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Winter home range sizes of female woodland caribou in the boreal forest of Northwestern Ontario

Romyn, Christina

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(Source: Natural Resources Canada)

By

Christina Romyn

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Major Advisor	Second Reader

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ABSTRACT

Romyn, C. Winter Home Range Sizes of Female Woodland Caribou in the Boreal Forest of Northwestern Ontario. NRMT 4030. 53pp.

Keywords: conservation, disturbance, home range, minimum convex polygon (MCP), northwestern Ontario, woodland caribou

Woodland caribou (*Rangifer tarandus caribou* Gmelin) are listed as "threatened" under the Canadian Species at Risk Act. Fourteen ranges occur within the continuous distribution of caribou in Ontario and have been studied using Global Positioning System (GPS) tracking technology. The Ontario Ministry of Natural Resource and Forestry (OMNRF) employs the use of Argos GPS collars to track caribou movements throughout the province. The purpose of this study was to examine the winter home range sizes of caribou in both a managed and unmanaged forest in northwestern Ontario and to relate winter home range sizes the level of disturbance in the area. Home range sizes were estimated from GPS collaring data using a 95% minimum convex polygon computed using the adehabitatHR package in R statistical programming. Home range sizes were evaluated using simple linear regressions with disturbance as the dependant variable. Home range sizes were most strongly negatively correlated with natural and anthropogenic disturbance in the entire study area ($R^2 = 0.239$). In the unmanaged forest, the level of disturbance was low (20%) home range sizes were large (1580 $km^2 \pm 1374$ km^2). Conversely, where disturbance was high (42%), especially at the species' southern range limit, home ranges were low (408 $km^2 \pm 311$ km^2). In the boreal forest, female caribou may restrict their ranges amid anthropogenic disturbances. Forest harvesting creates small habitat patches that may serve as ecological traps for caribou and increase the risk of predator detection. Therefore, smaller home ranges may serve as an indicator of habitat loss for caribou.

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INTRODUCTION

The area that is inhabited by an animal or group of animals during a specific period is defined as their home range (Burt 1943). Many ecologists have studied home range sizes of animals to obtain an understanding of the intraspecific variation in their sizes (Borger et al. 2006). Intraspecific variation in home range sizes may provide insight into the constraints owing to the surrounding habitat alterations (Beauchesne et al. 2014). Disturbances in forested regions have altered habitat conditions for many wildlife species and some of the impacts may include altered behaviour patterns, decreased abundance and extirpation from highly disturbed areas (Donovan et al. 2017; Beauchesne et al. 2014). Thus, studying and understanding space use of mobile species is crucial for their conservation in the face of accelerating habitat loss (Wilson et al. 2019).

In Canada, woodland caribou (*Rangifer tarandus caribou* (Gmelin) (hereafter referred to as caribou), are listed as a threatened species (COSEWIC 2000) and have disproportionately large home range sizes in comparison to other mammals because they move long distances into habitats to support successful reproduction, calf-rearing, and foraging depending on the season (Wilson et al. 2019; Ferguson and Elkie 2004a). The forest-dwelling ecotype of caribou have been found to have significant within-species differences among populations throughout Canada (Wilson et al. 2019). Variations in home range sizes may be attributed to the habitat alterations from forestry activities and other disturbances (Beauchesne et al. 2014). Previous studies (Courtois et al. 2007; Beauchesne et al. 2014; Lesmerieses et al. 2013; Donovan et al. 2017) suggest that caribou will initially expand their home ranges to avoid disturbances; however, as the

level of fragmentation increases on the landscape, caribou can become restricted in smaller patches of habitat, decreasing their home range size. Consequently, individuals confined in smaller home ranges may be forced into ecological traps and easily detected by predators. The current disturbance levels in the boreal forest and their cumulative amount on the landscape are a major threat to the conservation of caribou populations (Lesmerieses et al. 2013).

The primary objective of this thesis is to examine the winter home range sizes of caribou in both a managed and unmanaged forest in northwestern Ontario. The second objective of this thesis is to relate the level of disturbance to the winter home range size. Currently, forestry operations only occur in the southern portion of the boreal forest, however, they are continuously expanding northward into the southern fringe of the caribou range. Consequently, the southern portion of northwestern Ontario's boreal forest (managed forest) has undergone significant alterations from anthropogenic disturbances, such as forest harvesting, in comparison to the northern portion (unmanaged forest), which is virtually free from anthropogenic disturbances, however, has undergone some natural disturbances (OMNRF 2014b, 2014c, 2014d). Thus, suitable habitat for caribou is reduced, altered, or fragmented by forest harvesting in managed forests (Beauchesne et al. 2014; Donovan et al. 2017). Therefore, it is hypothesized that winter home range size will be smaller in the managed forest than in the unmanaged forest. It is futher hypothesized that winter home range size and the level of disturbance is correlated. Lastly, the results of this study will provide the information necessary to understand the intraspecific variation in caribou home range sizes to help elucidate critical population limiting factors as well as aid in conservation of this species.

LITERATURE REVIEW

WOODLAND CARIBOU IN ONTARIO

Caribou currently persist across much of northern Ontario, with isolated populations as far south as Lake Superior (OMNRF 2014a). The continuous distribution includes a region from the Quebec border to the Manitoba border, extending southward towards Sioux Lookout, Geraldton, Hearst and Cochrane, and extending northwards to the northern limit of the boreal forest. The discontinuous distribution includes a region south of Geraldton towards Lake Superior and extends westward towards Nipigon across the coast eastwards towards Wawa. The discontinuous distribution also encompasses islands adjacent to the shore of Lake Superior such as the Slate Islands, Pic Island and Michipicoten Island (Figure 1).

In 2014, the OMNRF adopted a range-based approach to caribou management that identified 14 ranges within the continuous distribution of caribou in Ontario (OMNRF 2014a). The northern region of the continuous distribution is delineated by the Swan, Spirit, Kinloch, Ozhiski, Missisa, and James Bay ranges. The southern region of the continuous distribution is delineated by the Berens, Sydney, Churchill, Brightsand, Nipigon, Pagwachuan and Kesagami ranges (Figure 1).

