Enhanced Assessment of the Adjusted Final Preferred Route of the Bipole III Transmission Project on Moose

Submitted to:

Manitoba Hydro

Submitted by:

Joro Consultants

February 2013

EXECUTIVE SUMMARY

Manitoba Hydro completed a Site Selection and Environmental Assessment (SSEA) and Environmental Impact Statement (EIS) for the Bipole III Transmission Line Project (Project). Concerns regarding moose (*Alces alces*) populations in western Manitoba subsequently resulted in revisions to the original Final Preferred Route (FPR). The Adjusted Final Preferred Routes (AFPRs) included relocations of the HVdc line in three locations to reduce potential effects on caribou and moose populations in these areas:

- Wabowden (not assessed in this report as adjustment was made in relation to boreal woodland caribou);
- GHA 14 (Moose Meadows Area) AFPR; and
- GHA 19A and 14A

Subsequently, Manitoba Hydro submitted a *Route Adjustment Supplemental Report for the Bipole III Transmission Line Project* on January 28, 2013. Project effects for all VECs were considered, including the cumulative effects of all stressors acting on the VECs, both natural and anthropogenic in the Bipole III EA and *Route Adjustment Supplemental Report for the Bipole III Transmission Line Project*.

In this report additional quantitative analyses and review were undertaken on moose habitat and population dynamics across a broader region due to concerns identified after the EA submission and during the Clean Environment Commission (CEC) hearings conducted during October and November 2012. In particular, concern for regional moose population decline in the area known by the Manitoba Métis Federation (MMF) as the “Bread Basket” were expressed during the hearings, which include the Duck and Porcupine Mountains. Therefore, it was considered appropriate to deepen the analysis on this particular VEC. The analysis presented further supports the final conclusions as previously reached in the Project EIS - that the residual effects on moose as a result of the Project are not significant.

Cumulative Effects Assessment (CEA) requires an evaluation of historical, present, and future conditions that contribute to the sustainability of a particular VEC. The analyses provided in this report attempted to determine a landscape or linear feature threshold that explains or relates to the current stressors on regional moose populations. Landscape and linear feature attributes were assessed against moose population density information obtained from Manitoba Conservation and Water Stewardship (MCWS) from 1960 to 2011 on a number of specific Game Hunting Areas (GHAs). A linear regression analysis failed to show any significant relationships between any of the landscape or linear feature metrics measured and moose population density. Given that the analysis failed to show any relationship with landscape or linear feature metrics, moose population declines cannot be explained by these factors alone.

Therefore, future landscape or habitat thresholds could not be established to provide an evaluation of future effects. Regardless, future landscape and disturbance patterns were evaluated to determine the extent of potential effects due to activities such as forestry and mining. Future linear feature densities, including the proposed Bipole III AFPR, were projected to increase between 6.1% (GHA 19A), 4.5% (GHA 14/14A) and 2.1% in GHA 12.

Moose population modeling was then undertaken to determine the magnitude of additional mortality required to produce the observed moose population declines in western Manitoba and to estimate the potential effects of increased mortality of moose as a result of the Project. Modeling of moose populations implicitly accounted for normal levels of wolf (*Canis lupus*) and bear (*Ursus americanus*) predation and utilized historical and current moose recruitment data as well as information on known licensed harvest. Other mortality factors were incorporated in models to collectively account for unnatural levels of predation, undetected diseases, as well as non-licensed hunting, including rights based hunting. Results of the modeling illustrate that unaccounted for sources of mortality are required to explain the prolonged decline of regional moose populations.

In GHA 14/14A, after accounting for normal rates of predation, licensed hunting, and a winter tick outbreak in 2002, the model suggests that between 16% and 20% of the moose population succumbed to other sources of mortality annually from 1992 to 2011 to explain the observed population decline. From the model results and MCWS survey data, the unknown sources of mortality leave high calf:cow ratios yet can, in some areas, remove an average of more than of 15% of the population each year for many consecutive years (e.g., GHA 14/14A from 1992 to 2011). In the presence of data inconsistent with high predation rates, and the absence of evidence for high rates of parasite or disease related mortality, the most plausible explanation for the population declines is hunting.

Based on the results of this enhanced analysis there is no change to the conclusions in the original *Bipole III EIS*, *Bipole III Mammal Technical Report*, and the *Route Adjustment Supplemental Report for the Bipole III Transmission Line Project*. In summary, with either the AFPR or the FPR for the HVdc transmission line component of the Project, and with the mitigation as described in Chapter 6 of the *Route Adjustment Supplemental Report* , the cumulative effects of the Project in combination with other past, current, and future projects are not expected to result in significant residual adverse effects on moose through habitat alteration, increased fragmentation/access, or additional hunting and predation.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF MAPS

1.0 INTRODUCTION

In November 2011, Manitoba Hydro completed a Site Selection and Environmental Assessment (SSEA) and an Environmental Impact Statement (EIS) as part of the environmental assessment (EA) process for the Bipole III Transmission Line Project (hereafter referred to as the Project). As part of the EIS, boreal woodland caribou (*Rangifer tarandus caribou*) and mammal technical reports were compiled to provide additional information on the potential effects of the Final Preferred Route (FPR). As discussed in the *Bipole III Transmission Project Route Adjustment Supplemental Report*, revisions were proposed for the FPR in three specific locations to address issues raised during the Clean Environment Commission (CEC) hearings conducted during October, 2012. The Adjusted Final Preferred Routes (AFPRs) included relocations of the HVdc line route in three locations to reduce potential effects on caribou and moose (*Alces alces*) populations in these areas:

- Wabowden (not assessed in this report as adjustment was made in relation to boreal woodland caribou);
- Game Hunting Area (GHA) 14 (Moose Meadows Area) AFPR; and
- GHA 19A and 14A

The application of disturbance thresholds to Valued Environmental Components (VECs) in environmental assessment can provide an objective evaluation of the cumulative effects of the project being assessed (Ross, 1994; Duinker, 1994; Hegmann et al., 1999; Noble, 2010; Canter, 2010). Cumulative effects assessment (CEA) on all VECs was undertaken as part of the overall Project EA; however, a more detailed examination of cumulative effects was conducted for boreal woodland caribou as part of a supplemental technical report for the Project. In the *Bipole III Transmission Project Caribou Supplemental Report*. The CEA for boreal woodland caribou was performed to assess the level of current and future disturbance within boreal woodland caribou evaluation ranges using the Environment Canada (2012) threshold of 35% disturbance to assess population sustainability for the evaluation ranges affected by the FPR. As a result of the concerns for moose expressed in the CEC hearings and subsequent identification of AFPRs, an enhanced assessment of the cumulative effects of the AFPRs was undertaken in GHAs 12, 13, 14, 18, and 19.

This report considers the historical and present day disturbance regimes with respect to moose populations for GHAs in western Manitoba in proximity to the Bipole III Project. It also provides information on adjacent moose populations in southern Saskatchewan and in Riding Mountain National Park (RMNP) to provide additional context for moose population sizes and trends through time. The CEA conducted for moose assessed historical and current landscape conditions using Forest Resource Inventory (FRI) for periods or eras where past aerial survey data were available. As MCWS manages and monitors moose populations on a GHA basis, the available data were used to assess moose population response to a number of habitat, disturbance, and access related landscape metrics. The GHA unit provided the basis for assessing the potential cumulative effects of the Project as FRI data derived for Forest Management Units (FMUs) correspond well with GHAs. This scale of area for CEA is consistent with those typically conducted for other VECs including boreal woodland caribou (range) and landscapes that are large enough to provide all the life requisites for that particular VEC (Hegmann et al., 1999).

Data used in this assessment included available past aerial moose survey data, age/sex data, and hunter harvest data that were acquired from MCWS from 1960 to present. Current conditions were assessed using the most current available habitat and disturbance information contained in the Land Cover Classification Enhanced for Bipole III (LCCEB). Data relative to linear development included historical road and trail data from Manitoba Infrastructure and Transport (MIT), Louisiana Pacific (LP), road inventory data and other linear feature data from various FRIs and LCCEB inventories that include: all weather roads, trails, transmission and distribution rights-of-way (ROWs) . Disturbance data included fire and forestry data as well as information relative to mining and exploration activities[1]. Habitat classifications were standardized across all FRI eras and current LCCEB to assess a number of common habitat characteristics across decades to detect any response of moose relative to these metrics and to determine any relationship with moose density or productivity. The various habitat types and seral stages used to generate the various patch metrics and linear disturbance calculations are described in Section 6.1.

Moose population modeling, discussed in Section 6.2, was also conducted to further understand historical GHA moose population dynamics and trends in western Manitoba. Variables for moose population modeling were based on information from the scientific literature, on historical and current moose population structure from western Manitoba moose populations, and on licensed hunting mortality from each GHA. Background survival information implicitly includes normal rates of natural mortality from disease, parasites, predation and accidental death. Where normal sources of mortality plus licensed hunting were unable explain population decline, additional mortality was added to identify the level of additional mortality required to explain the decline. Mortality from these other sources would include extraordinary levels of mortality from normal causes, as well as underestimated licensed hunting, illegal hunting, and rights based hunting, for which no data are available. Moose population modeling provided

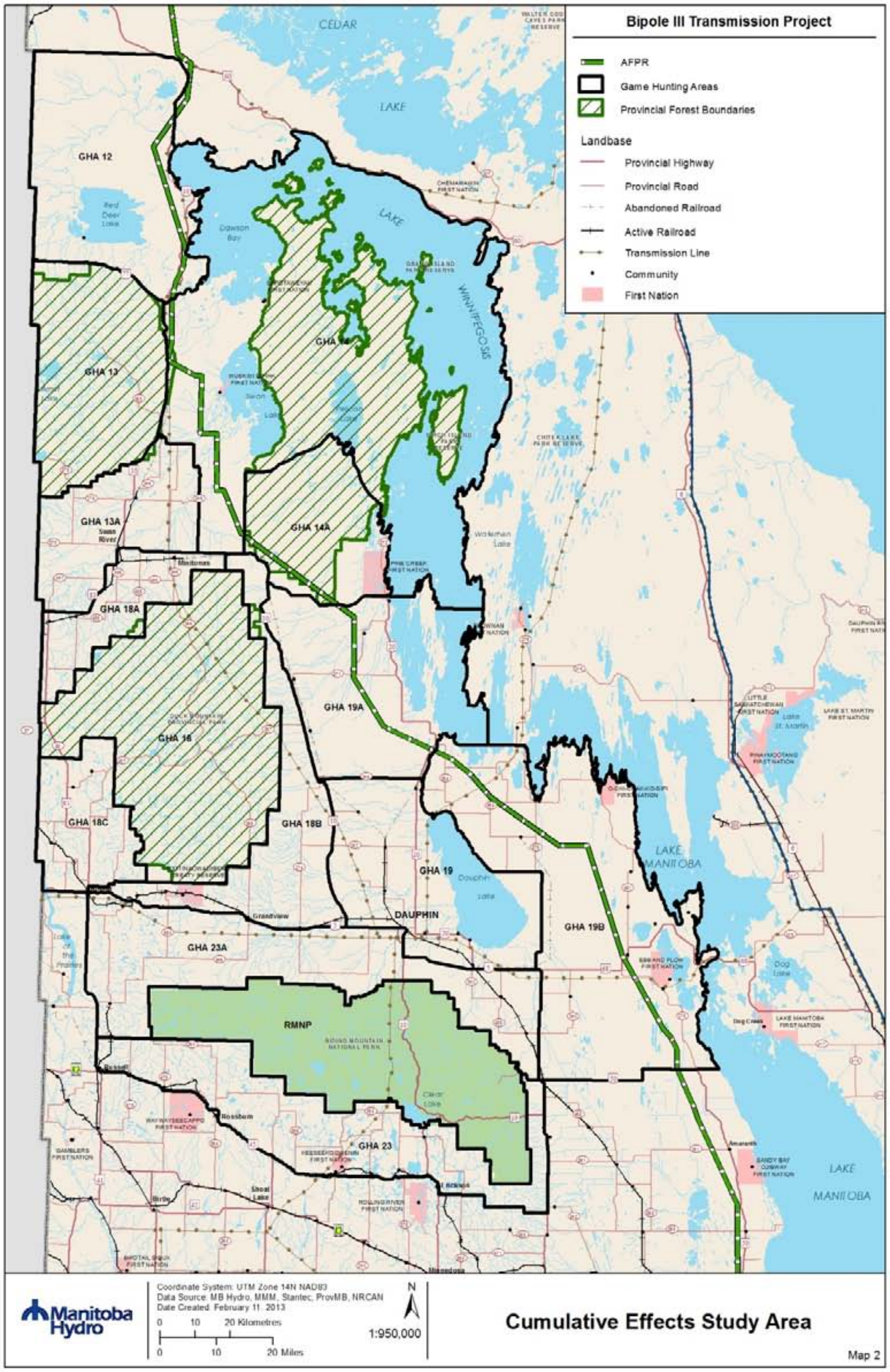
[1] Note that at the time this report was prepared data describing the extent and size of the bison ranch in GHA19A was not yet available.

the natural growth capabilities of the regional moose populations, the likely effects of licensed moose harvest, and the level of unexplained mortality resulting from all other sources.

Section 2 characterizes the study area and outlines the spatial scale of the analysis used in the report. Sections 3 and 4 move into background for the report explaining the approach to the cumulative effects analysis and includes a review of literature related to moose population dynamics and the factors that can affect these dynamics including habitat and access created along linear features, and a review of influences of predation, disease, and hunting. Section 5 presents the analysis of the data collected for the report and presents a review of moose population dynamics, harvest history, natural disturbances on the landscape, and trends of these factors in western Manitoba, RMNP, and southern Saskatchewan. Having established the regional scale of the analysis, and described the trends on moose populations over time across this region, Section 6 brings together this information with an analysis of the past, current, and future disturbances in the region that, together with the proposed Bipole III project, can act cumulatively on moose. Section 6 also considers the level of existing and predicted future linear disturbance for each GHA. Section 7 summarizes the results of the analysis and Section 8 presents the conclusions of the report.

2.0 STUDY AREA

The analysis conducted in this report is specific to moose populations and landscape metrics in the various GHAs in western Manitoba, including 12, 13, 14, 18, and 19. Game Hunting Areas in western Manitoba, which overlapped with Bipole III, were chosen as the evaluation units for the CEA as they represent the landscape units used by MCWS for moose census and management. As described above, the available spatial landscape data were also available through the various FRIs for FMUs which corresponded ideally with GHA units. Map 1 illustrates the Project Study Area and Evaluation GHAs as defined in the *Bipole III Route Adjustment Supplemental Environmental Assessment Report* (January 2013).



Map 1: Game Hunting Areas included in the moose CEA analysis

3.0 BACKGROUND

3.1 General Cumulative Effects

Cumulative effects are defined by the Canadian Environmental Assessment Agency (CEAA) as changes to the environment that are caused by an action in combination with other past, present, and future human actions (Hegmann, 1999). Cumulative effects assessments are expected to assess effects over a large area, for a long period of time (both past and future), and consider direct or indirect effects on VECs (Ross, 1994; Duinker, 1994; Hegmann et al., 1999; Noble, 2010; Canter, 2010).

4.0 LITERATURE REVIEW

The following provides a literature review of information provided to the CEC in various technical reports and Interrogatory Responses (IRs) as well more detailed information on moose population dynamics in Canada, western Manitoba and southern Saskatchewan. Pertinent available information on linear density thresholds for moose or other ecological features were investigated to compare those found in any of the GHAs associated with the Bipole III Project. Information on disease, parasites and predation are summarized based on literature and were considered in the development of moose modeling parameters.

4.1 Moose Population Dynamics in Canada

Moose populations across Canada are experiencing diverse population trends, with some increasing in size (e.g. Newfoundland and Saskatchewan), some stable (e.g. northwestern Ontario), and others believed to be in decline (e.g. western Manitoba). Moose populations are most regularly reported through a measurement of density (moose/km^2). The Ontario Ministry of Natural Resources (OMNR) (2009) characterized the population ranges for moose as high density populations (0.4/km^2), moderate density (0.2 to 0.4/km^2), and low density (0.2/km^2). Higher moose densities generally occur in protected areas, such as national or provincial parks, where hunting is absent and influence of predation in minimal (Karns, 1998).

Moose populations can quickly grow from small to large populations, given the right circumstances. There have been two separate moose introductions to Newfoundland; the first was one bull and one cow in 1878 (Pimlott, 1953) and the second was an initial "population" of two bulls and two cows in 1904 (Pimlott, 1959). From these introductions, the Newfoundland moose population has grown to a reported 125,000 moose (as of 2004), with the population having exceeded 150,000 in the late 1980s to early 1990s (McLaren et al., 2004). Surveys in areas with no hunting pressure have documented high moose densities (greater than 15/km^2) with the average density of approximately 4/km^2 (McLaren et al., 2009).

Based on hunter surveys and population estimates, the carrying capacity (*K*) of moose in the Newfoundland boreal forest is 6-9/km^2 (Mercer and McLaren, 2002).

Similarly, other areas of Canada have documented growth of moose populations. Moose have been increasing in number and expanding their range south in parts of Saskatchewan (Government of Saskatchewan, 2012a). Saskatchewan moose populations were estimated to contain approximately 40,000 individuals in 1960 (Karns, 1998) and have grown to a current estimate of 50,000 individuals (Government of Saskatchewan, 2012b). This population growth has been accredited to a lack of predators, minimal hunting and abundance of nutritious crops on agricultural fields (Government of Saskatchewan, 2012b).

