (2001b). Highway mitigation fencing reduces wildlife-vehicle collisions. *Wildlife Society Bulletin*. 29(20): 646-653.

Clevenger, A. and Sawaya, M. (2010). Piloting a non-invasive genetic sampling method for evaluating population-level benefits of wildlife crossing structures. *Ecology and Society*. 15: 7-

Clevenger, A., Wierzchowski, J., Chruszcz, B., and Gunson, K. (2002). GIS-generated, expert-based models for identifying wildlife habitat linkages and planning mitigation passages. *Conservation Biology*. 16(2): 503-514.

Colchero, F., Conde, A., Manterola, C., Chavez, C., Rivera, A., and Ceballos, G. (2010). Jaguars on the move: Modeling movement to mitigate fragmentation from road expansion in the Mayan forest. *Animal Conservation*. 14: 158-166.

Cook, S., Norris, D. and Theberge, J. (1999). Spatial dynamics of a migratory wolf population in winter, south-central Ontario (1990-1995). *Canadian Journal of Zoology*. 77: 1740-1750.

Corlatti, L., Hacklander, K., and Frey-Roos, F. (2009). Ability of wildlife overpasses to provide connectivity and prevent genetic isolation. *Conservation Biology*. 23(3): 548-556.

Cserkesz, T., Ottlecz, B., Cserkesz-Nagy, A., and Farkas, J. (2013). Interchange as the main factor determining wildlife-vehicle collision hotspots on the fenced highways: Spatial analysis and applications. *Eur J Wildl Res*. DOI 10.1007/s10344-013-0710-2.

Cushman, S. and Lewis, J. (2010). Movement behaviour explains genetic differentiation in American black bears. *Landscape Ecology*. 25: 1613-1625.

Cushman, S., Raphael, M., Rugguero, L., Shirk, A., Wasserman, T., and O'Doherty, E. (2011). Limiting factors and landscape connectivity: The American marten in the Rocky Mountains. *Landscape Ecology*. 26: 1137-1149.

D'Antonio, A., Monz, C., Newman, P., Lawson, S., and Taff, D. (2013). Enhancing the utility of visitor impact assessment in parks and protected areas: A combined social-ecological approach. *Journal of Environmental Management*. 124: 72-81.

Dearden, P. and Rollins, R. (2009). *Parks and protected areas in Canada: Planning and management*. (3rd Ed.). Toronto: Oxford University Press.

De Bord, D. (2009). *Alces alces* Eurasian Elk. *Animal Diversity Web*. http://animaldiversity.ummz.umich.edu/accounts/Alces_alces/

DeFries, R., Hansen, A., Turner, B., Reid, R., and Liu, J. (2007). Land use change around protected areas: Management to balance human needs and ecological function. *Ecological Application*. 17: 1031-1038.

D'Eon, R., Wilson, S., and Hamilton, D. (2006). Ground-based inventory methods for ungulate snow-track surveys. *Ministry of Environment: Ecosystems Branch British Columbia*. No. 33a.

Dixon, J., and Sherman, P. (1991). Economics of protected areas. *Ambio*. 20: 68-74.

ESRI. (2013). ArcGIS 10.1 http://www.esri.com/software/arcgis/arcgis10

Fahrig, L., and Rytwinski, T. (2009). Effects of roads on animal abundance: An empirical review and synthesis. *Ecology and Society*. 14: 21-40.

Finnegan, L., Wilson, P., Price, G., Lowe, S., Patterson, B., Fortin, M., and Murray, D. (2012). The complimentary role of genetic and ecological data in understanding population structure: A case study using moose (*Alces alces*). *European Journal of Wildlife Restoration*. 58: 415-423.

Foote, A. and Keeping, D. (2007). Wildlife assessment of Kalahari ecosystems (WAKE). *University of Alberta*.

Forbes, G. and Theberge, J. (1996). Cross-boundary management of Algonquin Park wolves. *Conservation Biology*. 10 (4): 1091-1097.

Ford, A., Clevenger, A., and Bennett, A. (2009). Comparison of methods of monitoring wildlife crossing-structures on highways. *Journal of Wildlife Management*. 73: 1213-1222.

Forman, R. (Author). Beckmann, J., Clevenger, A., Huijser, M., and Hilty, J. (Eds.). (2010). *Safe Passages: Highways, Wildlife, and Habitat Connectivity*. Washington DC: Island Press.

Forman, R. and Alexander, L. (1998). Roads and their major ecological effects. *Annual Review of Ecological Systems*. 29: 207-231.

Forman, R. T. T., D. Sperling, J. A. Bissonette, A. P. Clevenger, C. D. Cutshall, V. H. Dale, L. Fahrig, R. France, C. R. Goldman, K. Heanue, J. A. Jones, F. J. Swanson, T. Turrentine, and T. C. Winter. (2003). *Road ecology: science and solutions*. Washington, D.C.: Island Press.

Frair, J., Merrill, E., Beyer, H., and Morales, J. (2008). Thresholds in landscape connectivity and mortality risks in response to growing road networks. *Journal of Applied Ecology*. 45: 1504-1513.

Frary, V., Duchamp, J., Machr, D., and Larkin, J. (2011). Density and distribution of a colonizing front of the American black bear *Ursus americanus*. *Wildlife Biology*. 17: 404-416.