Figure 1. Woodland caribou ranges within Ontario.

Source: OMNRF (2014b)

HOME RANGES

The area over which is inhabited by an animal or group of animals during a specific period is defined as their home range (Burt 1943). According to Borger et al. (2006) home ranges have been studied by many ecologists to obtain an understanding of the intraspecific variation in their sizes. Moreover, a recent study conducted by Wilson et al. (2009) on the forest-dwelling ecotype of caribou found significant within-species differences in home range sizes among the populations throughout Canada. Variations in home range sizes may be attributed to habitat alterations from forestry activities and other anthropogenic disturbances (Beauchesne et al. 2014). In addition, caribou may restrict their movements and home ranges in response to the level of disturbance on the landscape (Beauchesne et al. 2014).

Several studies suggest that caribou will initially expand their home ranges to avoid disturbances; however, as the level of fragmentation increases on the landscape, caribou can become restricted to smaller patches of habitat, decreasing their home range size (Courtois et al. 2007; Beauchesne et al. 2014; Lesmerieses et al. 2013; Donovan et al. 2017). Consequently, individuals confined to smaller home ranges may be forced into ecological traps and easily detected by predators (Lesmerieses et al. 2013). Furthermore, a number of variables, such as reproductive status, forage, population abundance, predation, ambient temperature and the availability of cover may also influence caribou home range size (Brown et al. 2003; Wilson et al. 2019). Caribou have disproportionally large home range sizes in comparison to other mammals because they move long distances into habitats to support successful reproduction, calf-rearing, and seasonally-dependent foraging. (Wilson et al. 2019; Ferguson and Elkie 2004a).

A limited number of studies have been conducted to examine the among-population variation in home range sizes of caribou. A recent study conducted by Wilson et al. (2019) studied 25 populations of the forest-dwelling ecotype of caribou in Canada and found significant among population variation in home range sizes. Of the 25 populations studied included 10 caribou ranges in Ontario. The home range sizes for the study conducted by Wilson et al. (2019) were obtained from the Integrated Range Assessments conducted by the Ontario Ministry of Natural Resources and Forestry for each range outlined in detail below. Several caribou in each range were collared and the points were used to calculate 95% minimum convex polygons to estimate annual home range sizes. The average annual home range size reported was 949 km^2 in the Brightsands Range, 633km^2 in the Churchill Range and 1307 km^2 in the Kinloch Range (OMNRF 2014b; 2014c; 2014d). Moreover, a two-year study in the Far North of Ontario reported the average winter home range size of the forest-dwelling ecotype of caribou as 2378 km^2 ± 667 km^2 in year 1 and 3,054km^2 ± 740 km^2 in year 2 (Berglund et al. 2014). Furthermore, caribou home range sizes in the Kinloch range were also found to be smaller in the east than the west and larger in the north than the south (OMNRF 2014d)..

Habitat Selection

Caribou in the boreal forest require large continuous undisturbed tracts of mature conifer forests dominated by jack pine (*Pinus banksiana* (Lamb.)) and black spruce (*Picea mariana* (Mill.) BSP)) (Brown et al. 2003; Ferguson and Elkie 2004a). These areas allow caribou to separate themselves from moose (*Alces alces* Clinton), white-tailed deer (*Odocoileus virginianus* Zimmermann), wolves (*Canus lupus* L.), and black bear (*Ursus americanus* Pallas) which prefer areas of early successional, mixed, or

deciduous forest (Cumming 1996; Bowman et al. 2010). In addition, caribou select habitat features that support successful reproduction, calf-rearing, provide summer or winter forage, and movement between habitat use areas (Ferguson and Elkie 2004a).

Several studies have been conducted using global positioning system (GPS) collaring data to define seasonal movement patterns of caribou. For example, Ferguson and Elkie (2004a) defined the different seasonal phases of movement in caribou using a statistical approach based on changes in rates of movement. The Ontario Ministry of Natural Resources and Forestry (OMNRF) categorizes caribou habitat into the following categories: nursery areas (May 1 to September 15), winter use areas (December 1 to March 31) and travel corridors (April and/or November). The above categories of habitat area are outlined in detail in the following sections.

Spring and Summer (Nursery) Habitat

During the calving and post-calving season female caribou disperse themselves on the landscape as a strategy to decrease encounter rates with predators (Bergerud 1985; Ferguson and Elkie 2004a). Female caribou will generally travel to isolated areas such as islands, shorelines, and peninsulas during the calving and post calving seasons to seek refuge and security (Carr et al. 2011). During the first 50 days following birth, calves are extremely vulnerable to mortality, predominately by predation (Pinard et al. 2012). However, by mid-summer, calves become more mobile and they begin to disperse throughout the nursery areas (Ferguson and Elkie 2004a). Carr et al. (2011) found that within nursery areas caribou tend to select areas with an abundance of groundcover vegetation, terrestrial lichens, lower shrub density and higher densities of mature conifer trees.

Winter Habitat

Caribou habitat selection in the winter is associated with forage availability and forest cover conditions. During the winter, lichen is the principal food source for caribou because it is an important source of carbohydrates (Schaefer and Pruitt 1991; Thompson et al. 2015). Some caribou may choose sites with specific lichen species, such as in northern British Columbia (BC) where Johnson et al. (2001) discovered that caribou frequently selected feeding sites across pine terraces with *Cladonia* spp. (Hill ex. P. Browne) and *Cladonia mitis*. Similarly, the primary late winter food source of caribou in Ontario is terrestrial lichens such as *Cladonia* spp. (Thompson et al. 2015). Winter areas selected by caribou have been found to have lower-than-average snow depths, which is believed to facilitate easier movement and easier access to ground lichens (Johnson et al. 2004). As such, caribou have been found to choose sites with greater canopy cover where snow depth is reduced and it is less energetically costly for them to move and crater (i.e. dig for forage) (Schaefer 1996). Areas with an abundance of lichen are also lower in deciduous browse, which consequently reduces the occurrence of other ungulate species such as moose and white-tailed deer (Bowman et al. 2010).