4.1.1 Information on Habitat and Access Thresholds for Moose

Roads and other linear corridors may modify wildlife movement on the landscape since linear features may offer improved travel and thereby access of wildlife into areas not previously accessible (Heckbert et al., 2010). Cumulative Effects Assessment habitat thresholds are dependent on the VEC of interest and are specific to the geographic area being studied. For example, Environment Canada (2012) has identified a threshold of disturbance at 35% in assessing sustainability of local populations of caribou. Although moose have been extensively studied, little research has focused on habitat or landscape thresholds in the management of the species. Salmo et al. (2003) recommended that access density and stream crossing indices be used as land-use indicators and that core areas and patch/corridor size be used as habitat indicators when conducting cumulative effects assessments. Salmo et al. (2004) compiled a table of management indicators and guidelines for moose based on studies across Canada. In summary, the authors identified a target threshold for linear disturbance on a landscape scale at 0.4 km/km^2 and a critical threshold of 0.9 km/km^2.

Other examples of linear density thresholds include those that have been developed in the forestry sector to ensure ecosystem sustainability. Although these thresholds are not specific to moose, they incorporate a broad spectrum of VECs on the landscape with the objective to ensure ecosystem sustainability. The Greater Fundy Ecosystem Research Group (2005) developed a threshold of 0.6 km/km^2 for active roads as a Criteria and Indicator of sustainability. Similarly, a threshold of 0.58 km/km^2 was identified by the Manitoba Model Forest for the annual Local Level Indicators of Sustainable Forest Management for Forest Management Licence (FML) 1 in eastern Manitoba (Keenan and Munn, 2008).

4.1.2 Moose Response to Linear Features

Linear features may result in both direct and indirect disturbance effects on ungulate populations. Peer-reviewed research pertaining to the distance of disturbance effects from linear corridors, specifically on moose, is sparse. The development of transmission lines may create a linear disturbance for wildlife as they may cause fragmentation and remove critical habitat. Transmission lines create a wide, straight ROW which may provide easily traversed travel corridors for predators (Jalkotzy et al., 1997; Stein, 2000). In general, transmission line ROWs provide increased browse biomass, if managed properly (Ballard et al., 1988). Rights-of-way are maintained at early successional stage to allow physical space between vegetation and conductors (Ricard and Doucet, 1999). When the ROW contains a large quantity of shrub and deciduous vegetation, forage availability is increased, and therefore the carrying capacity of these ROWs as quality moose habitat is increased (Ballard et al., 1988). Joyal et al. (1984) examined moose use of power line corridors and found that ROWs were used less in winter than the adjacent forest; however, the edge habitat that the ROW created was the most important forage and was the most often used by moose. They did conclude that with proper maintenance (no chemical treatments) and a narrow ROW (a 90 m ROW was crossed more often than a ROW measuring 140 m), there would be a weak influence of ROWs on moose populations. A study conducted by Ricard and Doucet (1999) found a similar relationship between moose use of transmission line ROWs. They found no difference between the presence of moose in the ROW in comparison to control plots in the adjacent forest. Although they found that the average browse production was lower in the ROW than the adjacent forest (43,495 twigs/ha versus 11,502 twigs/ha, respectively), on average there was more biomass browsed in the ROW than the forest plots (Ricard and Doucet, 1999). Therefore they found no effect of the ROW on moose habitat selection.

Other forms of linear features may have impacts on the survival and habitat usage of moose. Of the available studies, several show that moose searches for forage may take them near roadways and trails (Gillingham and Parker, 2008; Laurian et al., 2012). Roads and areas along the roads may offer some benefits to moose given roads can create highly desirable resources or microhabitats that are otherwise rare (Laurian et al., 2008). There is conflicting evidence regarding whether moose actually avoid areas near roads or whether they are in fact attracted to them. Laurian et al. (2008) found that moose avoid roads up to 500 m on each side; however, 20% of the moose in their study approached within 50 m of a road while searching for forage. Yost and Wright (2001) observed less than expected numbers of moose within 300 m of a road but greater numbers of moose between 900 to 1,200 m from the road. Recent research conducted by Laurian et al. (2012) found that moose avoided both highways and forest roads by 100 to 250 m with males avoiding these roads more than females; however, most of these studies suspect that moose did not move in close proximity to roads due to the lack of forage and salt pools rather than the disturbance caused by oncoming vehicles (Yost and Wright, 2001; Laurian et al., 2008; Laurian et al., 2012). Wasser et al. (2011) found moose select for forage over security from predators as moose were shown to select for habitat with shrubs, areas of recent wildfires (within 40 years), areas near water and areas of less coniferous cover.

4.1.3 Wolf Predation Changes along Linear Features

Wolves (*Canis lupus*) in this region have a diverse food supply which includes white-tailed deer (*Odocoileus virginianus*), elk (*Cervus elaphus*), moose, and beaver (*Castor canadensis*). Wolves have been shown to be generalists in Manitoba, using a wide variety of prey. Research conducted in western Manitoba has shown wolf diet to be comprised primarily of elk and beaver with other prey species identified to a lesser extent. The results of the analysis of 369 wolf scats collected in RMNP from fall 2001 to summer 2003 identified the relative occurrence of food items in summer were: elk (48.2%), beaver (33%), hare (*Lepus americanus)* (8.9%), moose (7.1%) and white-tailed deer (2.7%). In winter, the relative occurrence of food items was: elk (56.4%), moose (17.1%), white-tailed deer (13.2%), beaver (12.5%), and hare (0.8%) (Sallows, 2007).

Various studies have shown the increased benefit of linear corridors for wolves. Linear corridors such as roads may increase a wolf's travel speed, influencing their interactions with prey species, their distribution, and their travel routes (Thomas, 1995; James and Stuart-Smith, 2000; Courbin et al., 2009). Factors such as landscape structure, topography, and anthropogenic disturbance/presence affect wolf distribution (Carroll et al., 2001). Changes on the landscape such as the development of linear corridors can result in decreased search times for prey, increased predation efficiency, and increased access to areas where prey were previously safe as a result of low access (Thomas, 1995; James and Stuart-Smith, 2000). Research which quantifies the relationship between linear corridors, moose, and increased wolf predation is limited. Kunkel and Pletscher (2000) investigated the effects of modifying habitat and landscape features through logging, on moose-wolf relationships in southeastern B.C., constructing a model which predicted kill site locations. Lower road density, lower elevation, a lesser distance from trails, and a greater distance to the edge of the size-class patch increased the probability that a site would be a kill site (Kunkel and Pletscher, 2000). Moose were more susceptible to predation by wolves in areas of lowest elevation, low snow depth, with easy travel routes on rivers. Road avoidance by wolves suggested moose were actually safer in areas closer to roads within areas where this research was conducted (Kunkel and Pletscher, 2000). This research suggested that roads associated with logging, result in prime moose foraging habitats, resulting in healthy moose which have a greater likelihood to escape predators. However, roads, trails and streams characterized by low human activity resulted in increased probability of moose predation by wolves (Kunkel and Pletscher, 2000).

When linear corridor development occurs in moose habitat, effects can be assessed by monitoring activity relative to distance from the feature. Laurian et al. (2008) studied the behaviour of moose relative to a road network north of Quebec City. Their results showed that both forest and highway roads were crossed by a small fraction of the collared moose, mostly between May and July. The buffer strip 0-50 m from the road showed the greatest moose avoidance, and buffer strips >2,000 m from development showed a more random distribution of moose. It was noted that there was some limited use in the 0-50 m buffer and was likely for feeding on sodium covered vegetation along the roadway. Moose home range was also shown to increase as the density/area of roads increased in the study area. The overall conclusion was that moose tend to avoid road corridors, which in the long term likely reduces their chance of mortality by way of wolves and vehicles.

Further to the above, and as discussed, the contribution of predation facilitated by increased access resulting in moose population decline is not well documented in the literature. However, there are several examples of positive moose population response in highly fragmented and accessible habitats in Manitoba, Saskatchewan and Ontario. Crichton (2004) documented a positive increase in the Happy Lake, Manitoba moose population following intensive access development and forest harvest through access management and hunting closures. A similar but less dramatic increase was also observed in the Beaver Creek area of eastern Manitoba where access was managed and hunting remained open (MCWS unpublished information). Saskatchewan has also conducted assessments on the effectiveness of road management and wildlife refuges in forest harvest areas to protect moose from over hunting where access is a concern. They documented increases in local moose populations after both large area and road corridor game preserves were established. The combination of road corridor refuges and access closure were considered the most appropriate management tool in forestry areas (pers. comm. E. Kowal, 2013). A major study in north western Ontario also assessed the effectiveness of forest harvest guidelines for moose using aerial survey data over a 16 year period (Rempel et al., 1997). The results of this study illustrated that moose population rate of increase was positive in both burns and unmodified clear-cut areas. Moose densities remained constant in modified clearcuts, which was thought to be a consequence of hunting. In all examples, hunting of moose was considered to be the main variable in explaining moose response with no documented effects or concern regarding increased predation by wolves as a result of increased access and fragmentation.

4.1.4 Influence of Disease and Parasites on Moose

Historically, ungulate pathogens and parasites have been monitored by MCWS in the western portion of the province through the testing of samples collected from harvested white-tailed deer and elk (MCWS, 2013). To date, there has been no evidence of *Parelaphostrongylus tenuis* (*P. tenuis*) in moose in this area. Additionally, chronic wasting disease (CWD) has never been found in any species of wildlife in Manitoba (MCWS, 2013). Current academic literature (Wasel et al., 2003; Wilson et al., 2003) also supports that these diseases are currently not found in moose in western Manitoba. Wilson et al (2003) further states that moose populations, such as the moose found in RMNP exhibit a high variation in the major histocompatibility complex (MHC) gene DRB, which is thought to be positively associated with increase immune system function and reduced threat of local extinction (Yuhki and O'Brien, 1990).

The following sections provide further background on ungulate parasites, specifically *Parelaphostrongylus tenuis* and winter tick, as they pertain to moose in western Manitoba.

4.1.4.1 Parelaphostrongylus tenuis

P. tenuis meningeal worm, also known as "brain worm", is a common parasitic nematode of the central nervous system, whose natural host is white-tailed deer (Wasel et al., 2003; Kopcha et al., 2012). *P.tenuis* within white-tailed deer characteristically completes its life cycle without causing any significant adverse health effects (Kopcha et al., 2012). However, *P. tenuis* occurrence in other ungulates such as moose, elk, and caribou, causes serious physical deterioration and eventual death.

Lankester and Samuel (1998) noted that *P. tenuis* had been documented in the south-western corner of Manitoba. Further, RMNP tests for *P. tenuis* on an ad hoc basis and have found evidence of *P. tenuis* in white-tailed deer in the park, although no formal report exists on the prevalence of *P. tenuis* in white-tailed deer in RMNP at this time (pers. comm. T. Sallows, 2012). In the south-eastern corner of Manitoba, Figure 1 shows a high prevalence of *P. tenuis* among white-tailed deer (Wasel et al., 2003) (Prevalence: percent infection in each of the management units). These findings are similar to the findings of the last survey conducted by MCWS performed in 1972, which indicate the range of *P. tenuis* has not shifted significantly.

Manitoba Conservation and Water Stewardship was not able to provide any records of moose from western Manitoba infected with *P. tenuis*. A single record from Manitoba exists at the Canadian Cooperative Wildlife Health Centre (CCWHC); the animal had been collected in 2008, south of study area, near Cromer, Manitoba (pers. comm. Bollinger, 2012). An inquiry to the Saskatchewan government yielded 6 confirmed reports of moose infected with *P. tenuis* in Wildlife Management Zones (WMZ) in eastern Saskatchewan adjacent to the Manitoba border (pers. comm. R. Tether, 2013); the confirmed cases were reported between 1996 and 2011 and are from as far north as Manitoba GHA 12 and as far south as Manitoba GHA 27. It seems reasonable that there may occasionally be cases of *P. tenuis* in moose in the study area, but unlikely that it has any important effect on the population.

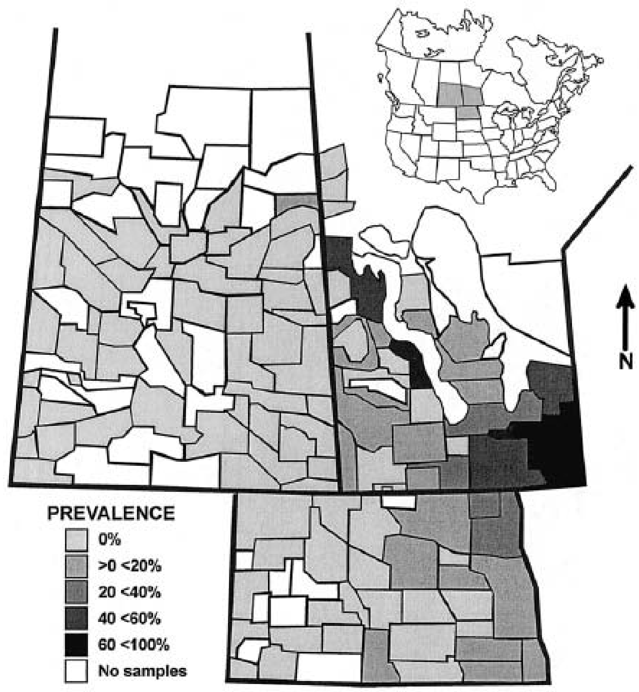


Figure 1: Prevalence of *Parelaphostrongylus tenuis* in white-tailed deer arrayed by deer management units in Saskatchewan, Manitoba, and North Dakota. A total of 1 902 deer heads were included in analysis. Map not to scale (Wasel et al., 2003)

Waring et al. (1991) demonstrated that white-tailed deer use road ROWs to feed, especially when the available forage is more abundant or of better quality than in adjacent landscapes. ROWs have the potential to provide white-tailed deer with good forage opportunities, given much of their diet consists of browse, grasses, forbs, mast, and succulents, many of which grow in ROW edge habitats.

4.1.4.2 Winter Tick

Winter tick (*Dermacentor albipictus*) is a common external parasite to moose, which are the most commonly, and severely infested host (Welch et al., 1991). Moose acquire the tick larvae in late summer and fall, which begin to feed on the moose's blood, molt into a nymph, and continue to feed on the blood. A second molt occurs in mid-February, which produces the male and female adult ticks. These also feed on the moose's blood, becoming engorged, with numbers peaking in late March through April (Lankester and Samuel, 1998). When large numbers of tick are present, moose will begin excessive grooming which damages the winter coat and can lead to other negative effects such as: restlessness, chronic anemia and reduced visceral fat (McLaughlin and Addison, 1986). A late winter followed by an early spring enhances tick survival, which leads to greater infestations and chances of large die-offs (Wilton and Garner, 1993; Samuel, 2007). Unlike mortality due to *P. tenuis*, die-offs from winter tick are often widespread and rapid but short-lived (Samuel, 2007), and continue for only 1-2 consecutive springs. Such epizootics are independent of deer density (Lankester, 2010). Lankester and Samuel (1998) summarize that some large die-offs of moose are a complex interaction between winter ticks, host-density and nutrition and weather.

A study on effects to moose population as a result of winter ticks found a mean number of 26,446 ticks/moose in Manitoba and a density of 1.17 ticks/cm^2 (Samuel and Welch, 1991). This was similar to areas of B.C. and Alberta with an overall average of 32,527 ticks/moose and 1.43 ticks/cm^2 (Samuel and Welch, 1991). With hair loss being a major after-effect of a tick infestation (McLaughlin and Addison, 1986), results from this study showed 89% of all moose exhibited some loss, with Manitoba having 100% of the moose experience hair loss (Samuel and Welch, 1991).

Large-scale mortality due to winter tick infections in association with severe winter conditions have been documented within moose populations along western Manitoba. Samuel (2004, pp. 16-17) cited a source of second hand information indicating that there was a winter tick outbreak in 2002 that reduced moose populations in western Manitoba. In the spring of 2002, MCWS Big Game Manager Dr. Vince Crichton speculated that a large reduction in other moose populations were also attributed to winter ticks (CCWHC, 2002). Manitoba Conservation and Water Stewardship staff indicated that as much as 33% of the moose population in eastern Saskatchewan died from winter tick that year (pers. comm. K. Rebizant, 2012). Within Manitoba, the moose population declines were indicated to be affected as far south as Turtle Mountain and as far north as the Porcupine Mountain area on the west side of the province (*Data source*: Parks Canada, RMNP). No records of winter tick in moose submitted from Manitoba exist at CCWHC (pers. comm. T. Bollinger, 2012). The best evidence supporting the 2002 decline is likely from the winter moose survey results from RMNP estimated the park moose population at 4,030 in early 2002 and 2,572 in early 2003, supporting the observations. A licensed hunting kill estimate of 374 moose in the two game hunting areas adjacent to the park in the intervening hunting season does not explain the decline, nor does the possibility of survey error.

5.0 MOOSE POPULATIONS, HARVEST HISTORY, AND TRENDS IN WESTERN MANITOBA AND SOUTHERN SASKATCHEWAN

The following sections provide background and status of moose populations in western Manitoba including available moose densities and harvest statistics provided by MCWS. Information from RMNP and southern Saskatchewan is provided to further understand the regional dynamics of moose distribution and density. The information illustrated in this section provides base line data for the evaluation of moose densities relative to landscape disturbance and linear development as well as for the modeling of moose populations.

5.1 Western Manitoba Moose Population Trends

Aerial moose population estimates and age/sex surveys have been performed by MCWS dating back to the 1960s and provide an estimate of historical moose population trends. The information from these surveys was incorporated into the evaluation of moose densities and disturbance metrics that are described in Section 6.1. Table 1 summarizes the data acquired from MCWS.