Friends of Algonquin Park. (2013). *General Algonquin park information*. http://www.algonquinpark.on.ca/visit/general_park_info/

Garcia-Rangel, S. and Pettorelli, N. (2013). Thinking spatially: The importance of geospatial techniques for carnivore conservation. *Ecological Informatics*. 14: 84-89.

Gehrt, S., Anchor, C., and White, L. (2009). Home range and landscape use of coyotes in a metropolitan landscape: Conflict or coexistence? *Journal of Mammalogy*. 90: 1045-1057.

Giam, X., Clements, G., Aziz, S., Chong, K., and Miettinen, J. (2011). Rethinking the ‘back to wilderness’ concept for Sunderland’s forests. *Biological Conservation*. 144: 3149-3152.

Gies, E. (2006). *The health benefits of parks: How parks keep Americans and their communities fit and healthy*. The Trust for Public Land: San Francisco, CA.

Glista, D., CeVault, T., and DeWoody, J. (2009). A review of mitigation measures for reducing wildlife mortality on roadways. *Landscape and Urban Planning*. 91: 1-7.

Government of New Brunswick. (n.d.). Be aware of bears: Tips for avoiding encounters or problems with black bears. http://www2.gnb.ca/content/dam/gnb/Departments/nr-rn/pdf/en/Wildlife/BewareBlackBears.pdf

Grilo, C., Ascensao, F., Santos-Reis, M., and Bissonette, J. (2011). Do well-connected landscapes promote road-related mortality? *European Journal of Wildlife Research*. 57: 707-716.

Grilo, C., Bissonette, J., and Santos-Reis, M. (2008). Response of carnivores to existing highway culverts and underpasses: Implications for road planning and mitigation. *Biodiversity Conservation*. 17: 1685-1699.

Guitet, S., Pithon, S., Brunaux, O., Jubelin, G., and Good, V. (2012). Impacts of logging on the canopy and the consequences for forest management in French Guiana. *Forest Ecology and Management*. 277: 124-131.

Gurrutxaga, M., Lozano, P., and Barrio, G. (2010). Assessing highway permeability for the restoration of landscape connectivity between protected areas in the Basque Country, Northern Spain. *Landscape Research*. 35(5): 529-550.

Heilman, G., Strittholt, J., Slosser, N., and Dellasala, D. (2002). Forest fragmentation of the conterminous United States assessing forest intactness through road density and spatial characteristics. *BioScience*. 52: 411-422.

Hochrein, H. (2008). Corridors and plant invasions: A comparative study of the role of roadsides and hiking trails on plant invasions in Moorea, French Polynesia. *Berkeley Natural History Museum*. 1-13.

Howard, V. and DelFrate, G. (1991). Homeranges and movement of coyotes in the Northern Chihuahuan Desert. *Great Plains Wildlife Damage Control Workshop Proceedings*.

Houle, M., Fortin, D., Dussault, C., Courtois, R. and Ouellet, J. (2010). Cumulative effects of forestry on habitat use by gray wolf (*Canis lupus*) in the boreal forest. *Landscpae Ecology*. 25: 419-433.

Hunt, L. and Hosegood, S. (2008). The effectiveness of signs at restricting vehicle traffic: A case of seasonal closures on forest access roads. *Canadian Journals of Forest Resources*. 38: 2306-2312.

Hunting Regulations 2013-2014. (2013). Ontario Ministry of Natural Resources. http://www.mnr.gov.on.ca/en/Business/FW/Publication/MNR_E001275P.html

Inglis, J. and Wilton, M. (1998). Seasonal movement patterns and feeding habits of large adut male black bears in Algonquin Provincial Park, Ontario. *PRFO Proceedings*. 169-179.

Introduction to Algonquin Park. (2005). *The Science Behind Algonquin's Animals*. http://www.sbaa.ca/about.asp?n=278&o=1

IUCN. (2013). International Union for Conservation of Nature. http://www.iucn.org/

Jedrzejewski, W., Schmidt, K., Theuerkauf, J., Jedrzejewski, B., and Kowalczyk, R. (2007). Territory size of wolves *Canis lupus*: Linking local (Bialowieza Primeval Forest, Poland) and Holarctic-scale patterns. *Ecography*. 30: 66-76.

Jones, B., Molenda, O., Hayward, C., D'Aguiar, M., Miller, N., Rye, L., and Cottenie, K. (2011). Patterns of tree diversity in response to logging in Algonquin Provincial Park. *Studies by Undergraduate Researcher at Guelph*. 4: 56-62.

Jones, M. and Pelton, M. (2003). Female American black bear use of managed forest and agricultural lands in coastal North Carolina. *Ursus*. 14: 188-197.

Kaczensky, P., Kuehn, R., Lhagvasuren, B., Pietsch, S., Yang, W., and Walzer, C. (2011). Connectivity of the Asiatic wild ass population in the Mongolian Gobi. *Biological Conservation*. 144: 920-929.

Kaphegyi, T., Dees, M., Zlatanova, D., Ueffing, C., Dutsov, A., and Kaphegyi, U. (2013). Rapid assessment of linear transport infrastructure in relation to the impact on landscape continuity for large ranging mammals. *Biodiversity Conservation*. 22: 153-168.

Kays, R., Curtis, A., and Kirchman, J. (2010). Rapid adaptive evolution of northeastern coyotes via hybridization with wolves. *Biology Letters*. 6: 89-93.

Kershaw, L. (2001). *Trees of Ontario*. Edmonton, AB: Lone Pine Publishing.