Travel Corridor Habitat

Migration between spring/summer habitat (nursery areas) and winter habitat are the caribou travel seasons. The forest management guidelines for Ontario by Racey et al. (1999) document that migration corridors used by caribou follow natural landscape features such as rivers, chains of lakes, eskers, or ridges. However, Ferguson and Elkie (2004b) found that, overall, caribou were more likely to avoid water and open areas while favouring conifer forests. Ferguson and Elkie (2004b) also found that caribou

avoided deciduous forests during the travel season because of the limited lichen forage availability as well as increased predation risk from wolves. However, a study in Alberta found that, while travelling, caribou select habitat that is less rugged, close to water, and near mature conifer forests (Saher and Schmiegelow 2005). Caribou are exceptional swimmers and perhaps use water to effectively escape from predators (OMNRF 2009). Lastly, there were no differences observed between habitat selection in the early winter and spring travel seasons where major movements occurred (Ferguson and Elkie 2004b).

IMPACTS OF ANTHROPOGENIC DISTURBANCES

Habitat loss and increases in predation are implicated in the decline of caribou populations in Canada (Viejou et al. 2018). Anthropogenic activities have assisted the decline of caribou through habitat loss and alteration, and by increasing human and predator access into caribou habitat (Cumming 1992). In addition, anthropogenic activities have expanded northward into the southern limits of caribou ranges in Ontario (Brown et al. 2003). Overall, anthropogenic activities have numerous direct and indirect impacts on caribou and are outlined below.

Increased Predation

The role of predation in limiting caribou populations has been well documented in the literature. The increased rate of predation, primarily by wolves, has been attributed to the alteration in forest composition and fragmentation due to forest harvesting (Johnson et al. 2004). In addition, caribou may be forced into ecological traps in the remaining habitat patches which make them more susceptible to predation

(Lesmerieses et al. 2013). Furthermore, the predation risk on harvested landscapes can increase significantly because post-harvesting succession creates habitat that is not only suitable but is preferred by other ungulate species of the boreal forest such as moose and white-tailed deer. Consequently, the densities of wolves may also increase in response to the increase in abundance of alternate prey species such as moose and white-tailed deer. In northern Ontario, Cumming and Beange (1993) speculated that wolf densities may have increased following harvesting and contributed to the decline in the population of caribou in the Cliff Lake area.

Furthermore, the ability of predators such as wolves to access caribou has been enhanced due to travel corridors being established in the form of logging roads. The use of roads by wolves leads to an increase in hunting efficiency and higher predation rates of caribou. A study conducted by James and Stuart-Smith (2000) in northeastern Alberta revealed that wolf-caused mortalities on caribou increased in proximity to linear features. Another study conducted by Polfus et al. (2011) found that mountain caribou in British Columbia tend to avoid roads, especially roads with a high level of traffic. Therefore, roads serve to fragment their habitat (Polfus et al. 2011). However, Viejou et al. (2018) found that female caribou in Ontario accounted for the increased vulnerability of their calves by avoiding roads, but those without calves did not.

Newton et al (2017) studied the selection of water and linear features by wolves over four years in three different study areas across northern Ontario. Although the study sites had a different degree of forestry activities and human disturbances, it was found that the selection of roads increased when there was a high density of roads on the landscape (Newton et al. 2017). Consequently, a high density of roads on the landscape resulted in a decline in the selection of natural linear features (Newton et al. 2017). A

study conducted by Bergerud and Elliot (1986) examined adult mortality and recruitment for three caribou populations in the interior of British Columbia and found that caribou cannot maintain their population numbers when wolf populations reach densities above 6.5 wolves per 1000 km^2. The main reason caribou cannot maintain recruitment when wolf populations are above this density is because they have a lower reproductive output than any other ungulate species in the boreal forest. Female caribou reach sexual maturity at 2.5 years of age, and generally, have only one calf per year (Skoog 1968; Bergerud 1971). Also, calves are highly susceptible to mortality from predators (Bergerud 1974).

Altered Movements, Avoidance and Displacement

Studies conducted on the impacts of anthropogenic activities have mainly been focused on disturbance avoidance behaviour which may lead to displacement of caribou. A study in southwestern Newfoundland found that caribou abundance increased further away from a mine site in all seasons, and avoided areas within 4 km of the mine (Weir et al. 2009). The study also found that within 6 km of the mine site, the number of caribou decreased as the mining activity progressed in the late winter, pre-calving and calving seasons. A study conducted by Carr et al. (2011) suggested a critical threshold for parturient caribou of 10 -15 km from disturbances and that disturbances be limited from the May – August calving and nursery period. Disturbances that may disrupt calving or nursery activities may displace caribou into unsuitable habitat, putting them at greater predation risk (Cumming and Beange 1993). Female exhibit a degree of fidelity to calving areas and tend to occupy the same general area within 10-20 km each year (Berglund et al. 2013) Moreover, the dispersal strategy by female caribou to avoid

detection by predators may be compromised by this forced aggregation, making them easier to find and capture (Dyer et al. 2001).

METHODS

STUDY AREA

The study area is approximately 70,000 km^2 and includes three caribou ranges; Brightsands (22,000 km^2), Churchill (21,300 km^2), and Kinloch (26,700 km^2) in the Boreal Shield ecoregion (Figure 2). These ranges are all typical of the boreal forest but are contrasted in terms of forest management. In Ontario, forestry activities are only permitted to occur on Crown lands within the area of undertaking under the *Environmental Assessment Act*, R.S.O. 1990. The Brightsands and Churchill ranges are located south of the area of undertaking, whereas, the Kinloch range is located north of the area of undertaking. The southern caribou ranges also have a higher level of anthropogenic disturbances than the northern ranges.