Table 1: Summary of western Manitoba moose population data by Game Hunting Area

GHA	Years of provided Population Estimates	Years of provided Calf:Cow Estimates
12	1965, 1973, 1991, 1998	1967, 1969-1988, 1992,
13	1997, 2007, 2010, 2012	1967-1988, 1997, 2007, 2010, 2012
14	1983, 1992, 2002, 2011	1967-1988, 2002, 2011
18	1963, 1964, 1965, 1966, 1969, 1993, 1998, 2007, 2010, 2012	1966, 1969-1988, 1998, 2007, 2010, 2012

Additional moose sightings during the January 2013 aerial survey of GHAs 14A and 19A can be found in Appendix 1.

5.1.1 Western Manitoba Moose Harvest History

Moose are highly valued for licensed hunting and rights-based subsistence hunting in Manitoba and are an integral component of the ecosystem (MCWS, 2012). Historical moose harvest data is limited and difficult to compare between years; however, available data collected by MCWS in their Big Game Hunter Reports for the province provide an overview of the historical licensed harvest of moose in the south western GHAs of the province (*Data source:* MCWS). A summary of the historical licensed harvest data compiled from these data can be found in Table 2. Records indicating the number of moose harvested through rights-based subsistence hunting are not maintained by MCWS and were therefore not available. Appendix 2 shows each GHA and the projected number of moose kills between 1977 and 2011 taken from the MCWS Big Game Hunter Reports.

Table 2: Summary of licensed moose harvest data in south western Manitoba from 1977 - 2011*

GHA	Year	Average Moose Harvest
12	1975-1979	107
	1980-1984	94
	1985-1989	88
	1990-1994	83
	1995-1999	58
	2000-2004	36
	2005-2009	12
	2010-2011	11
13/13A	1975-1979	98
	1980-1984	81
	1985-1989	81
	1990-1994	71
	1995-1999	67
	2000-2004	61
	2005-2009	34
	2010-2011	26
14/14A	1975-1979	243
	1980-1984	221
	1985-1989	116
	1990-1994	101
	1995-1999	106
	2000-2004	49
	2005-2009	3
	2010-2011	2
18/A/B/C	1975-1979	316
	1980-1984	177
	1985-1989	121
	1990-1994	186
	1995-1999	246
	2000-2004	197
	2005-2009	99
	2010-2011	59
19A	1975-1979	19
	1980-1984	32
	1985-1989	30
	1990-1994	19
	1995-1999	18
	2000-2004	13
	2005-2009	8
	2010-2011	3

GHA	Year	Average Moose Harvest
23/23A	1975-1979	241
	1980-1984	151
	1985-1989	145
	1990-1994	84
	1995-1999	189
	2000-2004	287

*Moose harvest data was provided by MCWS and MCWS Big Game Hunter Reports for each GHA. The table shows the average number of moose harvests for each 5 year period; however, not all years had data. The harvest number is an annual GHA estimate projected from reported kills. A number of GHAs were lacking special season data or a special season did not exist at all.

5.2 Status and Context of Adjacent Moose Populations

5.2.1 Riding Mountain Moose Population

Riding Mountain National Park (RMNP) provides valuable baseline data representing a stable, healthy moose population co-existing with a healthy wolf population. RMNP is differentiated from the GHAs by minor anthropogenic disturbance and moose population fluctuations in the absence of hunter harvest. Moose population data from systematic annual aerial surveys conducted within the park show moose populations have been relatively stable between 1976 and 2010 (*Data source*: Parks Canada, RMNP) (Table 3). In 1976 the population estimate for moose was 2,252 comparative to the 2012 moose population estimate of 2,949 moose (Table 3). No hunter harvest of moose occurs within the park through either licensed hunting or subsistence rights-based hunting, though moose that cross the park boundary are subject to both licensed and rights-based hunting. The park is characterized by very little anthropogenic development with large tracts of the landscape remaining contiguous and intact. The wolf population estimates in the park show a relatively stable wolf population. Annual systematic wolf population estimates within the park have fluctuated between an estimated 59 wolves in 1983-84 to 113 estimated wolves in 2011-2012. Healthy moose and wolf populations coexist within RMNP. Figure 2 represents the moose population estimates based on systematic annual aerial surveys conducted within the park in comparison to the systematic annual wolf population estimates (*Data source*: Parks Canada, RMNP).

Table 3: Aerial moose survey summaries from Riding Mountain National Park between 1976 and 2012

Year	Population Estimate	Density (km^2)	Herd Structure (Bull:Cow:Calf)
1976	2,252	0.78	-
1977	2,344	0.82	91:100:65
1978	3,744	1.30	80:100:66
1979	3,760	1.31	-
1980	3,884	1.35	-
1981	3,804	1.33	-
1982	3,140	1.09	-
1983	3,292	1.15	50:100:32
1984	2,764	0.96	24:100:51
1985	1,904	0.66	45:100:63
1986	2,344	0.82	35:100:69
1987	1,616	0.56	-
1988	2,452	0.85	-
1989	1,751	0.61	-
1990	2,243	0.78	-
1991	3,441	1.20	-
1992	3,066	1.07	-
1993	-	0.00	-
1994	3,689	1.29	-
1995	5,641	1.97	-
1996	4,400	1.53	-
1997	3,805	1.33	-
1998	-	0.00	-
1999	4,803	1.67	-
2000	4,682	1.63	?:100:53
2001	3,763	1.31	?:100:67
2002	4,030	1.40	?:100:48
2003	2,572	0.90	?:100:50
2004	2,332	0.81	?:100:69
2005	2,678	0.93	?:100:58
2006	2,506	0.87	?:100:63
2007	2,473	0.86	?:100:55
2008	2,804	0.98	?:100:50
2009	2,781	0.97	?:100:58
2010	3,003	1.05	?:100:54
2011	2,535	0.88	?:100:50
2012	2,949	1.03	?:100:44

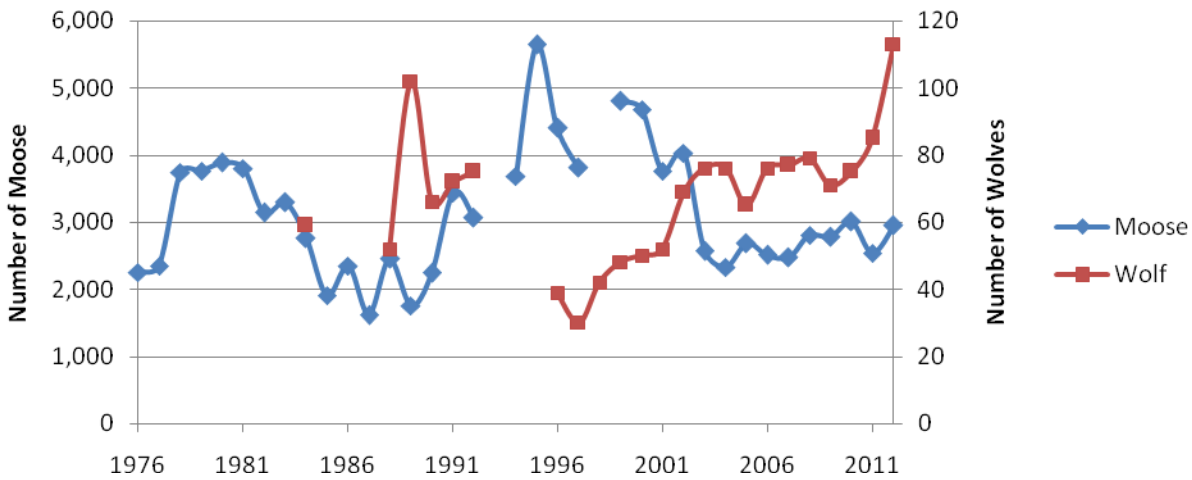


Figure 2: RMNP annual moose population estimates in relation to wolf population estimates

A decline in moose population estimates is noted between 1984 when moose population estimates were 2,764 moose, and 1985 when the population estimate was 1,904. There is no known reason for this decline as the wolf population estimates at that time were on the lower scale of their population fluctuations over the last several decades. There may have been an environmental reason, such as a particularly bad winter and/or spring that may account for the population decline at that time. A second sharp decline in the moose population estimates within the park occurred between 2002 and 2003 when the moose population in RMNP declined from 4,030 moose in 2002 to 2,572 moose in 2003. This timeframe of moose population decline is consistent with reports of moose population decline in other areas of the province and mid-west Canada, thought to be the result of a particularly bad outbreak of winter tick (*Dermacentor albipictus*) reported at that time (CCWHC, 2002). Wolf population numbers within the park were stable at the time of this moose population decline. Figure 3 represents the calf:100 cow ratio in RMNP in comparison to the wolf population. Calculating Caughley's (1977) survival-fecundity rate of increase indicates the necessary recruitment rate for a stable population with an annual adult female survival rate of 0.88 is 28 calves per 100 cows (i.e., a calf:cow ratio of 0.28).

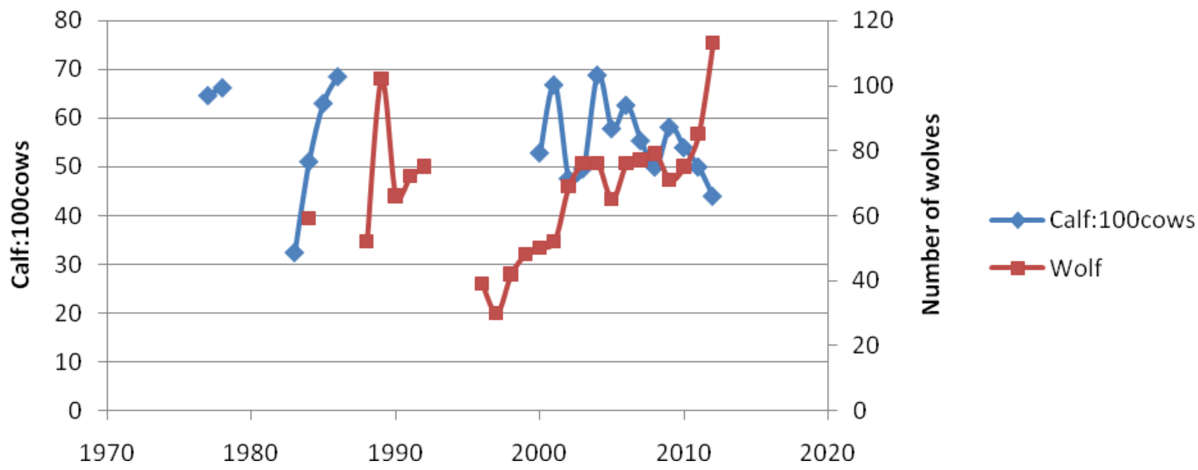


Figure 3: RMNP annual moose calf:100 cows in relation to wolf population estimates

5.2.2 Southern and East-Central Saskatchewan Moose Populations

In contrast to western Manitoba moose populations, moose populations in the southern portion of Saskatchewan are experiencing significant growth. According to news releases from the Government of Saskatchewan (2012a), moose expansion and population growth has been occurring for the past 30 years. A new research project is underway at the University of Saskatchewan to investigate the movement patterns of 25 GPS radio-collared moose in rural Saskatchewan. The study aims to identify moose movement in relation to rural highways, specifically in the central and southern parts of the province where moose population densities have grown (University of Saskatchewan, 2013).

Data collected during aerial surveys spanning from 1982 - 2010 across portions of east-central Saskatchewan indicate that in wildlife management zones (WMZ) near the Manitoba border, moose densities are generally high (pers. comm Y. Hwang, 2012). In WMZ 37 (Duck Mountain Provincial Park), a 1997/98 survey indicated a density of 0.45 moose/km^2 (pers. comm Y. Hwang, 2012) (Table 4). In other WMZs near the border, moose estimates have varied between 600 to 3,400 moose with densities ranging from 0.21 to 1.09 moose/km^2 (pers. comm Y. Hwang, 2012) (Table 4). Herd structure is also healthy with 28 to 54 calves per 100 cows (pers. comm Y. Hwang, 2012) (Table 4). As a result of these high moose populations, hunting quotas have been increased from 250 antlerless tags in 2008 to 1,335 tags in 2012 (Government of Saskatchewan, 2012a).

Overall, there are an estimated 50,000 moose in Saskatchewan, of which approximately 10% are located in the southern farmland (Government of Saskatchewan, 2012b). Moose are thriving due to the vast source of forage species such as canola (*Brassica* spp.), alfalfa (*Medicago sativa*), and peas (*Fabaceae* spp.) on cropland and the lack of natural predators in these areas (Government of Saskatchewan, 2012b). Manitoba moose populations are found to be, in general, at lower densities than Saskatchewan populations, with RMNP being an exception.

Table 4: Aerial moose survey summaries from Wildlife Management Zones in east-central Saskatchewan, near the Manitoba border (pers. comm Y. Hwang, 2012)

Study Area (WMZ)	Year	Population Estimate +/- Confidence Limits	Density (km^2)	Herd Structure (Bull:Cow:Calf)
WMZ 37 (Duck Mountain Provincial Park)	1997/98	306 ± 8	0.45	43:100:30
WMZ 56	1997/98	2,013 ± 18.4	0.65	21:100:52
	1999/00	2,696 ± 17.1	0.87	31:100:53
	2002/03	2,420 ± 19.9	0.78	25:100:54
	2006/07	3,380 ± 19.8	1.09	52:100:51
	2009/10	2,490 ± 18.6	0.82	21:100:53
WMZ 57	1999/00	2,218 ± 19.1	0.88	37:100:44
	2002/03	1,853 ± 21.6	0.74	30:100:37
	2006/07	1,898 ± 19.7	0.76	34:100:43
	2009/10	1,529 ± 15.7	0.56	37:100:42
WMZ 59	1992/93	N/A	0.7	N/A
	1999/00	2,915 ± 19.9	0.6	38:100:39
	2006/07	2,181 ± 18.8	0.45	41:100:28
	2009/10	1,985 ± 20.9	0.42	42:100:35
WMZ 60,61,62	1997/98	600 ± 20	0.26	40:100:34
	2000/01	2,057 ± 21.3	0.21	48:100:39
WMZ 67	1997/98	1,482 ± 20	0.4	35:100:34
	2003/04	3,099 ± 25.1	0.5	46:100:43
	2006/07	2,021 ± 18.9	0.32	42:100:55
	2009/10	1,860 ± 18.4	0.31	43:100:36

5.2.3 Combined Moose Survey Trend Data

Figure 4 illustrates the moose population density for the western Manitoba GHAs including RMNP and the WMZ data from southern Saskatchewan. Table 5 provides the moose calf: 100 cows in the Manitoba GHAs, Saskatchewan WMZ, and RMNP.

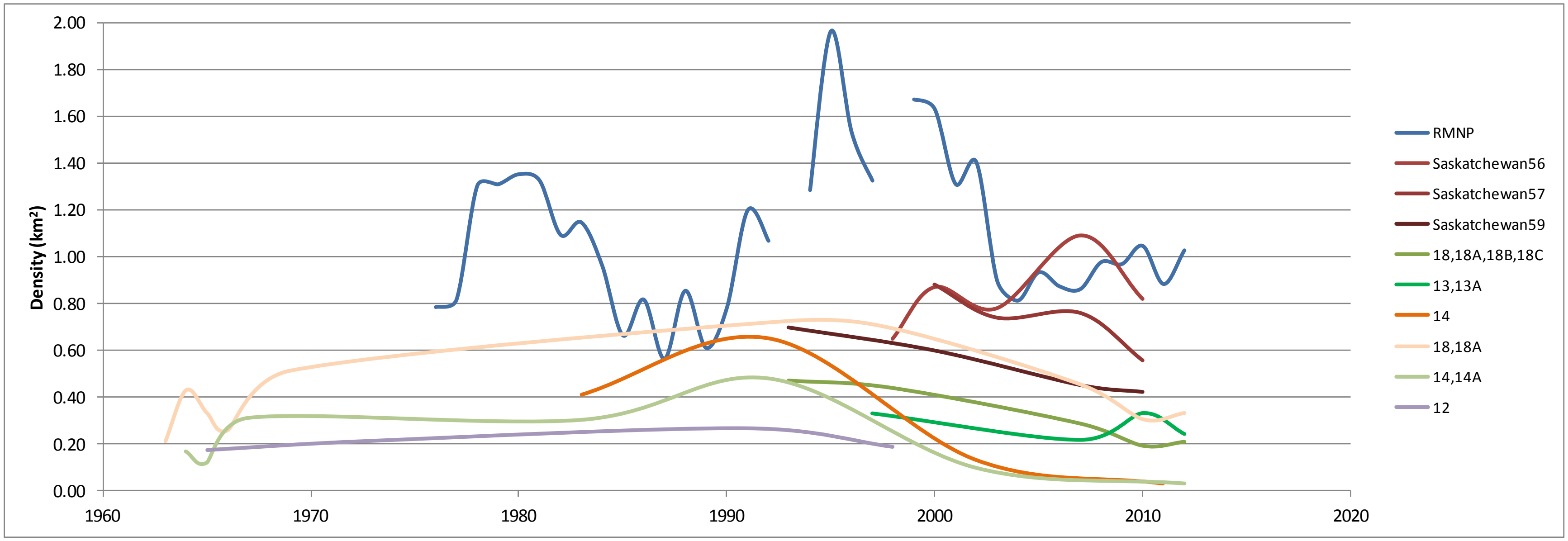


Figure 4: Moose Population Density of Manitoba Game Hunting Areas, Saskatchewan Wildlife Management Zones, and Riding Mountain National Park*

*All densities area based on aerial survey population estimates and were calculated using total area minus water except for the Saskatchewan WMZ for which density calculation methods are unknown. *Data Source*: Parks Canada for RMNP, Hwang, Y. for Saskatchewan, and MCWS for Manitoba.