Kindall, J. and van Manen, F. (2007). Identifying habitat linkages for American black bears in North Carolina, USA. *Journal of Wildlife Management*. 71: 487-495.

Koh, S., Bazely, D., Tanentzap, A., Voigt, D., and Da Silva, E. (2010). *Trillium grandiflorum* height is an indicator of white-tailed deer density at local and regional scales. *Forest Ecology and Management*. 259: 1472-1479.

Kolenosky, G. and Johnson, D. (1967). Radio-tracking timber wolves in Ontario. *American Zoology*. 7: 289-303.

Kunkel, K., Pletscher, D., Boyd, D., Ream, R. and Fairchild, M. (2004). Factors correlated with foraging behavior of wolves in and near Glacier National Park, Montana. *Journal of Wildlife Management*. 68 (1): 167-178.

Kusak, J., Huber, D., Gomercie, T., Schwaderer, G., and Guzvica, G. (2009). The permeability of highway in Gorski kotar (Croatia) for large mammals. *European Journal of Wildlife Research*. 55: 7-21.

Kusak, J., Skrbinsek, A., and Huber, D. (2005). Home ranges, movements, and activity of wolves (*Canis lupus*) in the Dalmatian part of Dinarids, Croatia. *European Journal of Wildlife Research*. 51: 254-262.

Latham, A., Latham, M., McCutchen, N., and Boutin, S. (2011). Invading white-tailed deer change wolf-caribou dynamics in northeastern Alberta. *Journal of Wildlife Management*. 75(1): 204-212.

Lariviere, S. Jolicoeur, H. and Crete, M. (2000). Status and conservation of the gray wolf (*Canis lupus*) in wildlife reserves of Quebec. *Biological Conservation*. 94: 143-151.

Lebel, F., Dussault, C., Masse, A., and Cote, S. (2012). Influence of habitat features and hunter behaviour on white-tailed deer harvest. *The Journal of Wildlife Management*. 76: 1431-1440.

Leblond, M., Dussault, C., and Ouellet, J. (2013). Avoidance of roads by large herbivores and its relation to disturbance intensity. *Journal of Zoology*. 289: 32-40.

Leblond, M., Dussault, C., Oullet, J., Poulin, M., Coutois, R., and Fortin, J. (2007). Electric fencing as a measure to reduce moose-vehicle collisions. *Journal of Wildlife Management*. 71(5): 1695-1703.

Leblond, M., Frair, J., Forin, D., Dussault, C., Oullet, J., and Courtois, R. (2011). Assessing the influence of resource covariates at multiple spatial scales: An application to forest-dwelling caribou faced with intensive human activity. *Landscape Ecology*. 26: ?

Lesmerises, F., Dussault, C., and St-Laurent, M. (2012). Wolf habitat selection is shaped by human activities in a highly managed boreal forest. *Forest Ecology and Management*. 276: 125-131.

Lewis, J., Rachlow, J., Horne, J., Garton, E., Wakkinen, W., Hayden, J., and Zager, P. (2011). Identifying habitat characteristics to predict highway crossing areas for black bears within a human-modified landscape. *Landscape and Urban Planning*. 101: 99-107.

Licht, D., Millspaugh, J., Kunkel, K., Kochanny, C. and Peterson, R. (2010). Using small populations of wolves for ecosystem restoration and stewardship. *BioScience*. 60 (2): 147-153.

Litvaitis, J. and Tash, J. (2008). An approach toward understanding wildlife-vehicle collisions. *Environmental Management*. DOI 10.1007/s00267-008-9108-4.

Lockwood, M., Worboys, G., and Kothari, A. (2006). *Managing protected area: A global guide*. Sterling, VA: Earthscan.

Long, R., Donovan, T., MacKay, P., Zielinski, W., and Buzas, J. (2011). Predicting carnivore occurrence with noninvasive surveys and occupancy modeling. *Landscape Ecology*. 26: 327-340.

Lugo, A. and Gucinski, H. (2000). Function, effects, and management of forest roads. *Forest Ecology and Management*. 133: 249-262.

Luque, S., Saura, S., and Fortin, M. (2012). Landscape connectivity analysis for conservation: Insights from combining new methods with ecological and genetic data. *Landscape Ecology*. 27: 153-157.

MacPherson, J. and Bright, P. (2011). Metapopulation dynamics and a landscape approach to conservation of lowland water voles (*Arvicola amphibius*). *:andscape Ecology*. 26

Madej, M. (2001). Erosion and sediment delivery following removal of forest roads. *Earth Surface Processes and Landforms*. 26: 175-190.

Markarian, M. (May 29, 2008). Saving California's Bobcats. *Animals & Politics*. http://hslf.typepad.com/political_animal/2013/05/saving-californias-bobcats.html

Masse, A. and Cote, S. (2012). Linking habitat heterogeneity to space use by large herbivores at multiple scales: From habitat mosaics to forest canopy openings. *Forest Ecology and Management*. 285: 67-76.

Mata, C., Hervas, I., Herranz, J., Suarez, F., and Malo, J. (2008). Are motorway wildlife passages worth building? Vertebrate use of road-crossing structures on a Spanish motorway. *Journal of Environmental Management*. 88: 407-415.

McCollister, M. and Van Manen, F. (2010). Effectiveness of wildlife underpasses and fencing to reduce wildlife-vehicle collisions. *Journal of Wildlife Management*. 74(8): 1722-1731.