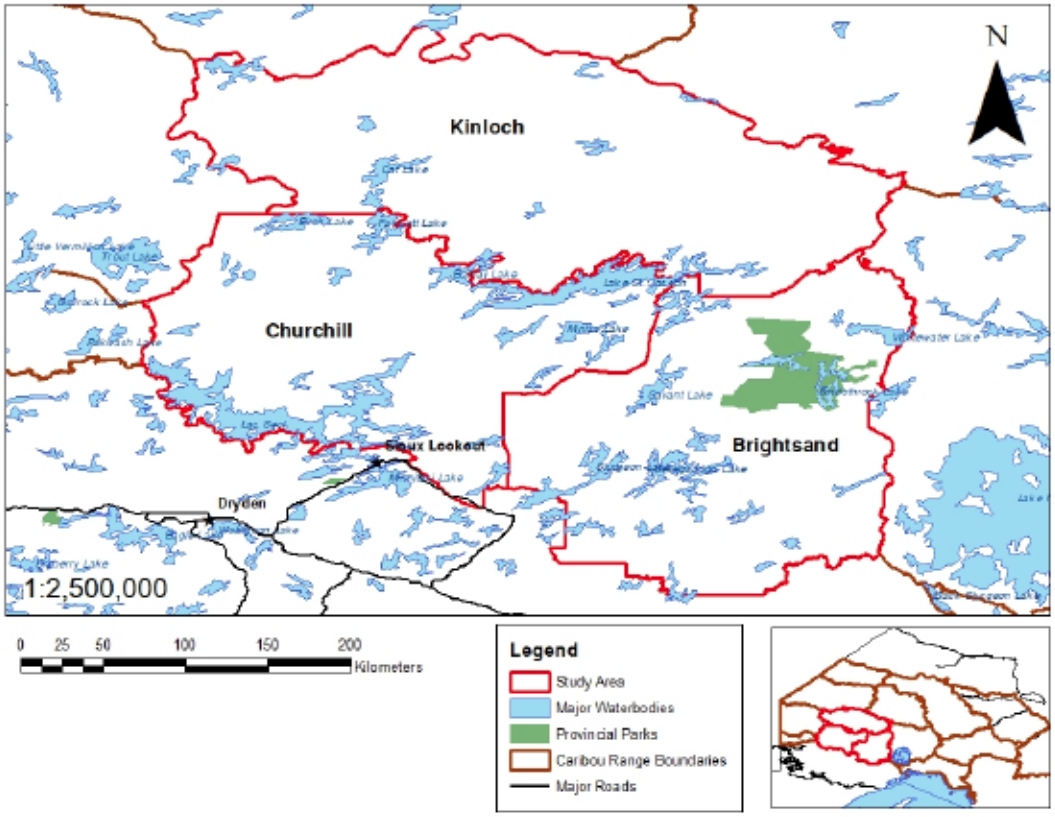

Figure 2. Map of the study area in northwestern Ontario.

The Brightsands range includes portions of the English River, Caribou, Black Spruce, Lake Nipigon, and Lac Seul Forest Management Units as well as a significant portion of Wabakimi Provincial Park (MNRF 2014 BS). The southern extent of the Brightsands Range is one of the southernmost extents for caribou occurrence within the continuous distribution in Ontario. The southern half of Brightsands the range is dominated by young immature forest and is heavily disturbed through a combination of natural and anthropogenic disturbances, including roads, harvest blocks, fire, and the railway. However, the northern half of the Brightsands range is dominated by large tracts of mature conifer and relatively free from anthropogenic disturbances such as timber harvest, roads, or infrastructure, particularly in Wabakimi Provincial Park. Although, some extensive natural disturbances such as wind and fire events have

occurred in the northern portion of the Brightsands range. The overall level of disturbance in the Brightsands Range is more than 40%, with the majority of the disturbance in the southern portion.

The Churchill range includes portions of the Caribou, Lac Seul and Trout Lake Forest Management Units. Many portions of the Churchill Range have had forest management activities influenced by various versions of caribou guidelines and a caribou habitat mosaic since 1992. The southern portion of the Churchill range has high densities of roads and disturbance levels. Whereas, the northern portion of the Churchill range exhibits lower levels of disturbance and has high concentrations of caribou. In addition, an aggressive fire regime has had a significant impact on the level of disturbance in the Churchill range. The overall level of disturbance is more than 40% and the disturbances are primarily in the southern, central and western portions of the Chuchill range.

The Kinloch Range is located north of the area of undertaking; therefore, no forestry activities are permitted to occur within the range. Three First Nation communities are located within the Kinloch range and a winter road that provides seasonal access to the communities from the town of Pickle Lake. The Kinloch range has large areas of older conifer forests because of past fire management strategies to suppress fires. However, natural disturbances are evenly distributed across the Kinloch range and anthropogenic disturbances are primarily limited to settlements, roads, utility lines, and some mining activity. The overall level of disturbance in the Kinloch range is approximately 20%.

DATA COLLECTION AND PREPARATION

A data sharing agreement was signed with the OMNRF to obtain previously collected caribou telemetry data (OMNRF 2014). Data from 28 female caribou inhabiting the study area were used for the purpose of this thesis. Of the 28 female caribou, 14 inhabited the area south of the area of undertaking and the other 14 inhabited the area north of the undertaking. For this study, the winter season was delineated with reference to the OMNRF general habitat description as December 1st to March 30th. Therefore, fixes outside the winter season were eliminated.