Table 5: Moose calf:100 cows in Manitoba Game Hunting Areas, Saskatchewan Wildlife Management Zones, and Riding Mountain National Park*

GHA	Average calf/100 cow	Median calf/100 cow	Maximum calf/100 cow	Minimum calf/100 cow	Years with Data	Data Range	# Years of Range
GHA 12	54.8	56.0	75	28	21	1967-1998	31
GHA 13/3A	50.1	49.5	75	25	24	1967-2012	45
GHA 14	47.9	48.0	62	33	17	1971-2011	40
GHA 14/4A	50.1	48.0	68	33	21	1967-2011	44
GHA18/18A	49.9	51.0	63	33	23	1967-2012	45
GHA 18/A/B	47.5	47.5	51	44	2	1979-1980	1
GHA 18/A/B/C	44.8	42.0	58	37	4	1998-2012	14
GHA 19	25.2	26.5	32	15	6	1979-1988	9
GHA 19A	46.3	48.0	57	29	6	1979-1988	9
RMNP	55.9	55.3	69	32	19	1987-2012	25
Sask 56	52.6	53.0	54	51	5	1998-2010	12
Sask 57	41.5	42.5	44	37	4	2000-2010	10
Sask 59	34.0	35.0	39	28	4	1993-2010	17
Sask 60/61/62	36.5	36.5	39	34	2	1998-2001	3

*Data was collected during aerial age/sex and population estimate surveys. *Data Source*: Parks Canada for RMNP, Hwang, Y. for Saskatchewan, and MCWS for Manitoba

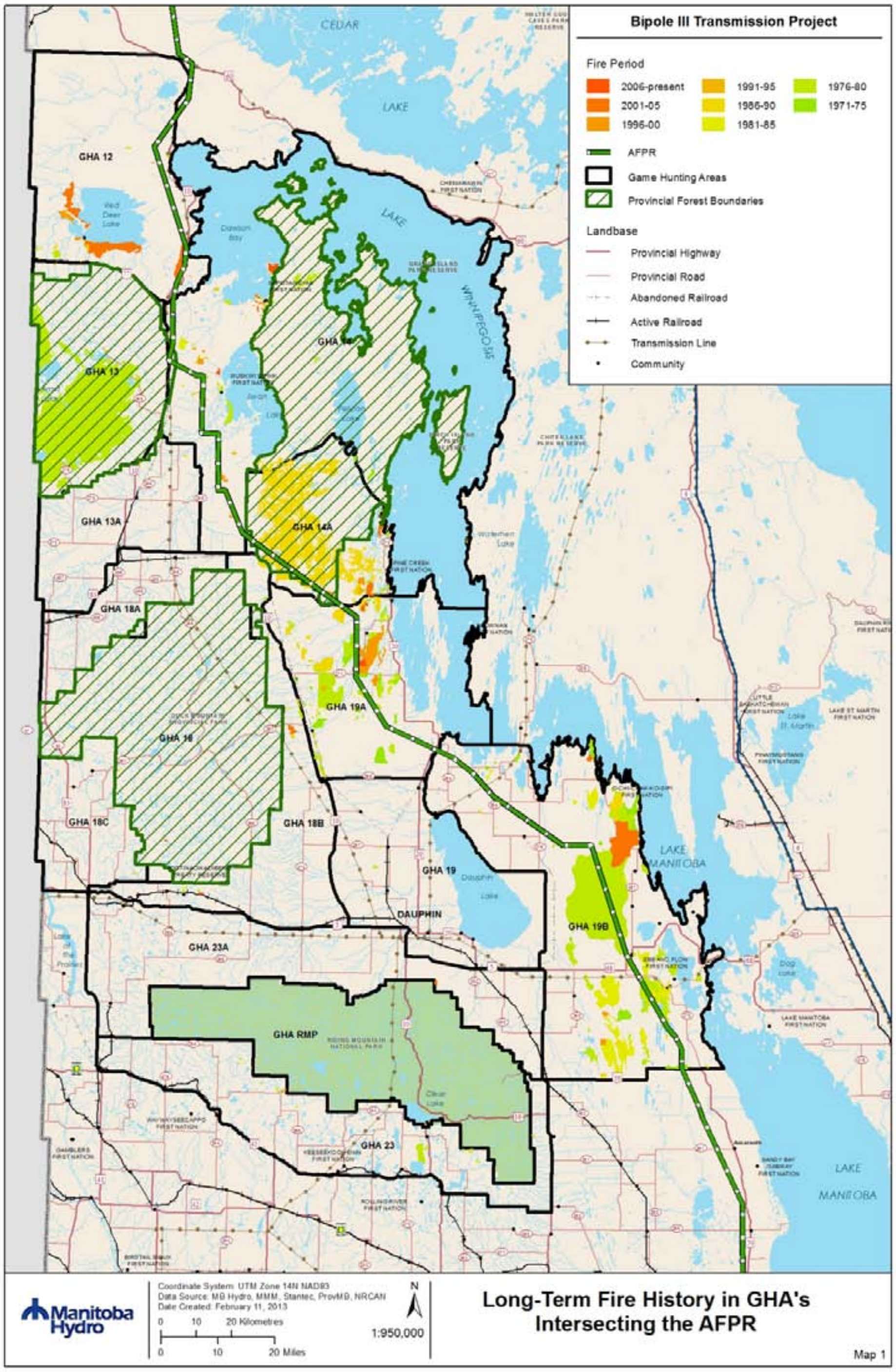
5.3 Other Factors Influencing Moose

5.3.1 Fire Dynamics

Numerous species living in the boreal forest have developed specific adaptations to fire and several species require fires for regeneration (Weber and Stocks, 1998). Moose are often attracted to recently disturbed habitat such as post-fire areas as it offers early successional vegetation used by moose for primary forage (Stewart et al., 2010). Wasser et al. (2011) found moose select habitat for shrubs and recent wildfires (within 40 years) near water and less coniferous cover suggesting that they select for forage over security from predators.

5.3.2 Fire History of Western GHAs

A fire history evaluation was completed for each GHA in southwestern Manitoba that intersects the Bipole III AFPR (Map 2) using the provincial fire layer. For each GHA, fire periods were measured for the total burned area and percentage of the GHA burned. Fire history based on MCWS fire history data were segregated into 18 fire year increments between 1928 and 2011. Each 5 year period was summed to determine the amount of area burned in each GHA intersecting the adjusted FPR. Time periods were identified by the amount of area burned in relation to the GHA greater than 1% and greater than 5%. The fire history for each GHA was assessed by five year periods and illustrated by a graph showing total area burned in km^2. The results can be found separately in Appendix 3.



Map 2: Fire history evaluation for Game Hunting Areas in western Manitoba intersecting the Bipole III AFPR

6.0 CUMULATIVE EFFECTS ASSESSMENT - METHODS

Cumulative effects assessment can be performed with a variety of tools to predict the potential effects as a result of past, current and future landscape influences. Some suggested tools include: impact models and spatial analysis using Geographic Information Systems (GIS), landscape level indicators of change, and numerical modeling (Hegmann, 1999). The analysis conducted for this enhanced analysis provides a spatial and temporal assessment of landscape and access metrics using GIS analysis in respect to historical and present moose population densities. A list of all data and mapping sources used for the GIS analysis can be found in Table 6. Effects of future development and the contribution of the Bipole III Project were projected based on available information on future resource development activities that included mainly forestry and mineral exploration (drill holes).

Moose population modeling was then conducted using historical recruitment and mortality information to provide further insight into moose population fluctuations and decline in western Manitoba. The potential mortality as a result of increased access from the Bipole III Project was assessed relative to the overall contribution to moose population response. Additional information from RMNP and southern Saskatchewan provide further context to the CEA for moose as a result of the Bipole III Transmission Project.

Table 6: Summary of all data and mapping sources used for GIS analysis of the enhanced assessment for moose

Source	Name	Description	Year
Manitoba Infrastructure and Transportation	1. Manitoba Official Government Road Map	Digitized highways from the hard copy map	1945-1946
	2. Manitoba Official Road Map	Digitized highways from the hard copy map	1953
	3. Manitoba Official Highway Map	Digitized highways from the hard copy map	1959
	4. Manitoba Official Highway Map	Digitized highways from the hard copy map	1970
	5. Manitoba Official Highway Map	Digitized highways from the hard copy map	1980-1981
	6. Manitoba Official Highway Map	Digitized highways from the hard copy map	1990-1991
	7. Manitoba Official Highway Map	Digitized highways from the hard copy map	2000-2001
	8. Manitoba Official Highway Map	Digitized highways from the hard copy map	2012
Manitoba Hydro Geodatabases	Drill Holes up to 2008	Drill holes in Manitoba up to 2008	2008
Manitoba Land Initiative	Fires up to 2011	Fires in Manitoba up to 2011	2012
Manitoba Conservation and Water Stewardship	FRI data 1960s	Forest Resource Inventory for the 1960's	1960
	FRI data 1970s	Forest Resource Inventory for the 1970's	1970
	FRI data 1980s	Forest Resource Inventory for the 1980's	1980
Tolko	Tolko Harvest 1968 - 2011	Historical Tolko Harvest Polygons (used 2001 - 2011)	2011
Louisiana Pacific	LP Harvest 1990 - 2011	Historical LP Harvest Polygons (used 2001 - 2011)	2011
	LP Planned Harvest 2013 - 2022	Future LP Planned Harvest Polygons for 10 year plan	2012

6.1 Comparisons of Historical Moose Density to Disturbance Metrics (Past & Present)

Forest Resource Inventory data were acquired over several decades to assess landscape changes through time in each GHA within western Manitoba. Forest Resource Inventory data from the 1960s (GHAs 12, 13, 14A) were used along with FRI data from the 1970s (GHA 18), 1980s (GHA 13, 13A, 14, 14A, 18, 18A,B,C, 19, 19A,B, 23A), and current LCCEB data for all GHAs associated with this analysis.

The analysis was constrained to include only suitable moose habitat defined and excluded agricultural lands and areas of human settlement within each respective GHA. All cover classifications from various FRIs and LCCEB were used in the development of six major habitat classifications to create a consistent habitat classification across decades. This was necessary in order to standardize landscape habitat characteristics due to differences among standard cover types identified in the FRI and LCCEB. Habitat classes were updated in the FRI and LCCEB to include all fire history and land disturbances such as forest harvesting areas that occurred after the date of FRI or LCCEB. Table 7 provides a summary of the habitat categories and associated FRI and LCCEB land cover classes.

Table 7: Summary of FRI and LCCEB land cover classes and habitat classification

Land cover classification	Habitat Classification	Classes	Cover Type Codes
LCCEB	Contiguous Mature	Coniferous	210-213
		Deciduous	220
		Broadleaf	221-223
		Mixedwood	230-233
	Shrub	Shrub Classes	50-52
	Wetlands	Wetland Classes	80-83
Land cover classification	**Habitat Classification**	**Sub Type**	**Stand Type/Cutting Class**
FRI	Contiguous Mature	Productive Forests	Stand Types 01-98, Cutting Class 2-5
	Shrub	Productive Forests	Stand Types 01-98, Cutting Class 0-1
		Willow Alder	Classes 721-725
	Wetlands	Marsh/Muskeg	Classes 831-839
		Treed Wetland	Classes 701-704

Habitat metrics were calculated for contiguous mature forest, shrub and wetlands using Patch Analyst in ArcGIS (ESRI, 2011). Metrics included total edge, edge density, mean patch edge, mean patch size, number of patches, median patch size, patch size coefficient of variance, patch size standard deviation, total landscape area, and class area. Descriptions of each metric can be found in Appendix 4. Metrics were generated for past, present, and future habitat composition for those GHAs where an associated moose population estimate was available. Roads and other linear features were digitized from other mapped sources for each time period and linear feature/road lengths and linear feature densities were calculated for each GHA and time period (era) separately.

The future analysis was carried out using only the LCCEB in the same manner. Changes to habitat were based on the instalment of Bipole III, predicted harvest from LP (2013-2022), and generalized predicted exploration drill hole disturbance. The projected number/area of exploration drill holes is based on average number/area of drill holes/year in the area to date.

Figure 5 and Figure 6 provide sample illustrations of habitat classification for different eras to depict landscape changes over time in GHAs 13 and 14.

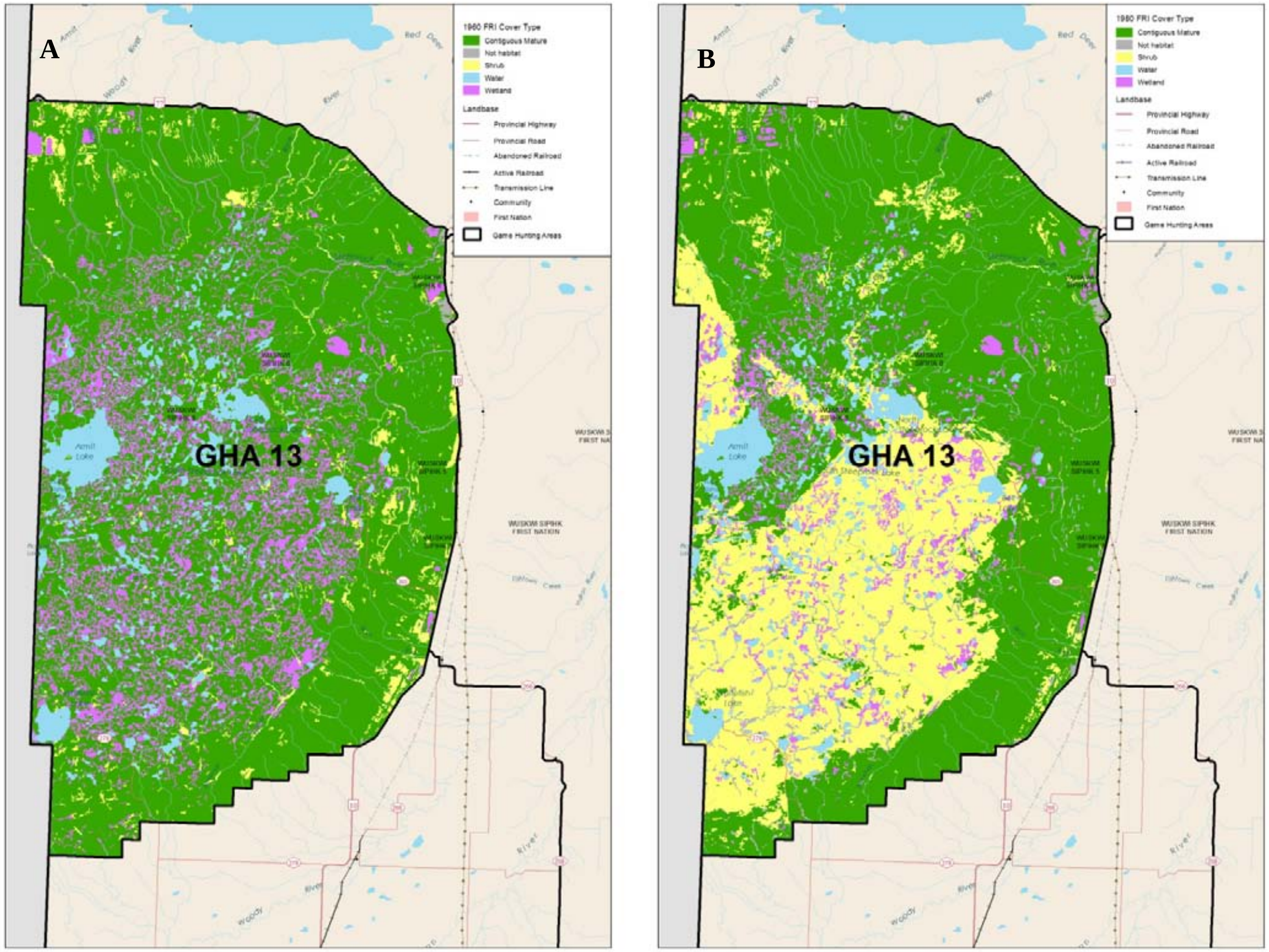


Figure 5: Forest Resource Inventory data for Game Hunting Area 13 in the 1960s (A) and 1980s (B)