McLoughlin, P., Vander Wal, E., Lowe, S., Patterson, B., and Murray, D. (2011). Seasonal shifts in habitat selection of a large herbivore and the influence of human activity. *Basic and Applied Ecology*. 12: 654-663.

Mech, L. (1995). The challenge and opportunity of recovering wolf populations. *Conservation Biology*. 9 (2): 270-278.

Ministry of Transpotation. (2013). http://www.mto.gov.on.ca/english/

Minor, E. and Lookingbill, T. (2010). A multiscale network analysis of protected-area connectivity for mammals in the United States. *Conservation Biology*. 24(6): 1549-1558.

Mitchell, M. and Powell, R. (2003). Response of black bears to forest management in the southern Appalachian mountains. *The Journal of Wildlife Management*. 67: 692-705.

Mladenoff, D., Sickley, T., Haight, R. and Wydeven, A. (1995). A regional landscape analysis and prediction of favorable gray wolf habitat in the northern Great Lakes region. *Conservation Biology*. 9 (2): 279-294.

Moen, R. (2009). Techniques to monitor road-crossings and animal-vehicle collisions. *University of Minnesota, Duluth*. 1-23.

Molles, M. and Cahill, J. (2008). *Ecology: Concepts and Applications* (Canadian Ed.). Toronto, ON: McGraw-Hill Ryerson.

Morellet, N., Van Moorter, B., Cargnelutti, B., Angibault, J., Lourtet, B., Merlet, J., Ladet, S., and Hewison, A. (2011). Landscape composition influences roe deer habitat selection at both home range and landscape scales. *Landscape Ecology*. 26: 999-1010.

Moyer, M., McCown, W. and Oli, M. (2007). Factors influencing home-range size of female Florida black bears. *Journal of Mammalogy*. 88: 468-476.

Musiani, M., Anwar, Sk. M., McDermid, G., Hebblewhite, M. and Marceau, D. (2010). How humans shape wolf behavior in Banff and Kootenay National Parks, Canada. *Ecological Modelling*. 221: 2374-2387.

Naughton-Treves, L., Holland, M. and Brandon, K. (2005). The role of protected areas in conserving biodiversity and sustaining local livelihoods. *Annual Review of Environmental Resurces*. 30: 219-252.

Nicholson, J. and van Manen, F. (2009). Using occupancy models to determine mammalian responses to landscape changes. *Integrative Zoology*. 4: 232-239.

Nikula, A., Heikkinen, S. and Helle, E. (2004). Habitat selection of adult moose *Alces alces* at two spatial scales in central Finland*.* *Wildlife Biology*. 10: 121-135.

Northrup, J., Pitt, J., Muhly, T., Stenhouse, G., Musiani, M., and Boyce, M. (2012). Vehicle traffic shapes grizzly bear behaviour on a multiple-use landscape. *Journal of Applied Ecology*. 49: 1159-1167.

Oakleaf, J., Murray, D., Oakleaf, J., Bangs, E., Mack, C., Smith, D., Fontaine, J., Jimenez, M., Meier, T. and Niemeyer, C. (2006). Habitat selection by recolonizing wolves in the northern Rocky Mountains of the United States. *Journal of Wildlife Management*. 70 (2): 554-563.

Olsson, M., Widen, P., and Larkin, J. (2008). Effectiveness of a highway overpass to promote landscape connectivity and movement of moose and roe deer in Sweden. *Landscape and Urban Planning*. 85: 133-139.

Ontario Parks. (2013). *Ontario Ministry of Natural Resources*. http://www.ontarioparks.com/english/

Parks Canada. (2013). *National parks of Canada: National parks system*. http://www.pc.gc.ca/progs/np-pn/pr-sp/index_e.asp

Patterson, B., Quinn, N., Becker, E. and Meier, D. (2004). Estimating wolf densities in forested areas using network sampling of tracks in snow. *Wildlife Society Bulletin*. 32 (3): 938-947.

Piccolo, B., Hollis, K., Warner, R., Van Deelen, T., and Etter, D. (2000). Variation of white-tailed deer home ranges in fragmented urban habitats around Chicago, Illinois. *Wildlife Damage Management Conferences Proceedings*. 351-356.

Provincial Parks and Conservation Reserves Act. (2006). Ontario Parks.

Puttock, G., Shakotko, P., and Rasaputra, J. (1996). An empirical habitat model for moose, *Alces alces*, in Algonquin Park, Ontario. *Forest Ecology and Management*. 81: 169-178.

Quinn, G. and Keough, M. (2002). *Experimental Design and Data Analysis for Biologists*. Cambridge: Cambridge University Press.

Quinn, C., Williams, D., and Porter, W. (2013). Landscape structure influences space use by white-tailed deer. *Journal of Mammalogy*. 94: 398-407.

R Core Team (2012). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. ISBN 3-900051-07-0, URL http://www.R-project.org/.

Ritters, K. and Wickham, J. (2003). How far to the nearest road? *Front Ecol Environ*. 1: 125-129.

Roever, C., Boyce, M., and Stenhouse, G. (2008). Grizzly bears and forestry I: Road vegetation and placement as an attractant to grizzly bears. *Forest Ecology and Management*. 256: 1253-1261.

Roger, E., Bino, G., and Ramp, D. (2012). Linking habitat suitability and road mortalities across geographic ranges. *Landscape Ecology*. DOI 10.1007/s10980-012-9769-5.