DATA ANALYSIS

Winter home range sizes were estimated using ninety-five percent (95%) minimum convex polygons (MCPs) calculated using the adehabitatHR package in R statistical programming (Appendix III R Script). The area of each individual MCP was calculated in ArcMap 10.5 using the calculate geometry tool. The 2015 Anthropogenic and Fire Disturbance Polygons obtained from Environment and Climate Change Canada (ECCC) were used to estimate the level of disturbance in each 95% MCP. To account for positional accuracy, the disturbance polygons and MCP's were buffered by 10 km. The disturbance shapefile (merged anthropogenic and fire) was clipped to the buffered MCPs. The area of disturbance and the area of the buffered MCP were calculated in ArcMap 10.5 using the calculate geometry tool. Lastly, the level of disturbance (%) was calculated using the following equation:

$$\% \text{ of disturbance} = \frac{area\ of\ disturbance}{area\ of\ buffered\ MCP} \qquad \text{Equation 1}$$

A two-tailed t-test was performed to compare winter home range sizes in the managed and unmanaged forest. In addition, simple linear regression analyses were performed on the managed and unmanaged forest as well as both forests combined to compare relationships between winter home range size and level of disturbance. All statistical analyses were tested using IBM SPSS 25. The statistical significance was determined at $\alpha = 0.025$ for all tests.

RESULTS

HOME RANGE ESTIMATION

The winter home range sizes for the 28-female caribou across the study area varied between 47 km^2 and 3526 km^2. The average home range size for caribou was 994 $km^2 \pm 1444$ km^2 (Table 1). However, the average winter home range sizes differed significantly for the managed and unmanaged forests ($t_{0.025/13}$, $t = 3.11$, $p = 0.007$) with the smaller winter home range sizes belonging to the managed forest. Caribou in the managed forest had an average home range size of 408 $km^2 \pm 311$ km^2, while caribou in the unmanaged forest had an average home range size of 1580 $km^2 \pm 1374$ km^2 (Table 1) (Figure 4). Overall, a considerable amount of variation was observed in the winter home range sizes of caribou in the unmanaged forest in comparison to the winter home range size of caribou in the managed forest. Figure 3 illustrates one individual caribou MCP.

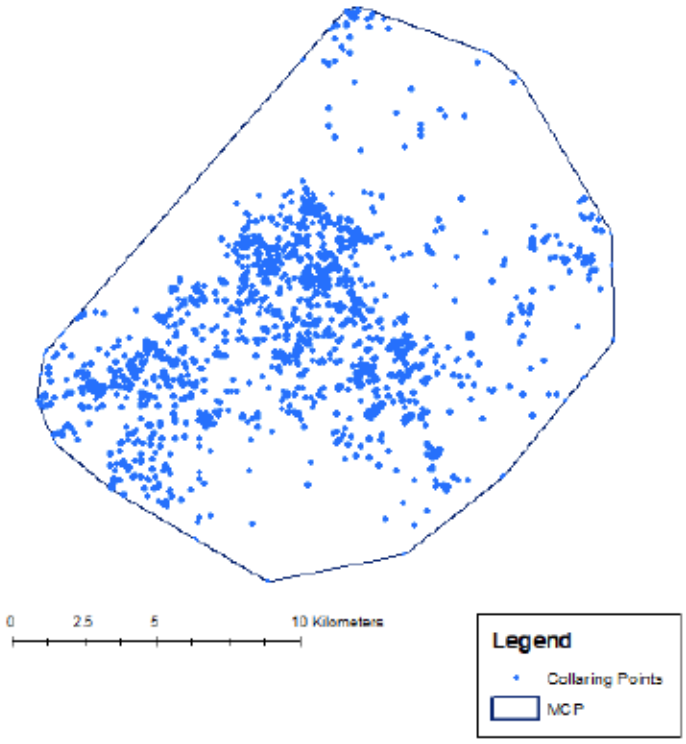

Figure 3. 95% MCP of one individual caribou in the Brightsand range.

Table 1. Summary of the average winter home range size for the managed forest, unmanaged forest, and the two forests combined.

Forest	Average (km^2)	Standard Deviation (km^2)
Managed	408	311
Unmanaged	1580	1374
Combined	994	1144

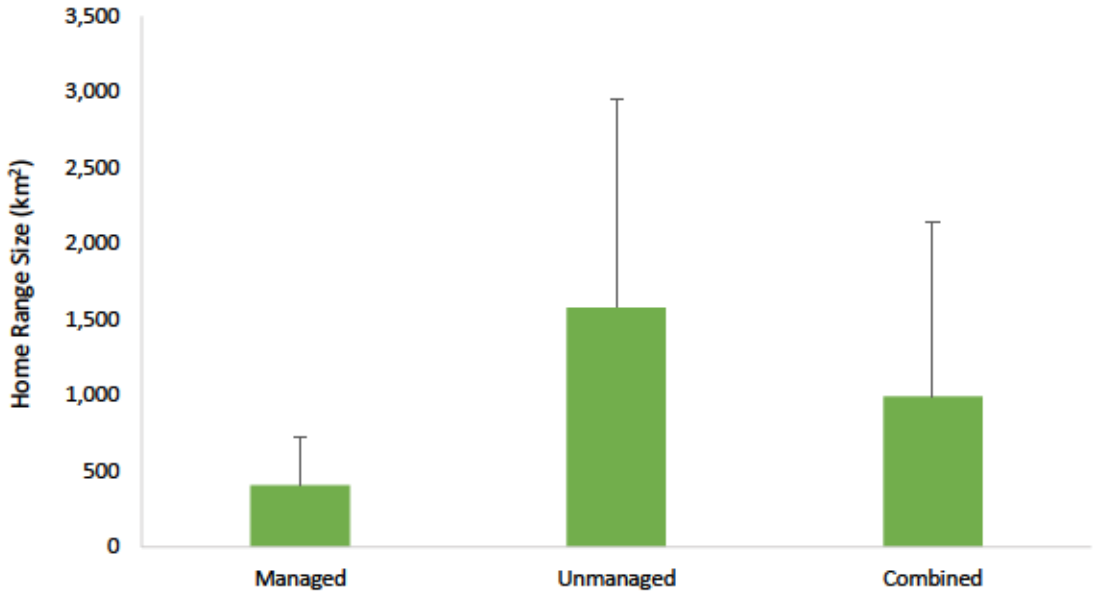

Figure 4. Caribou winter home range size (mean ± SD) in a managed forest, unmanaged forest and the two forests combined.