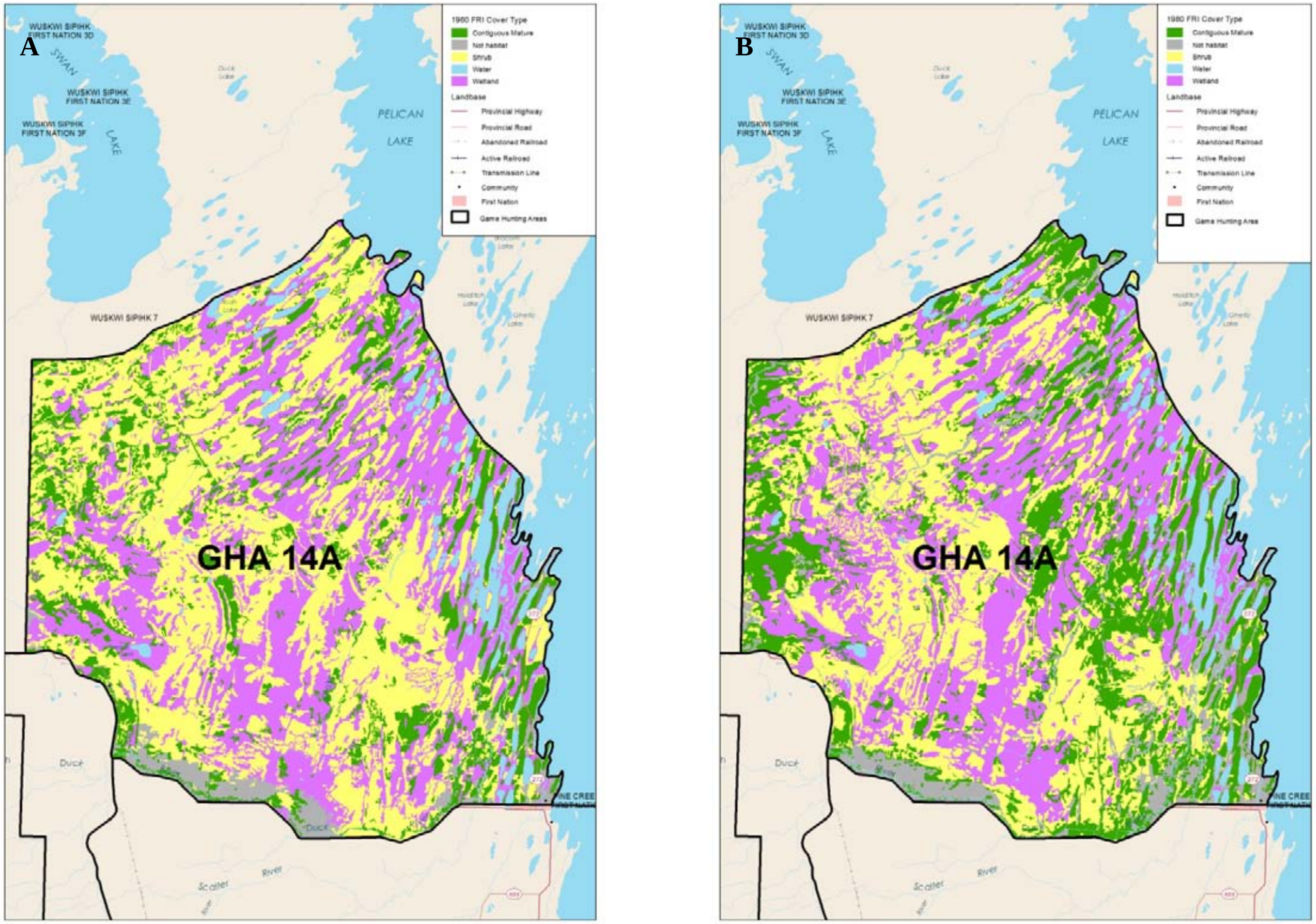


Figure 6: Forest Resource Inventory data for Game Hunting Area 14A in the 1960s (A) and 1980s (B)

6.1.1 Regression Analysis

Using all available historical and current FRI, LCCEB, LP, and MIT data, landscape and linear density metrics were generated for each decade/era for the available moose habitat area within each GHA. Where available, the associated aerial survey data for each GHA were used to derive average moose densities that related to landscape conditions (metrics) and linear density for that particular era. A correlation matrix was generated in the statistical program *R* to identify metric variables that were potentially correlated. Multi-linear regression was then conducted on various combinations of correlated variables to determine possible significance or explanation of moose density relative to the multiple landscape and linear density metrics. Regression analysis was then conducted in the statistical program *R* using moose density as a response variable to test for any significance among the various landscape metrics and to identify, is possible, a "threshold" metric by which to assess the cumulative effects of the Project.

6.2 Moose Population Modeling

All modelling was conducted using the stochastic option in the software package RISKMAN Version 1.9.003 (Taylor et al., 2006) and by using individual survival and recruitment parameters. RISKMAN is a computer software package for conducting matrix-based stochastic and deterministic population modeling of harvested and non-harvested wildlife populations designed to aid in assessing risks to populations associated with different management decisions. The time intervals selected for modeling for each GHA were determined by the years for which population surveys were completed. RISKMAN was used to model existing population estimate data, the recorded historical licensed hunter harvest, and the additional "other" mortality that would have had to occur to derive the final population estimate data provided by MCWS. Key elements of population models include age and sex specific survival rates, age-specific pregnancy and twinning rates, and initial population sizes. Survival and parturition matrices were constructed from information available from the scientific literature and population composition data from moose aerial survey data from western Manitoba.

6.2.1 Survival Matrix

The literature reports relatively consistent adult survival rates of near or above 90% for adult female moose across North America: Alberta (89-92%, Mytton and Keith, 1981); Yukon (91%, Larsen et al. 1989); Alaska (>90%, Ballard et al., 1991; Testa, 2004; Keech et al., 2011). The populations in the Yukon and Alaska studies noted above were subject to predation by wolves and bears; hunting related mortality was excluded from survival analysis in all cases. In a study in Alaska by Keech et al. (2011), adult female survival declined with age, notable after about age 12. Based on the literature adult female survival rates were set at 0.91 for individuals 1-11 years old and 0.81 for individuals over 12 years of age (Table 8);

these rates are considered to implicitly include normal rates of natural mortality from disease, parasites, predation and accidental death.

Adult male moose are known to have a shorter lifespan and lower annual survival rates than female moose (Ballard et al., 1991; Modafferi and Becker, 1997). This is evident from observed bull:cow ratios that are less than 1:1.

Table 8: Age and sex specific annual survival rates employed in population models for western Manitoba moose

Age in May	Age Class	Female Survival Rate (SE)	Male Survival Rate† (SE)
0	Calves	0.55 (0.05)	0.55 (0.05)
1	Yearlings	0.91 (0.01)	0.85 (0.01)
2-11	Two year olds plus adults	0.91 (0.01)	0.85 (0.01)
12-17‡	Older adults	0.81 (0.02)	0.75 (0.02)

†The yearling and adult male survival rates were determined by adjusting the female survival rates downward by a constant to yield the mean bull:cow ratio observed in the surveys conducted after 1990 (66:100)
‡ The survival rate was set to 0.0 for males age 15 and for females age 18

6.2.2 Parturition Matrix

Moose pregnancy rates across North America are typically between 82% and 100% and twinning rates vary from 0% to 90%, with rates from 20% to 50% most common (Schwartz, 1997). Values for the model were set to values consistent with the literature and that, when coupled with the calf survival rate, generated calf recruitment rates consistent with those observed in western Manitoba moose surveys (Table 9).

Table 9: Age specific parturition and twinning rates employed in population models for western Manitoba moose

Age in May	Age Class	Parturition Rate* (SE)	Twinning Rate† (SE)
1	Yearlings	0.00	0.00
2	Two year olds	0.30 (0.1)	0.00
3-11	Adults	0.85 (0.1)	0.30 (0.1)
12-17‡	Older adults	0.60 (0.1)	0.30 (0.1)

† Twinning rate is expressed as a proportion of parturient animals.
‡ The parturition rate was set to 0.0 for females age 18.

The survival and parturition matrices used for population modelling had three key attributes:

(1) The age specific pregnancy rates and twinning rates, coupled with the calf survival rates yielded a winter calf:cow ratio of 52 calves per 100 cows. This matches the post 1990 survey result mean calf:cow ratio for all moose surveys conducted by MCWS in western Manitoba (n=19).

(2) The adult female survival rate is consistent with rates from the published literature.

(3) The specified adult male survival rates yield a bull:cow ratio of 66 bulls per 100 cows. This matches the post 1990 survey result mean for all moose surveys conducted by MCWS in western Manitoba (n=13).

6.2.3 Initial Population Sizes

Population estimates for GHA 12, 13/13A, and 14/14A were used as initial population and final population benchmarks for the model intervals (Table 15 to Table 17). Given moose harvest rates were not available for every year the average number of moose harvested from each GHA population was calculated from the available harvest data for the interval.

Average numbers of moose harvested in each GHA for each time span (e.g. 1992 to 1998) were calculated (Table 15 to Table 17). Where data representing the standard errors of input parameters were not available, the standard error was set to 10% of the estimated value of the parameter.

6.2.4 No Harvest and Licensed Harvest Models

For every interval in each population an initial model was run without application of any hunting or extra mortality, population growth and the modelled final population size was determined from the recruitment and survival rates alone. The results of these model runs appear as no harvest models in Table 15 to Table 17 and represent potential population growth in the absence of hunting or other additional sources of mortality not accounted for by the survival rates specified. For each population in each interval a second model was run with the licensed hunting mortality estimate from MCWS applied. These appear as licensed harvest models in Table 15 to Table 17. When the licensed harvest model population was lower than the MCWS final population estimate modelling ceased for that interval, as licensed hunting was able to explain the rate of population decline.

6.2.5 Other Mortality Models

When the licensed harvest model population was higher than the MCWS final population estimate an additional model was run to evaluate the amount of additional mortality, unexplained by licensed hunting that was required to explain the observed decline. Mortality from these other sources would include extraordinary levels of mortality from normal causes, as well as underestimated licensed hunting, illegal hunting, and rights-based hunting, for which no data are available. Other mortality model simulations were conducted by holding the licensed harvest numbers static and increasing the proportion of the population removed annually until the modelled population estimate approached the MCWS final population estimate for the interval. The other mortality models, the annual proportion of the population removed and the modelled population estimate for each interval appear in Table 15 to Table 17. For comparison with licensed hunter kill, the average annual licensed hunter kill has also been presented as a proportion.

7.0 RESULTS

7.1 Natural Disturbance Assessment

7.1.1 Results of Fire History Evaluation

With respect to the GHAs which intersect the AFPR, GHA 19A and 19B had the most time periods with fires that burned over 1% of the GHA (7 and 6 periods, respectively), while GHA 14A had the most time periods with fires that burned over 5% of the GHA (2 periods) (Table 10).

Table 10: Number of periods between 1928 and 2011 which experienced fire greater than 1% or 5% of the Game Hunting Area intersecting the adjusted FPR

GHA	Periods with >1% burned	Periods with >5% burned
12	2	1
13	1	1
13A	2	0
14	2	1
14A	2	2
18	1	1
18A	0	0
18B	1	1
18C	0	0
19	0	0
19A	7	1
19B	6	1
23	0	0

7.1.2 Results of Fire History Evaluation in all GHAs

Figure 7 represents all the GHAs evaluated for fire history and the black bars represent the pooled GHA fire data.

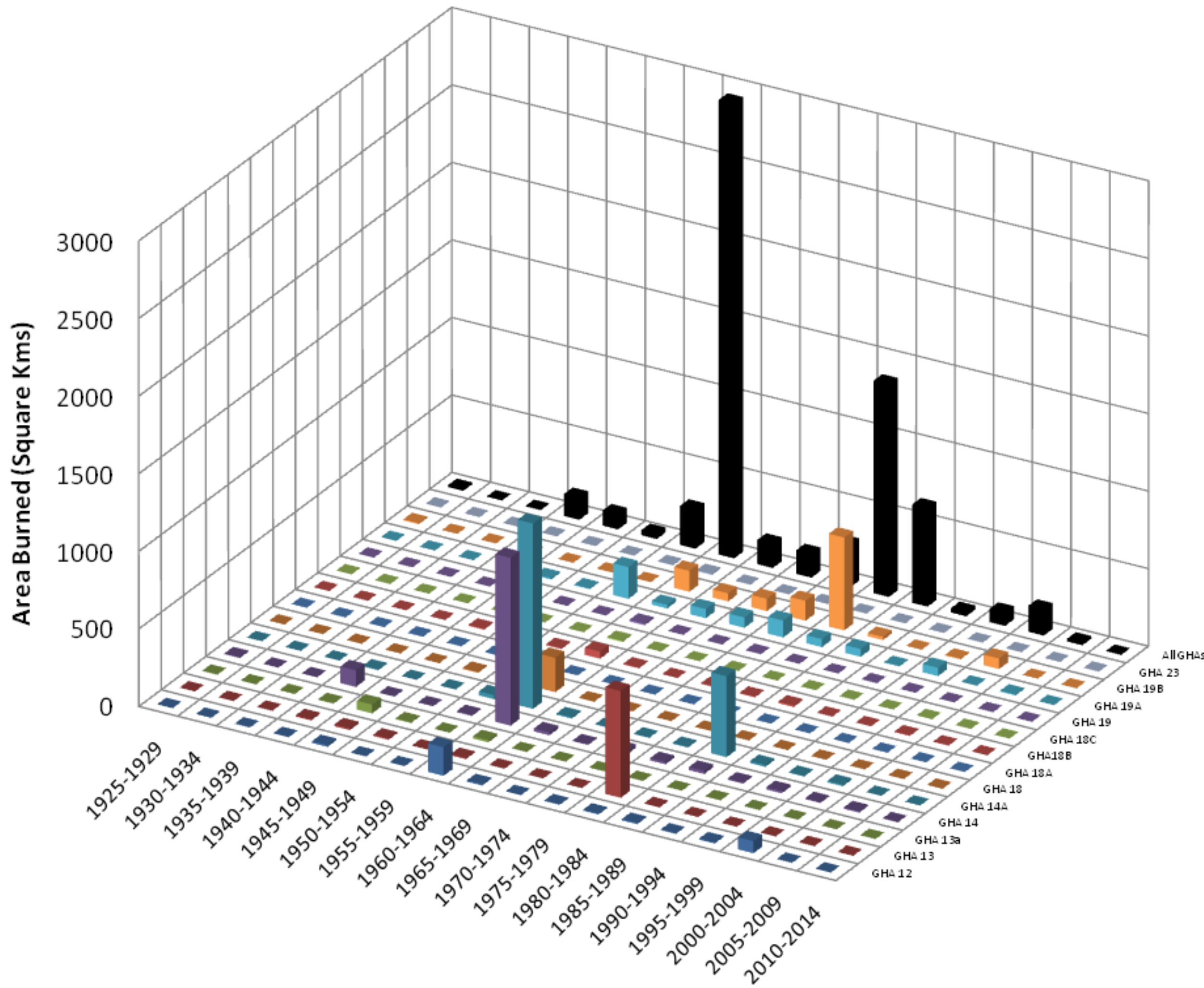


Figure 7: Fire History Evaluation in all Game Hunting Areas

7.2 Comparisons of Historical Moose Density to Disturbance Metrics (Past & Present)

Moose survey data for the various GHAs was limited and not available for all areas consistently through the period of assessment. In some cases, MCWS combined surveys over multiple GHAs, and thus analysis occurred on both separate and joint GHAs accordingly. Table 11 summarizes the available data and associated historical and current spatial land cover data used to assess GHA moose densities relative to various landscape metrics and linear feature/road densities. Linear feature density results are also included.

Table 11: Summary of the available data and associated historical landscape data used to assess population density to the various landscape metrics

GHA	Productive Moose Habitat (km^2)	Era of Landscape Data	Years of Survey	Years of Major Burn	Population Density ($moose/km^2$)	Linear Density (km/km^2)
12	2,426.93	1990 Estimate (metrics current)	1991, 1998	2002	0.23	0.05
12	2,343.17	1960s	1965	1961	0.18	0.06
13	2,054.23	Current	2007, 2010, 2012		0.43	0.15
13	2,129.98	1990 Estimate (metrics 1980s)	1997	1980	0.52	0.15
14	4,497.94	Current	2002, 2011		0.07	0.10
14	4,526.31	1980s	1983, 1992	1989	0.45	0.11
18	4,269.67	Current	2007, 2010, 2012		0.38	0.16
18	4,321.10	1990s metrics from 1980s	1993, 1998		0.73	0.13

The results of single and multi-regression analyses did not yield any potential threshold value or significant correlations that explain moose density. Of the key variables assessed, moose density relative to percentage of shrub, contiguous upland patch size and edge density, linear feature/road length, and linear feature/road density were considered; however, based on the results below, all variables demonstrate P-values far greater than 0.05, illustrating no significant relationship to moose density on the landscapes studied.

The following figures illustrate examples of linear regression analysis for several candidate variables (Figure 8 - Figure 11). Two dominant cover-types (contiguous mature forest and shrubland) and two linear feature/road metrics (linear feature/road density and total length) are provided. In each of these figures the regression line shows a positive relationship. In other words higher densities of moose are associated with more shrubland, more contiguous mature forest, higher densities of linear feature/roads, and higher total linear feature/road length, however, in all cases these relationships are not significant.