Roger, R., Laffan, S., and Ramp, D. (2011). Road impacts a tipping point for wildlife populations in threatened landscapes. *Population Ecology*. 53: 215-227.

SARA. (2013). The eastern wolf of La Mauricie National Park of Canada. *Parks Canada: Species at Risk*. http://www.pc.gc.ca/nature/eep-sar/itm5/eep-sar5f.aspx

Sargent, R. and Labisky, R. (1995). Home range of male white-tailed deer in hunted and non-hunted populations. *Proceedings of the Annual Conference of Southeast Association of Fish and Wildlife Agencies*. 49: 389-398.

SBAA. (2005). Eastern wolf: Wolf research in Algonquin Provincial Park. *The Science Behind Algonquin's Animals*. http://www.sbaa.ca/projects.asp?cn=314

Schrecengost, J., Kilgo, J., Ray, H., and Miller, K. (2009). Home range, habitat use and survival of coyotes in western South Carolina. *The American Midland Naturalist*. 162: 346-355.

Selva, N., Kreft, S., Kati, V., Schluck, M., Jonsson, B., Mihok, B., Okarma, H., and Ibisch, P. (2011). Roadless and low-traffic areas as conservation targets in Europe. *Environmental Management*. 48: 865-877.

Shanley, C., Kofinas, G., and Pyare, S. (2013). Balancing the conservation of wildlife habitat with subsistence hunting access: A geospatial-scenario planning framework. *Landscape and Urban Planning*. 115: 10-17.

Shepard, D., Kuhns, A., Dreslik, M., and Phillips, C. (2007). Roads as barriers to animal movement in fragmented landscapes. *Animal Conservation*. 11: 288-296.

Sherwood, B., Cutler, D., and Burton, J. (Eds.). (2002). *Wildlife and Roads: The Ecological Impact*. London: Imperial College Press.

Simard, J. and Fryxell, J. (2003). Effects of selective logging on terrestrial small mammals and arthropods. *Canadian Journal of Zoology*. 81: 1318-1326.

Smith, T. and Smith, R. (2009). *Elements of ecology* (7^{th} Ed.). San Francisco, CA: Pearson Benjamin Cummings.

StatSoft Electronic Statistics Textbook. (2013). *General Linear Models (GLM)*. https://www.statsoft.com/textbook/general-linear-models/

Stenhouse, G., Latour, P., Kutny, L., MscLean, N. and Glover, G. (1995). Productivity, survival, and movements of female moose in a low-density population, Northwest Territories, Canada. *Arctic*. 48: 57-62.

Thompson, I., Davidson, I., O'Donnell, S., and Brazeau, F. (1989). Use of track transects to measure the relative occurrence of some boreal mammals in uncut forest and regeneration stands. *Canadian Journal of Zoology*. 67: 1816-1823.

Tozer, D., Burke, D., Nol, E., and Elliot, K. (2012). Managing ecological traps: Logging and sapsucker nest predation by bears. *The Journal of Wildlife Management*. 76: 887-898.

Trombulak, S. and Frissell, C. (2000). Review of ecological effects of roads on terrestrial and aquatic communities. *Conservation Biology*. 14: 18-30.

van der Ree, R. Jager, J., van der Grift, E., and Clevenger, A. (2011). Effects of roads and traffic on wildlife populations and landscape function: Road ecology is moving toward larger scales. *Ecology and Society*. 16: 48-57.

Varman, K. and Sukumar, R. (1995). The line transect method for estimating densities of large mammals in a tropical deciduous forest: An evaluation of models and field experiments. *Journal of Bioscience*. 20(2): 273-287.

Vucetich, J., Peterson, R. and Waite, T. (1997). Effects of social structure and prey dynamics on extinction risk in gray wolves. *Conservation Biology*. 11 (4): 957-965.

Ward, J., Beharrell, N., Fanning, E., Howell, K., and Ward, J. (Eds.). (2004). Frontier Tanzania: Savanna biological research methods manual. *Frontier Tanzania Environmental Research Report 104*. The society for Environmental Exploration, UK and the University of Dar es Salaam, Tanzania.

Way, J., Ortega, I. and Auger, P. (2002). Eastern coyote home range, territoriality, and sociality on urbanized Cape Cod. *Northeast Wildlife*. 57: 1-18.

Williams, D., Quinn, A., and Porter, W. (2011). Landscape effects on scales of movement by white-tailed deer in an agricultural-forest matrix. *Landscape Ecology*. 26

Witt, J., Webster, C., Froese, R., Drummer, T., and Vucetich, J. (2012). Scale-dependent drivers of ungulate patch use along a temporal and spatial gradient of snow depth. *Canadian Journal of Zoology*. 90:972-983.

Wooding, J. and Hardisky, T. (2001). Home range, habitat use, and mortality of black bears in North-central Florida. *International Conference on Bear Research and Management*. 9: 349-356.

Woodroffe, R. and Ginsberg, J. (1998). Edge effects and the extinction of populations inside protected areas. *Science*. 280: 2126-2128.

Worboys, G., Francis, W., and Lockwood, M. (Eds.). (2010). *Connectivity Conservation Managament: A Global Guide*. Washington DC: Earthscan.

Y2Y. (2013). *Yellowstone to Yukon Conservation Initiative*. http://y2y.net/

Zuur, A., Leno, E., and Elphick, C. (2010). A protocol for data exploration to avoid common statistical problems. *Methods in Ecology and Evolution*. 1: 3-14.