LEVEL OF DISTURBANCE

The level of disturbance (fire and anthropogenic) in each buffered MCP ranged from 12% to 61% across the study area and the average level of disturbance was approximately 31%. In the managed forest, the average level of disturbance (42%) was much higher than in the unmanaged forest (20%). Figure 5 illustrates a negative relationship between winter home range size and the level of disturbance in the study area, which was confirmed with a Pearson's correlation coefficient of 0.489 The linear regression also displayed a significant relationship between winter home range size and level of disturbance ($p < 0.05$). The R^2 value was 0.239, therefore, 23.9% of the

variation can be explained by the model containing only disturbance.

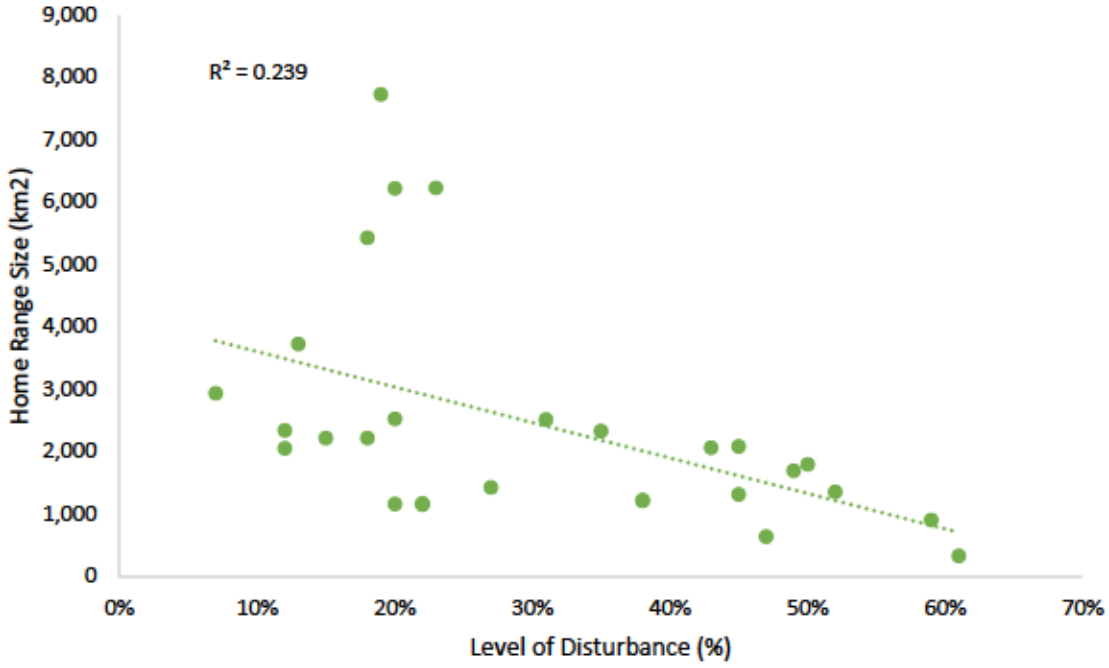

Figure 5. Linear regression of winter home range size as a function of level of disturbance in the study area ($y = -5682.7\ x + 4180$, $R2 = 0.239$, $P < 0.05$)

When comparing the relationship between winter home range size and the level of disturbance in the managed and unmanaged forests within the study area, no significant relationship was found ($p > 0.05$). The results of the linear regressions both revealed a negative. Table 2 shows the R^2 value for the managed forest (0.189) is higher than the unmanaged forest (0.030). Therefore, in the managed forest 18.9% of the variation can be explained by the model containing only disturbance, whereas, in the unmanaged, only 3% of the variation is explained by the level of disturbance. Figure 6 displays one individual caribou's MCP from the study area and the level of disturbance within the MCP.

Table 2. Summary of linear regression results for unmanaged and managed forests.

Model	Variable	a	b	R^2	*p*
Managed	% Disturbance	-2115.2	2366.8	0.189	0.120
Unmanaged	% Disturbance	-4262.4	4227.1	0.030	0.552
Combined	% Disturbance	-5682.7	4180	0.239	0.008

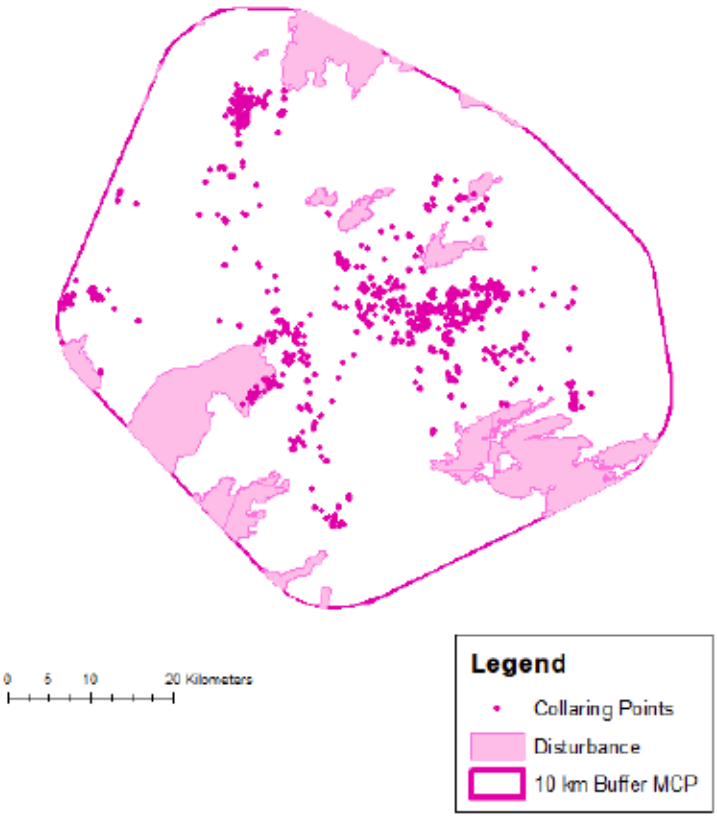

Figure 6. One individual female caribou collaring points, a 95% MCP with a 10 km buffer as well as the 2015 disturbance polygon shapefile.