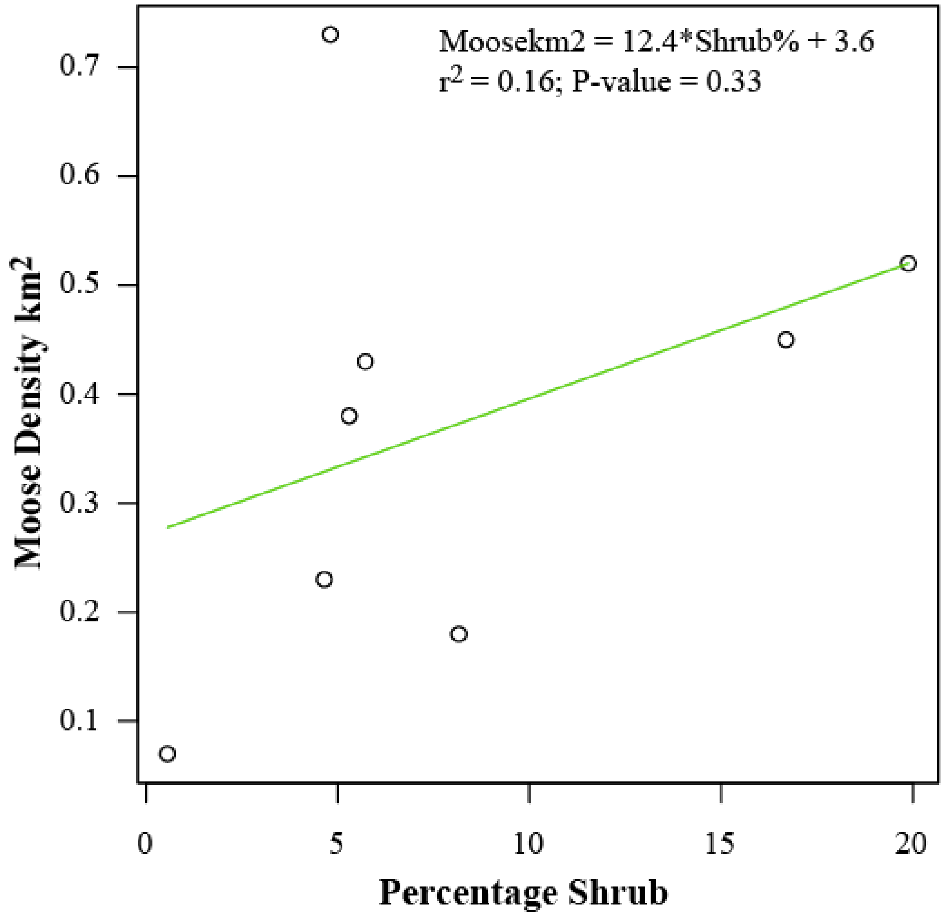


Figure 8: Linear regression of relationship of percent shrubland to moose density per square kilometer. The regression slope is positive but the relationship is non-significant with a r^2 = 0.16 and a P-value of 0.33[2]

[2] P Value is a statistical test of significance. When $P<0.05$, it is considered to be significant. R^2 Value represents the proportion of variation in the linear relationship

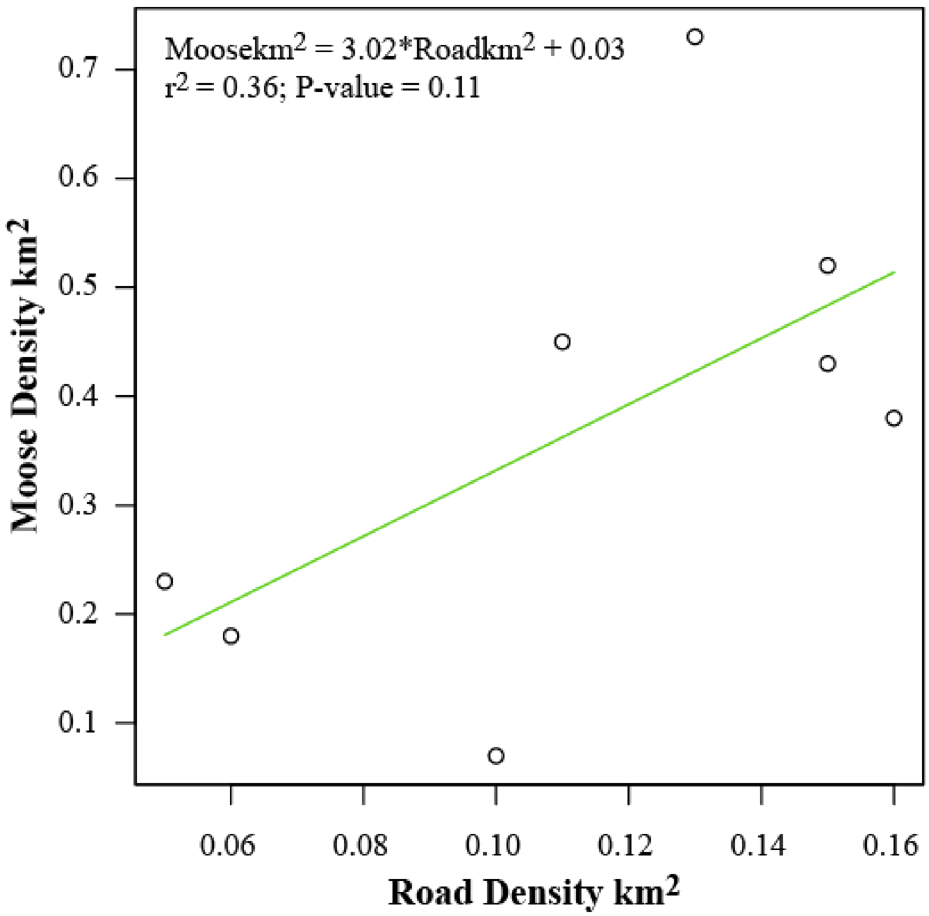


Figure 9: Linear regression of relationship of linear feature/road density per square kilometer to moose density per square kilometer. The regression slope is positive but the relationship is non-significant with a r^2 = 0.36 and a P-value of 0.11

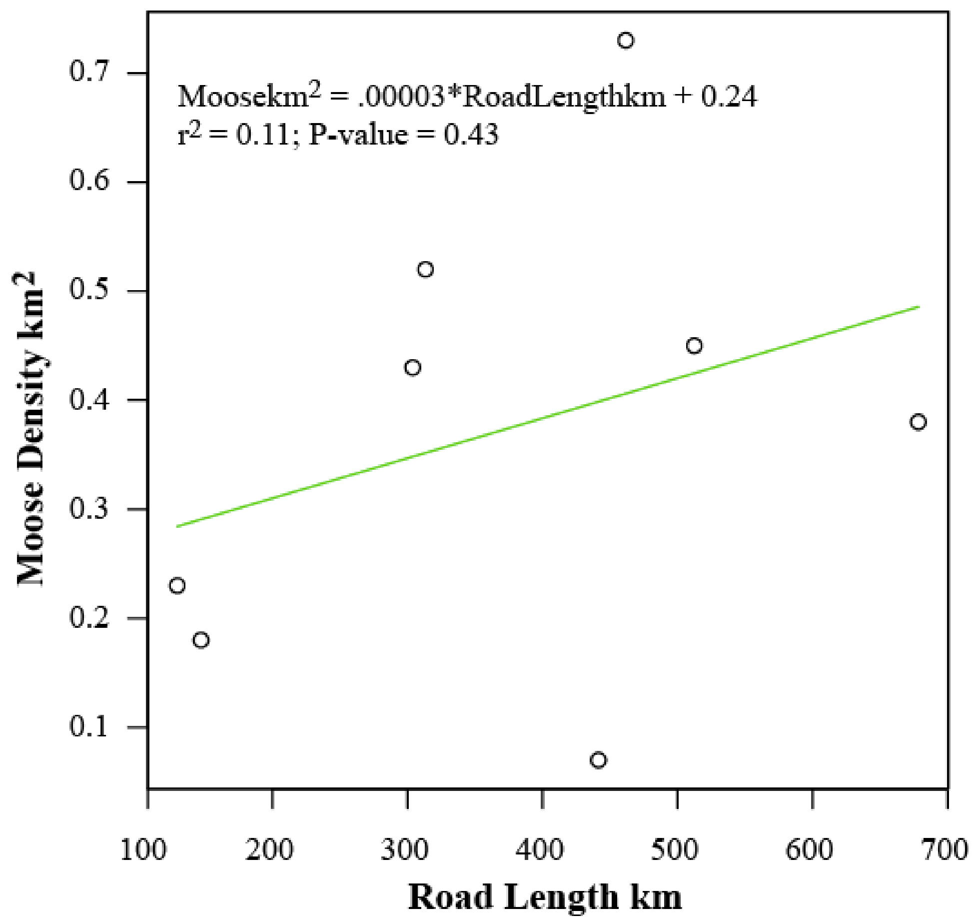


Figure 10: Linear regression of relationship of linear feature/road length in kilometres to moose density per square kilometer. The regression slope is positive but the relationship is non-significant with a r^2 = 0.11 and a P-value of 0.43

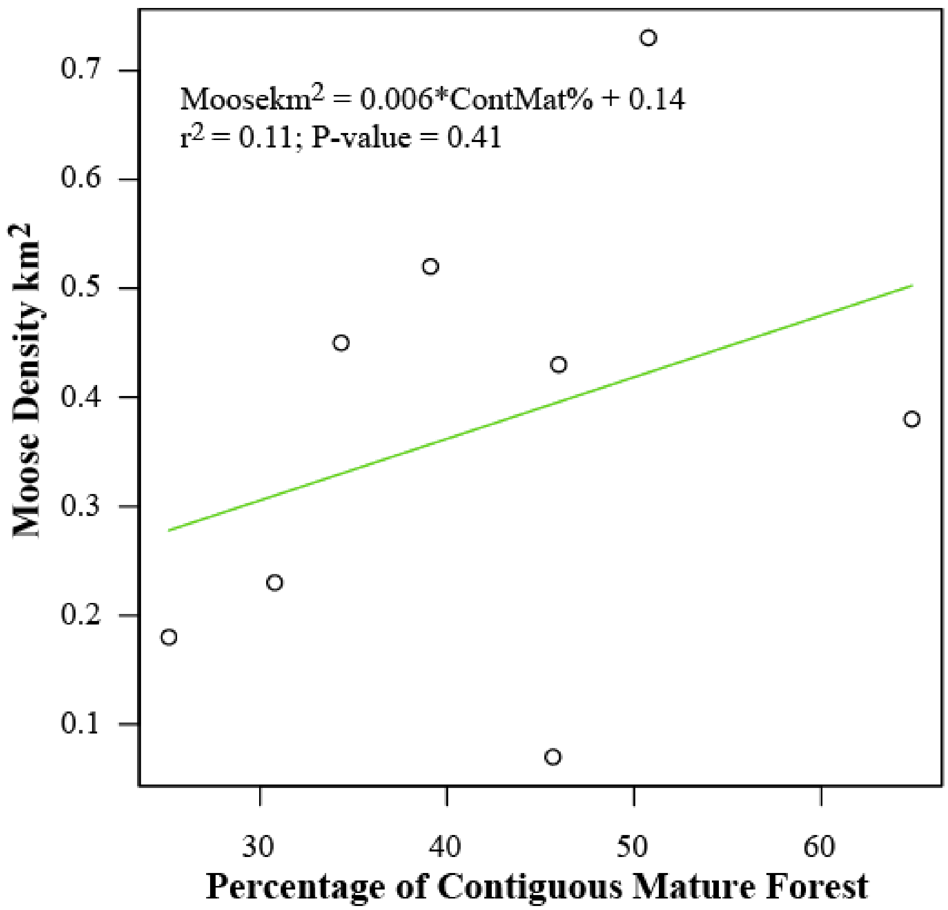


Figure 11: Linear regression of relationship of percentage of contiguous mature forest to moose density per square kilometer. The regression slope is positive but the relationship is non-significant with a r^2 = 0.11 and a P-value of 0.41

Correlation Analysis

There were a variety of landscape metrics that had some significant correlations amongst each other; however, there are few that illustrated any relationship with moose. The one exception illustrates moose density is negatively correlated to area of wetland as a proportion of the GHA (Figure 12).

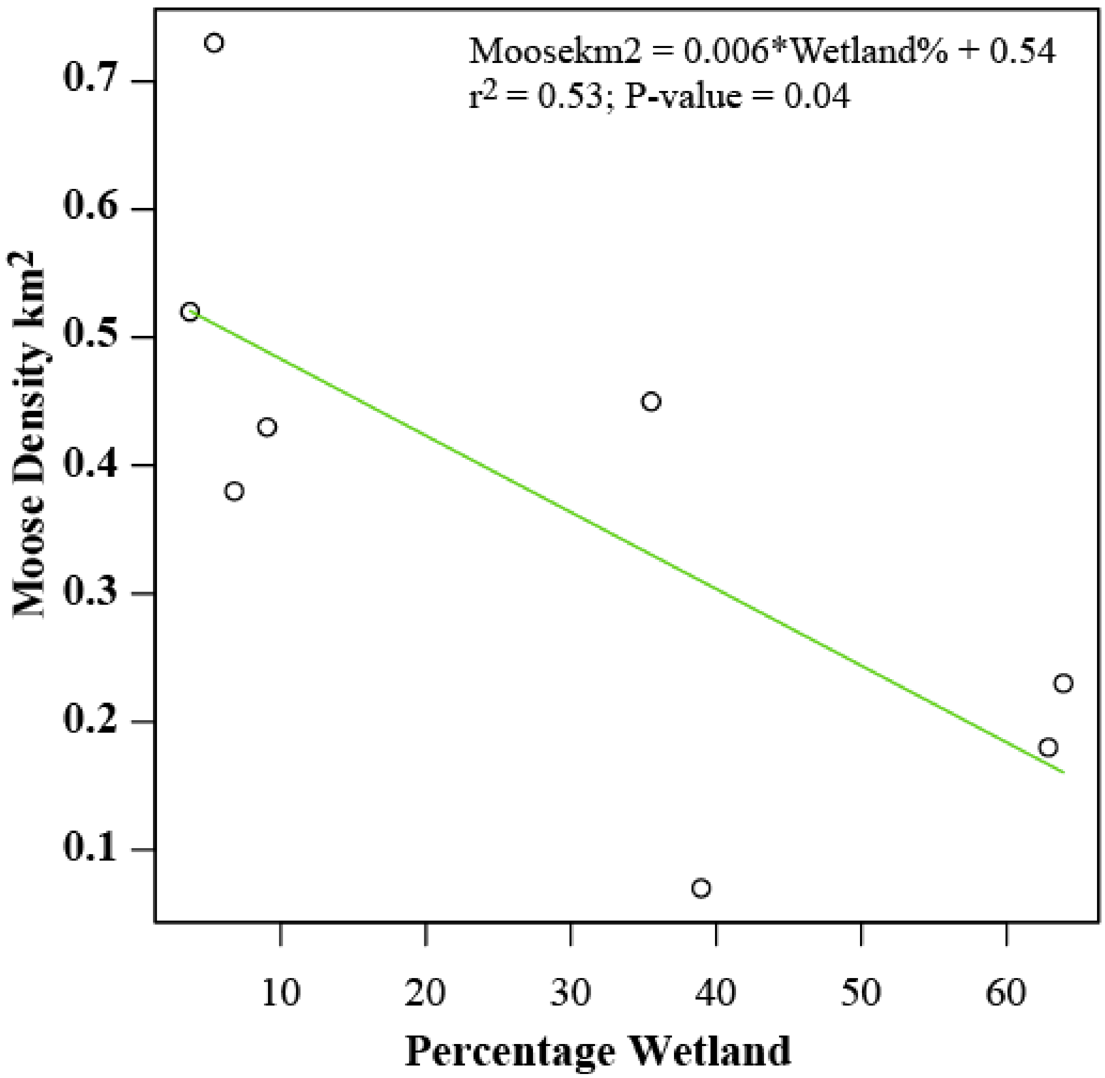


Figure 12: Linear regression of relationship of percent wetland to moose density per square kilometer. The regression slope is negative and the relationship is slightly significant with a r^2 = 0.53 and a P-value of 0.04

Appendix 5 shows the correlation between the pairs of variables in the rows and columns and only those that had a P-value of 0.05 or less are shown in the table. Insignificant relationships have been replaced by an asterisk.

7.2.1 Summary of Future Disturbance Regime

Although no threshold of disturbance or linear feature metric could be identified, Table 12 provides a summary of the calculated current habitat metrics for shrublands, contiguous forest, and linear feature density metrics as well as disturbance calculations for current forestry operations and drill holes for all GHAs in the Project Study Area. The assessment of future landscape conditions illustrates current and future linear disturbance metrics for the GHAs intersecting the Bipole III AFPR and FPR and is found in Table 13. The increase in linear density data illustrates the percentage change of current to future linear density. Overall, the degree of increase in linear density between the FPR and AFPR is minimal. Table 14 displays the length of the FPR and AFPR paralleling existing linear features, agriculture, and fragmented habitats.

Table 12: Summary of current disturbances in evaluation Game Hunting Areas

GHA	Habitat Area (km^2)	Shrubs (km^2)	Linear Corridor Density (km/km^2)	Linear Feature Length (km)	Contiguous Mature Forest (km^2)	Drill Holes (km^2)	Harvest (km^2) and % of GHA
12	2,426.93	113.52	0.05	129.44	752.04	0.29	17.06 (0.69%)
13	2,054.23	193.51	0.15	303.84	1,554.40	0.75	74.42 (2.20%)
14	4,497.94	29.49	0.10	441.43	2,410.59	0.00	7.05 (0.13%)
18	4,269.67	372.88	0.16	678.36	3,418.77	0.00	247.16 (3.28%)
19A	1,219.93	11.70	0.31	372.34	981.46	0.00	2.88 (0.15%)

Table 13: Summary of linear feature density and length metrics and future disturbance in the Game Hunting Areas intersected by the Bipole III Project within the Project Study Area

GHA	Current Linear Density (km/km^2)	Future Linear Density (including AFPR) (km/km^2)	Future Linear Density (including FPR) (km/km^2)	AFPR Increase in Linear Density (%)	FPR Increase in Linear Density (%)	Current Linear Length (km)	Future Linear Length (Includes AFPR and Future Forestry Access) (km)	Future Linear Length (Includes FPR and Future Forestry Access) (km)	AFPR Contribution to Linear Length (length and %)	FPR Contribution to Linear Length (length and %)	Future Drilling (km^2)	Future % of Forest Harvest Area
12	0.05	0.074	0.074	2.07	2.07	129.44	179.67	179.57	50.22 (27.95%)	50.13 (27.92%)	0.30	0.0047
14	0.10	0.143	0.141	4.51	4.26	441.43	644.25	633.09	59.55 (9.24%)	48.38 (7.64%)	0.00	0.0022
19A[3]	0.31	0.367	0.366	6.14	6.09	372.34	447.29	446.65	32.51(7.27%)	31.86 (7.13%)	0.00	0.00083

[3] Note that the size and extent of the bison ranch in GHA 19A was unknown at the time this report and analysis was conducted. It is anticipated that existing and future disturbance calculations are underestimated.