6.0 APPENDICES

Table 17. Landscape level data on three different buffer scales on the six primary transects in Algonquin Provincial Park.

Primary/ Buffer	Road Density (km/km^2)	Forest (%)	Water (%)	Mean Ruggedness (m)
$130km^2$				
1	0.57	79.32	9.44	46.91
2	0.72	78.53	12.82	45.75
3	1.14	76.48	11.56	49.42
4	1.54	83.83	6.27	32.89
5	1.46	81.79	5.60	32.81
6	0.85	80.64	11.43	43.16
$80km^2$				
1	0.59	79.67	7.62	46.58
2	0.73	78.35	12.70	46.07
3	1.09	78.23	9.53	49.73
4	1.57	85.25	5.26	33.39
5	1.46	85.90	5.25	32.45
6	0.88	76.49	12.27	41.78
$40km^2$				
1	0.73	83.19	6.75	45.69
2	0.91	76.57	12.96	46.08
3	1.05	82.45	4.90	52.62
4	1.25	95.55	5.59	33.40
5	1.29	87.12	4.79	31.44
6	0.90	73.46	15.39	40.63

Table 18. Landscape level data on three different buffer scales on the six branch transects in Algonquin Provincial Park.

Branch/ Buffer	Road Density (km/km^2)	Forest (%)	Water (%)	Mean Ruggedness (m)
$130km^2$				
1	0.59	78.50	10.37	47.49
2	0.59	80.79	13.07	43.05
3	1.22	89.50	8.77	52.84
4	1.04	90.88	5.62	33.59
5	0.64	88.49	4.37	36.17
6	0.86	81.16	10.12	41.26
$80km^2$				
1	0.64	82.07	9.53	47.93
2	0.61	83.59	10.95	44.08
3	1.19	86.30	6.94	53.96
4	0.96	92.73	4.35	34.34
5	0.64	91.00	4.18	35.68
6	0.96	86.23	5.45	42.79
$40km^2$				
1	0.70	84.00	9.21	47.34
2	0.68	85.86	9.11	44.96
3	1.16	78.11	7.40	54.91
4	0.73	90.74	5.13	33.73
5	0.58	87.34	4.28	33.34
6	0.84	88.52	3.46	42.78

Table 19. Total individuals count by species on three repeated observations of the six transects in Algonquin Provincial Park (P = primary logging road and B = branch logging road).

	Transect 1		Transect 2		Transect 3		Transect 4		Transect 5		Transect 6	
Species	P	B	P	B	P	B	P	B	P	B	P	B
Moose	9	12	8	12	7	7	4	4	7	9	6	9
Deer	3	2	3	2	4	4	3	6	8	5	4	0
Canine	0	1	1	2	2	0	2	1	1	1	0	0
Bear	2	0	0	0	0	0	0	1	0	3	0	3
Total	14	15	12	16	13	11	9	13	16	18	10	12
Moose	8	7	3	9	2	1	3	1	3	1	2	5
Deer	2	0	0	0	2	1	1	3	6	3	1	0
Canine	0	0	0	5	0	1	1	1	1	0	3	6
Bear	0	6	1	12	0	1	0	1	1	2	0	7
Total	10	13	4	26	4	4	5	6	11	6	7	18
Moose	4	5	5	8	5	4	2	2	1	2	4	5
Deer	1	0	1	1	4	0	2	3	4	3	4	0
Canine	0	0	0	0	1	1	0	1	1	2	1	1
Bear	0	6	0	5	0	0	0	0	0	0	0	3
Total	5	11	6	14	10	5	4	6	7	7	9	9

Table 20. Counts of the types of evidence collected on the six transects with three repeats (P = primary logging road and B = branch logging road).

	Transect 1		Transect 2		Transect 3		Transect 4		Transect 5		Transect 6	
Evidence	P	B	P	B	P	B	P	B	P	B	P	B
Tracks	10	12	12	16	13	11	8	8	15	14	11	8
Scat	4	3	0	0	0	0	1	4	1	4	0	4
Other	0	0	0	0	0	0	0	1	0	0	0	0
None	0	0	0	0	0	0	3	1	1	0	3	2
Total	14	15	12	16	13	11	12	14	17	18	14	14
Tracks	9	7	3	10	4	3	4	3	9	5	4	3
Scat	0	7	1	16	0	1	1	3	2	1	1	15
Other	0	0	0	0	0	0	0	0	0	0	2	0
None	2	3	7	2	8	5	7	8	3	6	5	3
Total	11	17	11	28	12	9	12	14	14	12	12	21
Tracks	5	5	6	9	9	4	4	5	6	5	9	4
Scat	0	6	0	5	1	1	0	1	1	2	0	4
Other	0	0	0	0	0	0	0	0	0	0	0	1
None	6	4	5	3	4	4	7	6	5	6	4	7
Total	11	15	11	17	14	9	11	12	12	13	13	16

Table 21. Counts of observations with ditches present or not over the three repeated surveys of six transects (P = primary logging road and B = branch logging road).