DISCUSSION

The results of this study supported the hypothesis that winter home range sizes of caribou in a managed forest are smaller in comparison to those in an unmanaged forest. The average winter home range size was 408 km^2 ± 311 km^2 in the managed forest. A limited number of studies have considered the winter home range size of caribou and several studies have reported the average annual home range size. A study reported the average annual home range of caribou in the Brightsands Range as 949 km^2 and 633 km^2 in the Churchill Range, which is similar to the results of this study (OMNRF 2014b, 2014c). The annual home range size reported in the Brightsands Range is speculated to be higher than the results of this study as well as the reported home range size in the Churchill Range because a large portion of the range is Wabakimi Provincial Park, which is absent from forestry activities and contains the highest concentrations of caribou (OMNRF 2014b).

Home range sizes in the unmanaged forest of the study area were significantly larger than those in the managed forest. The average winter home range size in the unmanaged forest (Kinloch Range) was 1580 km^2 ± 1374 km^2 which is comparable to the reported average annual home range size for the Kinloch range (1307 km^2) (OMNRF 2014d). Moreover, a two-year study in the Far North of Ontario reported the average winter home range size of the forest-dwelling ecotype of caribou as 2378 km^2 ± 667 km^2 in year 1 and 3,054km^2 ± 740 km^2 in year 2 (Berglund et al. 2014). The study encompassed all of the forest-dwelling ecotypes of caribou across all of the far north ranges which all have a variety of different levels of natural disturbance. Furthermore, caribou home range sizes in the Kinloch range have been found to be smaller in the east than the west, and larger in the north than the south (OMNRF 2014d).

The results of this study showed significant variation in the winter home range sizes of caribou in the unmanaged forest within the study area. The variation may be influenced by the amount of suitable habitat throughout the range. Research has indicated that home ranges are larger when the abundance of suitable habitat (i.e., conifer forest and treed wetlands) is low and smaller when the amount of suitable habitat is high (OMNRF 2014e). However, this pattern was only observed in the ranges located in the Far North of Ontario where forest harvesting is not permitted, and the level of anthropogenic disturbance is relatively low. In contrast, home range sizes in the managed forest exhibited relatively low variation (Figure 4). In this area, some of the individuals are at the most southern extent of their range where forest harvesting operations occur frequently and a number of other anthropogenic disturbances such as railways, roads and communities are present. In particular, forestry activities, have significantly altered the forest composition and fragmented the landscape in the managed portion of the study area (OMNRF 2014b, 2014c).

Past anthropogenic activities have reduced the arrangement of suitable caribou habitat (i.e., large tracts of mature conifers) which permit caribou to space away from predators (OMNRF 2014b, 2014c, 2014d; Donovan et al. 2017). Hence, the low variation in home range size in the managed forest may be attributed to the low amount of suitable habitat on the landscape, forcing caribou to restrict their movements to remaining habitat patches (OMNRF 2014e). Consequently, the small patches induce caribou to concentrate into aggregations and make them more vulnerable to predation and act as an ecological trap (Lesmerises et al. 2013). Although the home range sizes are consistent with other studies, in some cases caribou have been found to respond to disturbances by expanding their home range under a given threshold (Beauchesne et al.

2014; McLoughlin and Ferguson 2000). In this study, one outlier from the managed forest was removed because it had a significantly larger winter home range than the other individuals in the managed forest. The 95% MCP for this individual revealed the it had travelled a large distance into Wabakimi Provincial Park in the northern portion of the Brightsands range.

The quality of caribou habitat was not assessed in the study area but might be an important predictor of home range size (Ferguson and Elkie 2004b). In addition, the level of disturbance in the study area may serve to qualitatively describe the quality of the habitat. Forest stands recently disturbed by natural and anthropogenic activities produce early successional forests that do not provide crucial habitat elements for overwintering survival of caribou. Caribou wintering habitat is associated with forage availability and forest cover conditions (Bowman et al. 2010; Johnson et al. 2004; Schaefer 1996) Winter areas selected by caribou have been found to have lower-than-average snow depths, which is believed to facilitate easier movement and easier access to ground lichens (Johnson et al. 2004). Terrestrial lichens such as *Cladonia spp.* are the primary late winter food source of caribou (Thompson et al. 2015) and are most commonly found in mature conifer stands that are limited in deciduous browse, which subsequently reduces the occurrence of other ungulate species such as moose and white-tailed deer (Bowman et al. 2010).

The results of the study suggest a significant negative relationship between winter home range and the level of disturbance across the managed and unmanaged forest areas. Although the relationship between winter home range size and the level of disturbance was not significant for the managed and unmanaged forests, there was a negative correlation, which tends to support the hypothesis that caribou decrease their

home range size in response to increasing disturbance. The level of disturbance (anthropogenic and fire) was significantly higher in the managed forest than the unmanaged forest. Caribou habitat in the managed forest is relatively fragmented and contains small patches of suitable habitat due to past forest harvesting and natural disturbances (OMNRF 2014b, 2014c). Observations of collaring data revealed that caribou funnel into the small patches of suitable habitat remaining in the managed forest. In comparison, winter habitat in the unmanaged forest is relatively abundant with large tracts of mature conifer and very few disturbances (OMNRF 2014d).

Although this study represents an important step in understanding the relationship between disturbance and caribou space use in northwestern Ontario, it is important to note that there are limitations to these results. The number of individuals used in this study to compare winter home range sizes in the managed and unmanaged forest is too small to make an accurate statistical analysis. Likewise, the number of individuals used to investigate the correlation between winter home range size and level of disturbance is also small. However, this study provides insight into the effects of natural and anthropogenic disturbances on caribou home range sizes. It is recommended that future studies deploy more collars on caribou in the managed forest to understand their space use of the remaining habitat patches. This information may provide insight into predation as a population-limiting factor to caribou in managed forests. Moreover, findings from additional further studies could improve forest management practices on the landscape, including the size, composition, and configuration of suitable habitat patches within managed caribou ranges.