Table 14: Summary of lengths of the Bipole III FPR and AFPR paralleling existing linear features or disturbed areas

GHA	Type	FPR Length (km and %)	AFPR Length (km and %)
14A and 19A	Paralleling Disturbed Areas	19.64 (28.11%)	15.95 (21.44%)
	Total (Parallel and Not Parallel)	69.85 (100%)	74.38 (100%)
14 (Moose Meadows Area)	Paralleling Disturbed Areas	12.31 (41.63%)	13.83 (41.82%)
	Total (Parallel and Not Parallel)	29.58 (100%)	33.08 (100%)

7.3 Moose Population Modeling

7.3.1 GHA 12

Based on the scenarios modelled and results provided in Table 15, the average portion of the moose population harvested in GHA 12 from 1973 to 1998 ranged from 12% to 16%. Factoring the recorded average harvest into the model (approximately 16.5% of the population), the 1973 to 1991 modelled population estimate fell below the final MCWS population estimate of 650 moose in GHA 12. With an average harvest rate of 12% between 1991 and 1998, an additional mortality (classified under "other mortality") of 6% would have had to occur within GHA 12 in order to achieve the MCWS population estimate of 454 moose (Table 15).

7.3.2 GHA 13/13A

Based on the scenarios modelled and the results provided in Table 16, the average portion of the moose population harvested in GHA 13/13A ranged from 2.5 - 6.5 percent of the total population. To account for the possibility that one third of the western Manitoba moose population died from winter tick infestation in spring 2002, the 1997 population estimate was reduced by 33% (from 1,118 to 745) prior to modelling. This approach does not require assumptions about the relative rates of population change before and after 2002, it is conservative in the estimate of the amount of additional mortality required to yield the observed decline between population surveys by MCWS (i.e., it may underestimate the amount of additional mortality required). Assuming an average harvest rate of 6.5% between 1997 and 2007, additional mortality (other mortality) of 7% of the population each year would have had to occur within GHA 13/13A in order to achieve the 2007 final population estimate of 731 moose recorded by MCWS (Table 16). Final modelled population estimates for GHA 13/13A from 2007 to 2010 were consistently lower than the final population estimated reported MCWS (Table 16). Given an average harvest rate of 2.5% from 2010 and 2012, an additional mortality (other mortality) of 23% of the population each year would have had to occur within GHA 13/13A in order to achieve the 2012 final population estimate of 817 moose recorded by MCWS (Table 16).

7.3.3 GHA 14/14A

Based on the scenarios modelled and the results provided in Table 17, the average portion of the moose population harvested in GHA 13/13A ranged from 8.0 - 11.5%. As with GHA 13/13A models above, to account for the possibility that one third of the western Manitoba moose population died from winter tick infestation in spring 2002, the winter 2002 population estimate for GHA 14/14A was reduced by 33% (from 494 to 329) prior to modelling. As the survey was immediately prior to the winter tick mortality there were no assumptions required about the population to which the correction was applied. The average licensed harvest rate of 8.0% occurring from 1983 and 1992 was sufficient to achieve the 1992 final population estimate of 2,480 moose recorded by MCWS (Table 17). Given an average harvest rate of 11.5% between 1992 and 2002, additional mortality (other mortality) of 20% of the population each year would have had to occur within GHA 14/14A in order to achieve the 2002 final population estimate of 494 moose recorded by MCWS (Table 17). Finally, given an average harvest rate of 1.3% between 2002 and 2012, additional mortality (other mortality) of 21% of the total population each year would have had to occur within GHA 14/14A in order to achieve the 2012 final population estimate of 148 moose recorded by MCWS (Table 17).

Table 15: Results of moose population modelling for GHA 12

Model Type	Time Span	MCWS Initial Pop Estimate	MCWS Final Pop Estimate	Average Number of Moose Harvested/Year	Year of Harvest Data Used	Average Portion of Pop Harvested by Licensed Hunters (SE)	Other Annual Mortality	Modelled Population Estimate
No Harvests	1973 to 1991	518	650	0	n/a	0.00 (0.00)	0.00	1,180
Licensed Harvest	1973 to 1991	518	650	95	1977 to 1988	0.17 (0.02)	0.00	442
No Harvests	1991 to 1998	650	454	0	n/a	0.00 (0.00)	0.00	1,436
Licensed Harvest	1991 to 1998	650	454	62	1994 to 1998	0.12 (0.02)	0.00	691
Other Mortality	1991 to 1998	650	454	62	1994 to 1998	0.12 (0.02)	0.06	459

Table 16: Results of moose population modelling for GHA 13/13A

Model Type	Time Span	MCWS Initial Pop Estimate*	MCWS Final Pop Estimate	Average Number of Moose Harvested/Year	Year of Harvest Data Used	Average Portion of Pop Harvested by Licensed Hunters (SE)	Other Annual Mortality	Modelled Population Estimate
No Harvests	1997 to 2007	1,118(745)	731	0	n/a	0.00 (0.00)	0.00	2,420
Licensed Harvest	1997 to 2007	1,118(745)	731	55	1997 to 2007	0.07 (0.02)	0.00	1,645
Other Mortality	1997 to 2007	1,118(745)	731	55	1997 to 2007	0.07 (0.02)	0.07	720
No Harvests	2007 to 2010	731	1,122	0	0	0.00 (0.00)	0.00	1,003
Licensed Harvest	2007 to 2010	731	1,122	31	2007 to 2010	0.04 (0.01)	0.00	905
No Harvests	2010 to 2012	1,122	817	0	n/a	0.00 (0.00)	0.00	1,384
Licensed Harvest	2010 to 2012	1,122	817	25.5	2010 to 2011	0.03 (0.01)	0.00	1,319
Other Mortality	2010 to 2012	1,122	817	25.5	2010 to 2011	0.03	0.23	823

*Where they appear, initial population values in parentheses were used as model input to reflect population decline from winter tick in 2002

Table 17: Results of moose population modelling for GHA 14/14A

Model Type	Time Span	MCWS Initial Pop Estimate*	MCWS Final Pop Estimate	Average Number of Moose Harvested/Year	Year of Harvest Data Used	Average Portion of Pop Harvested by Licensed Hunters (SE)	Other Annual Mortality	Modelled Population Estimate
No Harvests	1983 to 1992	1,560	2,480	0	n/a	0.00 (0.00)	0.00	3,971
Licensed Harvest	1983 to 1992	1,560	2,480	158	1983 to 1988	0.08 (0.02)	0.00	2,319
No Harvests	1992 to 2002	2,480	494	0	n/a	0.00 (0.00)	0.00	6,727
Licensed Harvest	1992 to 2002	2,480	494	94	1994 to 2002	0.12 (0.08)	0.00	3,568
Other Mortality	1992 to 2002	2,480	494	94	1994 to 2002	0.12 (0.08)	0.20	470
No Harvests	2002 to 2012	494(329)	148	0	n/a	0.00 (0.00)	0.00	1,059
Licensed Harvest	2002 to 2012	494(329)	148	3	2003 to 2011	0.01 (0.01)	0.00	1,021
Other Mortality	2002 to 2012	494(329)	148	3	2003 to 2011	0.01 (0.01)	0.16	146

*Where they appear, initial population values in parentheses were used as model input to reflect population decline from winter tick in 2002

8.0 DISCUSSION AND CONCLUSION

The regression analyses to determine a potential threshold for assessing cumulative effects of habitat change (including linear corridors and fragmentation) failed to yield any useful results. Therefore, it was not possible to determine a potential threshold value for moose based on landscape or linear features in the region. This is also supported through our evaluation of available literature on habitat and fragmentation thresholds specifically for moose. The explanation of moose decline in the area as a result of increased linear development was not supported by this analysis. In contrast, moose populations in southern Saskatchewan have apparently increased in some areas within highly fragmented farmlands. Although no spatial data were available to assess linear density in southern Saskatchewan, it would be expected that moose density and linear features would not be negatively correlated. Similarly, in RMNP, moose populations have fluctuated while linear feature density has remained constant. The potential future effects of other resource development were also assessed, resulting in limited predicted future disturbance and linear development in GHAs 14/14A and 19A, where the AFPRs are proposed. The total increase in linear features within each GHA predicted in the future are 2.07% for GHA 12, 4.51% for GHA 14, and 6.14% for GHA 19A. In summary, landscape and linear development do not explain moose decline in western Manitoba.

Overall, moose productivity is high in western Manitoba and MCWS moose survey results since 1990 document calf:cow ratios consistent with those observed in increasing populations. Yet western Manitoba moose populations declined during that period. As to potential causes of decline, Gasaway et al. (1992, p. 16) showed recruitment of 0.22 calves per cow during a period of moose population decline in Alaska and associated a population with 0.64 calves per cow as undergoing a population irruption (i.e., a rapid increase). They later noted (Gasaway et al., 1992, p. 27) that predation was the primary cause of calf mortality during observed population declines. Keech et al. (2011) reported calf survival rates of 0.30 when predators were present. In western Manitoba, moose surveys conducted by MCWS since 1990 (n=19) had a mean calf:cow ratio of 0.52, much higher than might be expected in populations with high levels of predation. Evidence of high predation should include poor recruitment, and the data from western Manitoba show that recruitment is sufficient for population increases.

In the absence of support for regional moose population declines being related to linear features or to predators that might use those linear features for access, an explanation other than predation is required for the population declines. Population models show that while some limitation on population increase is attributable to licensed hunting (e.g., GHA 14/14A prior to 1992), most populations in nearly all time intervals require the action of some unknown agent(s) to yield the observed decline. This is particularly noticeable for GHA 14/14A where mortality over and above licensed hunting needs to average between

16% and 20% of the annual standing crop of moose. This average additional annual mortality needs to persist for the entire period from 1992 to 2011 to account for the observed population decline. In the 1990s this would be in the order of 300 to 500 moose annually. From the model results and MCWS survey data, the unknown sources of mortality leave high calf:cow ratios yet can, in some areas, remove an average of more than of 15% of the population each year for many consecutive years (e.g., GHA 14/14A from 1992 to 2011). In the presence of data inconsistent with high predation rates, and the absence of evidence for high rates of parasite or disease related mortality, the most plausible explanation for the population declines is hunting.

Consequently, the level of moose mortality that could arise from the AFPR (hunting and predation related to increased access) is difficult to predict. Mitigation efforts are expected to benefit moose and adaptive management will be required as described in the Bipole III EIS. Based on the results of this enhanced analysis there is no change to the original conclusions in the *Bipole III EIS*, *Bipole III Mammal Technical Report*, and the *Route Adjustment Supplemental Report for the Bipole III Transmission Line*. In summary, with either the AFPR or the FPR for the HVdc transmission line component of the Project and mitigation as described in Chapter 6 (in the *Route Adjustment Supplemental Report)*, the cumulative effects of the Project in combination with other past, current, and future projects are not expected to result in significant residual adverse effects on moose.

9.0 REFERENCES

Ballard, W.B., A.F. Cunning, and J.S. Whitman. 1988. Hypotheses of Impacts on Moose due to Hydroelectric Projects. Alces 24: 34–47.

Ballard, W.B., J.S. Whitman, and D.J. Reed. 1991. Population dynamics of moose in south-central Alaska. Wildlife Monographs 114: 1-49.

Canter, L., Ross, B. 2010. State of practice of cumulative effects assessment and management: the good, the bad and the ugly. Impact Assessment and Project Appraisal 28(4): 261-268.

Carroll, C., R.F. Noss., and P.C. Paquet. 2001. Carnivores as focal species for conservation planning in the Rocky Mountain region. Ecological Applications. 11(4): 961- 980.

Caughley, G. 1977. Analysis of vertebrate populations. John Wiley and Sons Ltd., New York.

CCWHC (Canadian Cooperative Wildlife Health Centre). 2002. Wildlife Damage Management Internet Center for Newsletter and Publication. Volume 9-1, Winter 2002.

Courbin, N., D. Fortin, C. Dussault, and R. Courtois. 2009. Landscape management for woodland caribou: The protection of forest blacks influences wolf-caribou co-occurrence. Landscape Ecology. 24: 1375-1388.

Crichton, V., Barker, T., & Schindler, D. W. (2004). Response of a wintering moose population to access management and no hunting - A Manitoba experiment. Alces 40: 87-94.

Duinker, P.N. 1994. Cumulative effects assessment: What’s the big deal? Pages 11–24 in A. J. Kennedy (ed.), Cumulative effects assessment in Canada: From concept to practice. Alberta Society of Professional Biologists, Calgary, Alberta.

Environment Canada. 2012. Recovery Strategy for the Woodland Caribou (Rangifer tarandus caribou), Boreal population, in Canada. Species at Risk Act Recovery Strategy Series. Environment Canada, Ottawa. xi + 138pp.

ESRI. 2011. ArcGIS Desktop: Release 9.3. Redlands, CA: Environmental Systems Research Institute.

Gasaway, W.C., R.C. Boertje, D.V. Grangaard, D.G. Kelleyhouse, R.O. Stephenson, and D.G. Larsen. 1992. The role of predation in limiting moose at low densities in Alaska and Yukon and implications for conservation. Wildlife Monographs 120: 1-59.

Gillingham, M.P., and K.L. Parker. 2008. The Importance of Individual Variation in Defining Habitat Selection by Moose in Northern British Columbia. Alces 44: 7–20.

Government of Saskatchewan. 2012a. News Release June 8, 2012: Moose Population Increasing in Southern Saskatchewan. http://www.gov.sk.ca/news?newsId=e94c4341-c0a4-44e1-ace6-844defc5721b

Government of Saskatchewan. 2012b. 2012 Supplement Moose Draw.

http://www.environment.gov.sk.ca/adx/aspx/adxGetMedia.aspx?DocID=3b96dd49-4c00-4c93-8fca-6062430f88ef

Greater Fundy Ecosystem Research Group. 2005. Forest Management Guidelines to Protect Native Biodiversity in the Greater Fundy Ecosystem (M. G. Betts and G. J. Forbes, editors). Parks Canada. 127 pp.

Heckbert, S., W. Adamowicz, P. Boxall, and D. Hanneman. 2010. Cumulative Effects and Emergent Properties of Multiple-Use Natural Resources. Multi-Agent-Based Simulation X Lecture Notes in Computer Science 5683: 1–13.

Hegmann, G., C. Cocklin, R. Creasey, S. Dupuis, A. Kennedy, L. Kingsley, W. Ross, H. Spaling, and D. Stalker. 1999. Cumulative Effects Assessment Practitioners Guide. Prepared by AXYS Consulting Ltd. and the CEA Working Group for the Canadian Environemtnal Assessment Agency, Hull, Quebec. 134 pp.

James, A. R. C., and A. K. Stuart-Smith. 2000. Distribution of Caribou and Wolves in Relation to Linear Corridors. The Journal of Wildlife Management 64 (1): 154–159.

Jalkotzy, M. G., P. I. Ross, and M. D. Nasserden. 1997. The Effects of Linear Developments on Wildlife: A Review of Selected Scientific Literature. Prep. for Canadian Association of Petroleum Producers. Arc Wildlife Services Ltd., Calgary. 115 pp.

Joyal, R., P. Lamothe, and R. Fournier. 1984. L’utilisation des emprises de lignes de transport d'energie electrique par l'orignal (Alces alces) en hiver. Canadian Journal of Zoology 62: 260–266.

Karns, P.D. Population Distribution, Density and Trends. 1998. Pages 125-139 *in* A.W. Franzmann and C.C. Schwartz, editors. Ecology and Management of the North American Moose, 2nd edition. University Press of Colorado. Boulder, CO.

Keech, M.A., M.S. Lindberg, R.D. Boertje, P. Valkenburg, B.D. Taras, T.A. Boudreau, and K.B. Beckmen. 2011. Effects of predator treatments, individual traits, and environment on moose survival in Alaska. Journal of Wildlife Management 75: 1361-1380.

Keenan, V. and T. Munn. 2008. Local level indicators of sustainable forest management for FML 01. Prepared for Tembec Enterprises. Forest Resource Management, Pine Falls Operations.

Kopcha, M., J.S. Rook, and D. Hostetler. 2012. *P. tenuis* – The White-tailed Deer Parasite. Michigan State University. http://old.cvm.msu.edu/extension/Rook/ROOKpdf/brainwormkaren.PDF. Accessed August 13, 2012.

Kunkel, K.E., and D.H. Pletscher. 2000. Habitat factors affecting vulnerability of moose to predation by wolves in southeastern British Columbia. Canadian Journal of Zoology 157: 150–157.

Lankester, M.W and W.M. Samuel. 1998. Pests, Parasites and Diseases. Pages 495-502 *in* A.W. Franzmann and C.C. Schwartz, editors. Ecology and Management of the North American Moose, 2nd edition. University Press of Colorado. Boulder, CO.

Lankester, M. W.2010. Understanding the impact of meningeal worm, *Parelaphostrongylus tenuis*, on moose populations. Alces 46: 53-70.

Larsen, D.G., D.A. Gauthier, and R.L. Markel. 1989. Causes and rate of moose mortality in the southwest Yukon. Journal of Wildlife Management 53: 548-557.