	Transect 1		Transect 2		Transect 3		Transect 4		Transect 5		Transect 6	
Ditches	P	B	P	B	P	B	P	B	P	B	P	B
Yes	7	9	3	7	6	3	8	3	2	4	3	6
No	7	6	9	9	7	8	4	11	15	14	11	8
Total	14	15	12	16	13	11	12	14	17	18	14	14
Yes	4	3	3	5	8	4	7	1	1	4	5	5
No	7	14	8	23	4	5	5	13	13	8	7	16
Total	11	17	11	28	12	9	12	14	14	12	12	21
Yes	2	1	2	0	4	6	4	0	2	5	7	5
No	9	14	9	17	10	3	7	12	10	8	6	11
Total	11	15	11	17	14	9	11	12	12	13	13	16

Table 22. Counts of the different types of vegetation observed on the six transects with the three repeats (P = primary logging road and B = branch logging road).

	Transect 1		Transect 2		Transect 3		Transect 4		Transect 5		Transect 6	
Vege Type	P	B	P	B	P	B	P	B	P	B	P	B
Forest	12	15	5	14	11	9	11	14	8	11	12	12
Marsh	0	0	0	0	2	0	0	0	0	3	0	0
Forest/Marsh	2	0	0	0	0	0	1	0	2	4	0	0
Forest/Open	0	0	1	0	0	1	0	0	0	0	0	0
Forest/Lake	0	0	3	1	0	0	0	0	5	0	0	0
Lake/Marsh	0	0	2	1	0	0	0	0	0	0	0	0
Forest/River	0	0	0	0	0	0	0	0	2	0	0	0
Forest/Rockface	0	0	0	0	0	0	0	0	0	0	2	0
Lake	0	0	1	0	0	0	0	0	0	0	0	0
Open	0	0	0	0	0	1	0	0	0	0	0	2
Total	14	15	12	16	13	11	12	14	17	18	14	14
Forest	10	11	6	12	9	5	8	5	13	8	9	15
Marsh	0	0	0	0	1	0	0	0	0	1	0	0
Forest/Marsh	0	0	1	0	1	0	3	1	0	3	0	1
Forest/Open	0	1	0	5	0	3	1	3	0	0	2	1
Forest/Lake	1	0	4	8	0	0	0	0	1	0	0	0
Lake/Marsh	0	0	0	3	0	0	0	0	0	0	0	0
Forest/River	0	0	0	0	0	0	0	0	0	0	0	0
Forest/Rockface	0	0	0	0	0	0	0	0	0	0	0	0
Lake	0	0	0	0	0	0	0	0	0	0	0	0
Open	0	5	0	0	1	1	0	5	0	0	1	4
Total	11	17	11	28	12	9	12	14	14	12	12	21
Forest	10	10	8	8	9	3	11	8	10	8	12	15
Marsh	0	0	0	0	2	0	0	0	0	0	0	0
Forest/Marsh	0	1	0	2	1	1	0	1	0	4	0	0
Forest/Open	1	3	0	2	2	3	0	3	0	1	0	0
Forest/Lake	0	0	2	2	0	1	0	0	1	0	0	0
Lake/Marsh	0	0	0	3	0	0	0	0	0	0	0	0
Forest/River	0	0	0	0	0	0	0	0	0	0	0	0
Forest/Rockface	0	0	0	0	0	0	0	0	0	0	1	0
Lake	0	0	1	0	0	0	0	0	0	0	0	0
Open	0	1	0	0	0	1	0	0	1	0	0	1
Total	11	15	11	17	14	9	11	12	12	13	13	16

Table 23. Counts of observations of the presence, partial presence, and absence of canopy cover on the six transects on the three repeated surveys (P = primary logging road and B = branch logging road).

	Transect 1		Transect 2		Transect 3		Transect 4		Transect 5		Transect 6	
Canopy Cover	P	B	P	B	P	B	P	B	P	B	P	B
Yes	1	0	0	1	0	0	0	1	0	1	2	4
Slight	5	1	3	4	0	1	1	7	6	7	5	5
No	8	14	9	11	13	10	11	6	11	10	7	5
Total	14	15	12	16	13	11	12	14	17	18	14	14
Yes	4	1	0	4	0	0	0	2	0	0	2	1
Slight	5	4	4	5	0	0	2	2	0	1	1	0
No	2	12	7	19	12	9	10	10	14	11	9	20
Total	11	17	11	28	12	9	12	14	14	12	12	21
Yes	5	4	1	1	0	0	0	3	1	0	2	3
Slight	0	5	5	5	1	3	1	2	0	1	3	7
No	6	6	5	11	13	6	10	7	11	12	8	6
Total	11	15	11	17	14	9	11	12	12	13	13	16

Table 24. Counts of observations in close proximity to water on three repeated surveys of the six transects (P = primary logging road and B = branch logging road).

	Transect 1		Transect 2		Transect 3		Transect 4		Transect 5		Transect 6	
Water	P	B	P	B	P	B	P	B	P	B	P	B
Yes	3	2	9	6	2	0	2	0	9	9	1	0
No	11	13	3	10	11	11	10	14	8	9	13	14
Total	14	15	12	16	13	11	12	14	17	18	14	14
Yes	1	1	5	14	2	1	4	1	1	5	3	2
No	10	16	6	14	10	8	8	13	13	7	9	19
Total	11	17	11	28	12	9	12	14	14	12	12	21
Yes	1	2	3	7	4	3	1	1	2	5	1	1
No	10	13	8	10	10	6	10	11	10	8	12	15
Total	11	15	11	17	14	9	11	12	12	13	13	16

Table 25. Counts of observations in proximity to trails and branching roads (P = primary logging road and B = branch logging road).