CONCLUSION

Home ranges of caribou are an important predictor of the quality of habitat on the landscape. Thus, identification of the drivers which contribute to among-population variation in home range sizes of caribou can help elucidate critical population limiting factors. In this study, winter home ranges of caribou varied significantly between managed and unmanaged forest areas of northwestern Ontario. However, home range sizes in managed forests with higher levels of disturbances are much smaller than those in unmanaged forests with lower levels of disturbance. Anthropogenic disturbances such as forest harvesting significantly alter the landscape and create small fragmented patches of mature conifers which act as ecological traps for caribou and make them more susceptible to predators. Therefore, it is recommended that future studies focus on the space use of caribou in the remaining habitat patches on the landscape. Lastly, these findings have the potential to improve forest management practices in managed forests including the size, composition, and configuration of suitable habitat patches within managed caribou ranges as well as aid in the conservation of this species.

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APPENDICES

APPENDIX I: CARIBOU DATA

Caribou ID	Home Range	Buffered Home Range	Forest Type	% Disturbance
C103	3323.109826	6230.93	1	0.23
C105	797.25664	2225.94	1	0.18
C110	363.105226	1431.21	1	0.27
C111	1196.659661	2939.60	1	0.07
C112	792.054271	2219.03	1	0.15
C115	730.972622	2061.26	1	0.12
C116	890.590327	2343.26	1	0.12
C117	3526.122487	6218.77	1	0.20
C118	3011.876834	5428.84	1	0.18
C119	274.625138	1224.66	1	0.38
C120	4324.206871	7731.81	1	0.19
C121	828.437487	2330.79	1	0.35
C122	258.810148	1173.97	1	0.22
C273	1795.421613	3727.47	1	0.13
C123	691.633325	2065.30	2	0.43
C210	312.651889	1364.01	2	0.52
C212	503.283778	1700.61	2	0.49
C214	0.335088	337.30	2	0.61
C222	209.111182	1219.62	2	0.38
C225	1005.501748	2532.04	2	0.20
C226	47.00329	637.82	2	0.47
C228	143.410316	914.39	2	0.59
C229	876.00591	2522.52	2	0.31

C230	722.063244	2084.80	2	0.45
C235	292.480647	1320.54	2	0.45
C236	220.134313	1168.12	2	0.20
C238	236.831532	1160.36	2	0.22
C239	455.937932	1797.46	2	0.50[1]

[1] 1 – Unmanaged, 2 – Managed

APPENDIX II: PYTHON SCRIPT

```
Add field 'YEAR' - type = short integer, precision = 4
Add field 'MONTH' - type = short integer, precision = 2
add field 'DAY' type = short integer, precision = 2

##Right click on column 'YEAR' and open field calculator
##Enter the following test in the 'YEAR=' field:
Left( [MONITOR_DA],4)
##right click on colum 'MONTH' and open field calculator
## Enter the following test in the 'MONTH=' field:
Mid( [MONITOR_DA],6,2)
## Right click on column 'DAY' and open the field calculator
## Enter the following text in the 'DAY=' field:
Mid( [MONITOR_DA],9,2)


## Add field 'SEASON' type = text, precision = 50
## Open field calculator, under 'expression' enter Reclass(!MONTH!,!DAY!) and under expression type select python 9.3.
Enter the following expression in the code block:

def Reclass(MONTH,DAY):
    if MONTH==12:
        return "WINTER"
    elif MONTH==1:
        return "WINTER"
    elif MONTH--2:
        return "WINTER"
    elif (MONTH--3 and DAY <31):
        return "WINTER"
    else:
        return "OTHER"
```

APPENDIX III: R PROGRAMMING MCP SCRIPT

```
install.packages("adehabitatHR")
install.packages("rgdal")
install.packages("sp")
install.packages("maptools")
library(adehabitatHR)
library(rgdal)
library(sp)

caribou <- readOGR(dsn=".", layer="caribou")
cp <- mcp(caribou[,3], percent=95)
## [,3] indicates the column number of the animal 'ident' field - change it as
necessary
plot(cp)
writeOGR(cp, dsn=".", "homerange", driver="ESRI Shapefile")
```

APPENDIX IV: SPSS LINEAR REGRESSION OUTPUTS

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.489[a]	0.239	0.210	1625.19849

a. Predictors: (Constant), % Disturbance

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients			95.0% Confidence Interval for B	
		B	Std. Error	Beta	t	Sig.	Lower Bound	Upper Bound
1	(Constant)	4180.032	684.287		6.109	0.000	2773.461	5586.603
	% Disturbance	-5682.749	1988.578	-0.489	-2.858	0.008	-9770.329	-1595.169

a. Dependent Variable: Buffered Home Range

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.174[a]	0.030	-0.051	2193.57033

a. Predictors: (Constant), % Disturbance

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients			95.0% Confidence Interval for B	
		B	Std. Error	Beta	t	Sig.	Lower Bound	Upper Bound
1	(Constant)	4227.113	1507.371		2.804	0.016	942.834	7511.393
	% Disturbance	-4262.382	6968.357	-0.174	-0.612	0.552	-19445.127	10920.364

a. Dependent Variable: Buffered Home Range

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.435[a]	0.189	0.122	620.06245

a. Predictors: (Constant), % Disturbance

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95.0% Confidence Interval for B	
		B	Std. Error	Beta			Lower Bound	Upper Bound
1	(Constant)	2366.810	550.665		4.298	0.001	1167.013	3566.607
	% Disturbance	-2115.197	1263.218	-0.435	-1.674	0.120	-4867.513	637.119

a. Dependent Variable: Buffered Home Range

APPENDIX V: SPSS OUTPUT T-TEST

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
HOMERANGE	Equal variances assumed	23.668	0.000	3.11	26	0.004	1171.20464	376.39574	397.51211	1944.89717
	Equal variances not assumed			3.11	14.332	0.007	1171.20464	376.39574	365.66616	1976.74312