	Transect 1		Transect 2		Transect 3		Transect 4		Transect 5		Transect 6	
Trails	P	B	P	B	P	B	P	B	P	B	P	B
Yes	2	0	2	2	0	1	1	0	0	0	0	0
No	12	15	9	13	12	10	11	12	17	18	13	12
Other	0	0	1	1	1	0	0	2	0	0	1	2
Total	14	15	12	16	13	11	12	14	17	18	14	14
Yes	0	0	0	0	1	0	0	0	0	0	0	2
No	10	14	10	26	10	7	11	7	12	12	11	17
Other	1	3	1	2	1	2	1	7	2	0	1	2
Total	11	17	11	28	12	9	12	14	14	12	12	21
Yes	0	0	1	0	2	0	0	0	2	0	1	0
No	9	15	7	14	10	7	8	11	10	12	11	15
Other	2	0	3	3	2	2	3	1	0	1	1	1
Total	11	15	11	17	14	9	11	12	12	13	13	16

Table 26. Total counts of the aggregate types found on the branch and primary roads over the three repeated surveys (P = primary logging road and B = branch logging road).

	Transect 1		Transect 2		Transect 3		Transect 4		Transect 5		Transect 6	
Aggregate	P	B	P	B	P	B	P	B	P	B	P	B
Gravel	14	9	4	1	0	7	0	5	0	0	0	1
Sand	0	0	6	13	0	2	0	0	0	0	0	0
Gravel Pit	0	0	0	2	0	0	0	0	0	0	0	0
Gravel/Grass	0	6	0	0	0	0	0	0	0	0	0	0
Gravel/Sand	0	0	2	0	13	0	12	5	17	18	14	12
Woodchip	0	0	0	0	0	2	0	0	0	0	0	0
Dirt/Woodchip	0	0	0	0	0	0	0	1	0	0	0	0
Soil	0	0	0	0	0	0	0	3	0	0	0	0
Rocky/Compact	0	0	0	0	0	0	0	0	0	0	0	1
Total	14	15	12	16	13	11	12	14	17	18	14	14
Gravel	0	7	0	2	0	3	0	0	0	0	0	0
Sand	0	0	0	2	0	0	0	1	0	0	0	0
Gravel Pit	0	0	0	0	0	0	0	0	0	0	0	0
Gravel/Grass	0	0	0	0	0	0	0	0	0	0	0	0
Gravel/Sand	11	10	11	24	12	4	12	7	14	12	12	21
Woodchip	0	0	0	0	0	2	0	5	0	0	0	0
Dirt/Woodchip	0	0	0	0	0	0	0	0	0	0	0	0
Soil	0	0	0	0	0	0	0	0	0	0	0	0
Rocky/Compact	0	0	0	0	0	0	0	1	0	0	0	0

Total	11	17	11	28	12	9	12	14	14	12	12	21
Gravel	0	0	0	0	0	1	0	4	1	0	0	3
Sand	0	0	0	0	0	0	0	0	0	0	0	0
Gravel Pit	0	0	0	0	0	0	0	0	0	0	0	0
Gravel/Grass	0	0	0	0	0	0	0	0	0	0	0	0
Gravel/Sand	11	12	10	17	14	7	11	3	11	13	13	13
Woodchip	0	0	0	0	0	1	0	3	0	0	0	0
Dirt/Woodchip	0	0	1	0	0	0	0	2	0	0	0	0
Soil	0	0	0	0	0	0	0	0	0	0	0	0
Rocky/Compact	0	3	0	0	0	0	0	0	0	0	0	0
Total	11	15	11	17	14	9	11	12	12	13	13	16

Table 27. The mean, median and mode of road widths of the primary and branch logging roads in Algonquin Provincial Park over the three surveys of observations (P = primary logging road and B = branch logging road).

	Transect 1		Transect 2		Transect 3		Transect 4		Transect 5		Transect 6	
Measurements	P	B	P	B	P	B	P	B	P	B	P	B
Mean	6.25	4.5	5.96	8.84	9.23	6.41	9.54	7.14	7.21	6.44	7	4.64
Median	6.75	4	5.25	5	9	6	9.25	5	7	6.5	7	4.5
Mode	7	4, 6	4.5	5	9	4, 4.5, 6, 9	9	5	7	6, 6.5	7	4.5
Mean	4	3.47	5.41	3.36	8	6.17	7.87	9.11	5.39	5.54	6.08	3.52
Median	4	3	4	3	8	6	8	4.25	5.5	5.5	6	3.5
Mode	4	3	4	3	8	6	8	3.5	5	5.5	6	3.5
Mean	4.91	3.63	4.86	4.12	8.25	5.78	8.18	6.17	5.75	5.77	6.46	4.09
Median	5	3	4	3.5	8	6	8	4	5.75	5.5	6.5	4
Mode	3, 5	3	3.5	3.5	8	7.5	8	4	5.5, 6	5.5	6.5	3.5

Table 28. The proportions of evidence found across the total primary and branch logging roads in Algonquin Provincial Park.

Scat Presence	Primary	Branch
90 Total	13	77
	14.44%	85.56%
Track Presence	Primary	Branch
273 Total	141	132
	51.65%	48.35%
Other Presence	Primary	Branch
4 Total	2	2
	50.00%	50.00%
None	Primary	Branch
130 Total	70	60
	53.85%	46.15%