Laurian, C., C. Dussault, J.-P. Ouellet, R. Courtois, M. Poulin, and L. Breton. 2008. Behavior of moose relative to a road network. Journal of Wildlife Management 72: 1550-1557.

Laurian, C., C. Dussault, J.-P. Ouellet, R. Courtois, and M. Poulin. 2012. Interactions between a Large Herbivore and a Road Network. Ecoscience 19: 69–79.

Lenarz, M.S., J. Fieberg, M.W. Schrage, and A.J. Edwards. (2010). Living on the Edge: Viability of Moose in Northeastern Minnesota. Journal of Wildlife Management 74: 1013-1023.

McLaren, B.E., B.A. Roberts, N. Djan-Chekar, and K.P. Lewis. 2004. Effects of overabundant moose on the Newfoundland landscape. Alces 40: 45–59.

McLaren, B.E., S. Taylor, and S.H. Luke. 2009. How moose select forested habitat in Gros Morne National Park Newfoundland. Alces 45: 125–135.

McLaughlin, R.F. and E.M. Addison. 1986. Tick (*Dermacentor albipictus*)- induced winter hair-loss in captive moose (*Alces alces*). Journal of Wildlife Disease 22: 502-510.

MCWS (Manitoba Conservation and Water Stewardship). 2012. 2012 Manitoba Hunting Guide. Manitoba Conservation, Wildlife and Ecosystem Protection Branch. Winnipeg, Manitoba.

MCWS. 2013. Wildlife Disease – Chronic Wasting Disease. Accessed February 1st 2013. Available at: http://www.gov.mb.ca/conservation/wildlife/disease/cwd.html

MCWS. 2013. Data source from data sharing agreement for this Project.

MCWS, Unpublished and undated information on the results of moose surveys conducted in the Beaver Creek area of eastern Manitoba documenting a local moose population response to access restrictions and continued hunting. (Slide presentation provided by Kelly Leavesley, Regional Wildlife Manager).

Mercer, W.E., and B.E. McLaren. 2002. Evidence of carrying capacity effects in Newfoundland moose. Alces 38: 123–141.

Modafferi, R.D., and E.F. Becker. 1997. Survival of radiocollared adult moose in lower Susitna River Valley, southcentral Alaska. Journal of Wildlife Management 61: 540-549.

MSES. 2013. Ungulate information gaps: Manitoba Hydro January 2013 Supplemental Report for the Bipole III Transmission Line Project. Management and Solutions in Environmental Science, unpublished report prepared for the Manitoba Metis Federation, February 2013, 5 pages.

Mytton, W.R., and L.B. Keith. 1981. Dynamics of moose populations near Rochester, Alberta, 1975-1978. Canadian Field-Naturalist 95: 39-49.

Noble, B.F. 2010. Cumulative environmental effects and the tyranny of small decisions: Towards meaningful cumulative effects assessment and management. Natural Resources and Environmental Studies Institute Occasional Paper No. 8. University of Northern British Columbia, Prince George, BC.

OMNR (Ontario Ministry of Natural Resources). 2009. Moose Population Objectives Setting Guidelines. 15pp.

Parks Canada. 2013. Data source from Riding Mountain National Park from data sharing agreement for this project.

Pimlott, D.H. 1953. Newfoundland moose. Transactions North American Wildlife Conference 18: 563-581.

Pimlott, D.H. 1959. Reproduction and productivity of Newfoundland moose. Journal of Wildlife Management 23: 381-401.

Rempel, R.S., P.C. Elkie, A.R. Rodgers, and M.J. Gluck. 1997. Timber-Management and Natural-Disturbance Effects on Moose Habitat: Landscape Evaluation. The Journal of Wildlife Management 61(2): 517-524.

Ricard, J.-G., and G.J. Doucet. 1999. Winter use of powerline rights-of-way by moose (Alces alces). Alces 35: 31–40.

Ross, W.A. 1994. Assessing cumulative environmental effects: Both impossible and essential. Keynote address, in Conference on Cumulative Effects Assessment in Canada: From Concept to Practice, A Kennedy (ed.), Calgary, AB: Alberta Society of Professional Biologists.

Salmo Consulting Inc., Diversified Environmental Services, GAIA Consultants Inc., Forem Technologies Ltd., and Axys Environmental Consulting Ltd. 2003. Volume 2 Cumulative Effects Indicators, Thresholds, and Case Studies. Calgary, AB. Prepared for British Columbia Oil and Gas Commission and Muskwa-Kechika Advisory Board. 83 pp.

Salmo Consulting Inc., AXYS Environmental Consulting Ltd., Forem Technologies, and Wildlife & Company Ltd. 2004. Deh Cho Cumulative Effects Study Phase 1 : Management Indicators and Thresholds.Calgary, AB. Prepared for Deh Cho Land Use Planning Committee. 172 pp.

Sallows, T.A. 2007. Diet Preference and Parasites of Grey Wolves in Riding Mountain National Park of Canada. M.Env. Thesis, University of Manitoba. 100 pp.

Samuel, W.M. 2004; in Leighton, F.A. 2011. Wildlife pathogens and diseases in Canada. Canadian Biodiversity: Ecosystem Status and Trends 2010, Technical Thematic Report No. 7. Canadian Councils of Resource Ministers. Ottawa, ON. iv + 53 p.

Samuel, W.M. 2007. Factors affecting epizootics of winter ticks and mortality of moose. Alces 43: 39-48.

Samuel, W.M. and D.A. Welch. 1991. Winter ticks on moose and other ungulates: factors influencing their population size. Alces 27: 169-182.

Schwartz, C.C. 1997. Reproduction, natality, and growth. Chapter 4, pp.141-171 in Ecology and management of the North American moose, A.W. Franzmann and C.C. Schwartz, editors. Smithsonian Institution Press, Washington.

Soprovich, D. 2012. Presentation at Manitoba Clean Environment Commission hearings on Bipole III for Peguis First Nation, November 21, 2012. Unpublished report, 12 pages unpaginated.

Stein, J.T. 2000. The Effects of Roads on Wolves and Bears Worldwide, Chapter 4 in Stein, J.T., From Extermination to Reintroduction: A Snapshot of North American Large Carnivore Conservation at the Millennium. Unpublished Master's Thesis, Yale School of Forestry and Environmental Studies, New Haven.

Stewart, A., P.E. Komers, and D.J. Bender. 2010. Assessing Landscape Relationships for Habitat Generalists. Ecoscience 17: 28–36.

Taylor, M., M. Obbard, B. Pond, M. Kuc, and D. Abraham. 2006. RISKMAN, Version 1.9.003. Queen's Printer for Ontario.

Testa, J.W. 2004. Population dynamics and life history trade-offs of moose (*Alces alces*) in south-central Alaska. Ecology 85: 1439-1452.

Thomas, D. 1995. A review of wolf-caribou relationships and conservation implications in Canada. Pages 261-273 *in* L.N. Carbyn, S.H. Fritts and D.R. Seip, editors. Ecology and conservation of wolves in a changing world. Canadian Circumpolar Institute, Occasional Publication No. 35, University of Alberta, Edmonton, Alberta. 624 pp.

University of Saskatchewan. 2013. U of S to initiate new moose research in rural Saskatchewan. Website: https://agbio.usask.ca/index.php?mact=News,cntnt01,detail,0&cntnt01articleid=279&cntnt01origid=52&cntnt01returnid=2804 (Accessed: 07 February 2013).

Waring, G.H., J.L. Griffis, M.E. Vaughn. 1991. White-tailed deer roadside behavior, wildlife warning reflectors, and highway mortality. Applied Animal Behaviour Science. 29(1–4): 215-223.

Wasel, S.M., W.M. Samuel, and V. Crichton. 2003. Distribution and ecology of meningeal worm, Parelaphostrongylus tenuis (Nematoda), in northcentral North America. Journal of Wildlife Diseases. 39: 338-346.

Wasser, S.K., J.L. Keim, M.L. Taper, and S.R. Lele. 2011. The influences of wolf predation, habitat loss, and human activity on caribou and moose in the Alberta oil sands. Frontiers in Ecology and the Environment 9: 546–551.

Weber, M.G., and Stocks, B.J. 1998. Forest fires and sustainability in the boreal forests of Canada. Ambio 27(7): 545-550.

Welch, D.A., W.M. Samuel and C.J. Wilke. 1991. Suitability of Moose, Elk, mule deer, and white-tailed deer as host for winter ticks (*Dermacentor albipictus*). Canadian Journal of Zoology 69(2): 2300-2305.

Wilson, P.J., S. Grewal, A. Rodgers, R. Rempel, J. Saquet, H. Hristienko, F. Burrows, R. Peterson, and B.N. White. 2003. Genetic variation and population structure of moose (*Alces alces*) at neutral and functional DNA loci. 683: Canadian Journal of Zoology 81: 670–683.

Wilton, M.L. and D.L. Garner. 1993. Preliminary observations regarding mean April temperatures as a possible predictor of tick-induced hair loss in moose in south central Ontario, Canada. Alces 29: 197-200.

Yost, A.C., and R.G. Wright. 2001. Moose, Caribou, and Grizzly Bear Distribution in Relation to Road Traffic in Denali National Park, Alaska. Arctic 54: 41–48.

Yuhki, N., and S.J. O'Brien. 1990. DNA variation of the mammalian major histocompatibility complex reflects genomic diversity and population history. Proc. Natl. Acad. Sci. U.S.A. 87: 836–840.

Personal Communications

Bollinger, T. 2012. Western and Northern Regional Director. Canadian Cooperative Wildlife Health Centre, Saskatoon, Saskatchewan. Email communication 05 December 2012.

Hwang, Y.T. 2012. Team Lead, Chief Ecologist. Ministry of Environment. Government of Saskatchewan. Email communication 19 December 2012.

Kowal, E. 2013. Area Wildlife Ecologist. Ministry of Environment. Government of Saskatchewan. Phone communication February 2013

Rebizant, K. 2012. Big Game Manager. Game, Fur and Problem Wildlife. Manitoba Conservation and Water Stewardship. Email communication 14 December 2012.

Sallows, T. 2012. Park biologist, Riding Mountain National Park. Parks Canada, Manitoba.

Tether, R. 2013. Wildlife Ecologist. Ministry of Environment. Government of Saskatchewan. Email communication 07 January 2013.

APPENDIX 1: AERIAL SURVEY OF GHA 14A AND 19A, JANUARY 2013

Methods - 2013 Aerial Survey

An intensive moose survey was completed within the Moose Meadows January 4 and 5, 2013. A Bell 407 helicopter was utilized to fly along aerial transects spaced 500 m apart. Flights were flying in a north-south direction, with the field staff consisted of four people (three observers and one recorder). Altitude of the aircraft varied from 200 to 400 ft due to variations in cover type and light for wildlife viewing purposes. Speed of the aircraft varied with canopy density and daylight.

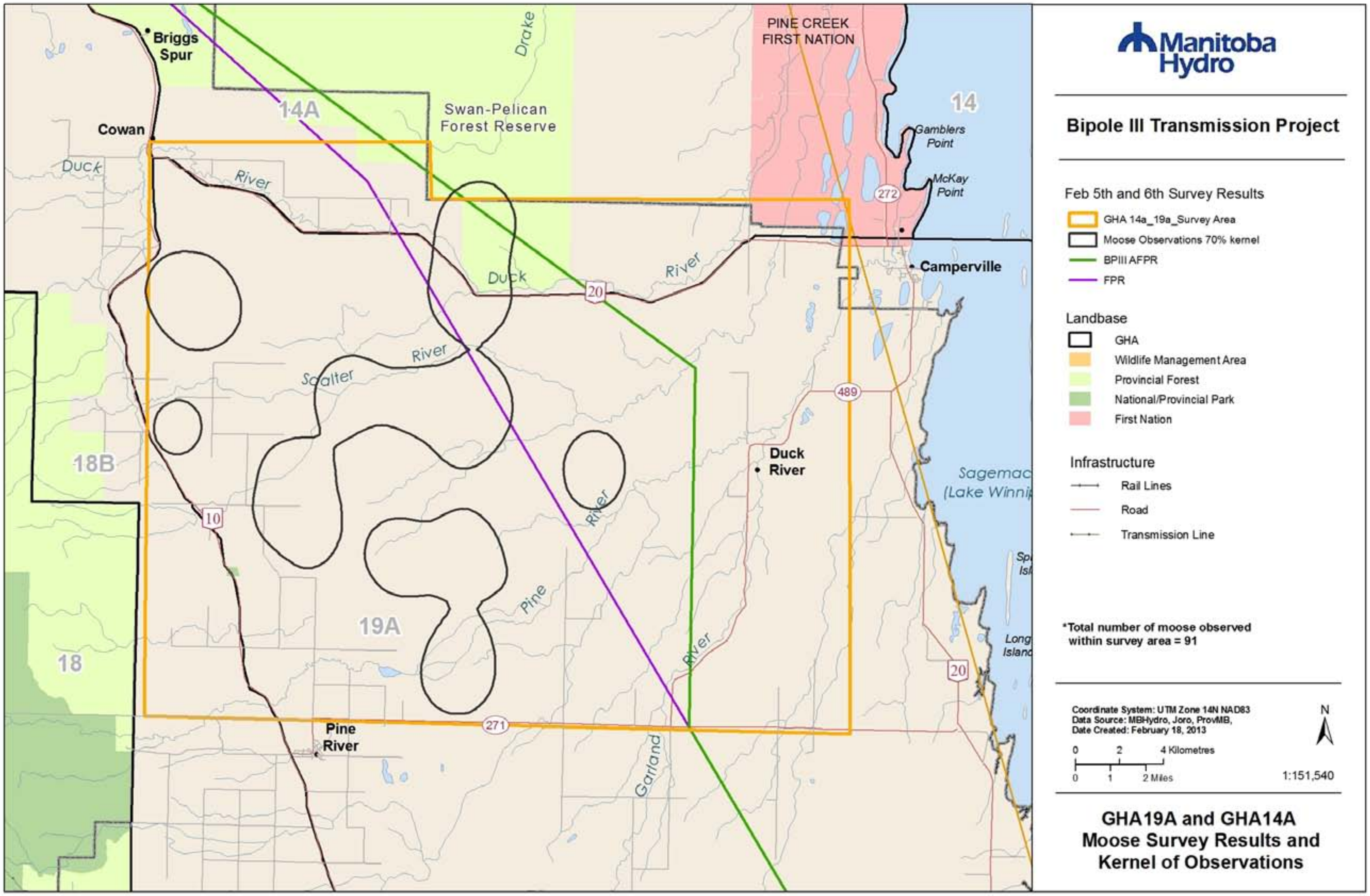
The survey area was designed to cover areas of GHA 19 A but also included the southern edge of GHA 14A (Map A1). The survey covered a total area of 778.87 km^2, of that area 675.17 km^2 consisted of GHA 19A and 103.7 km^2 consisted of GHA 14A. Age/sex of moose was identified whenever possible. Care was taken to ensure moose were not double counted by identifying moose locations on the GPS and group composition. GPS locations were recorded using handheld GPS units. Survey tracks and waypoints were downloaded daily to ensure proper data management.

Results - 2013 Aerial Survey

A total of 91 moose were observed across the aerial survey area. A total of 13 moose were observed in GHA 14A (4 cows, 2 calves, and 7 moose of unknown sex) and 78 were observed in GHA 19A (9 bulls, 24 cows, 21 calves, and 24 moose of unknown sex).

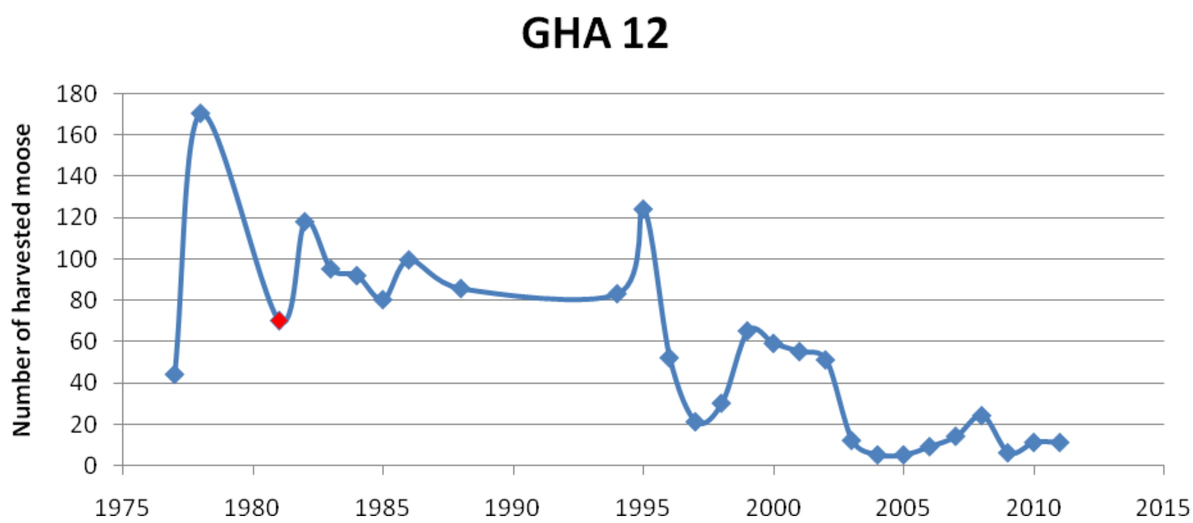
Total number of moose observations during January 4 to 5 GHA 19A and 14A survey

GHA	Bulls	Cows	Calves	Unknown	Total
14A	0	4	2	7	13
19A	9	24	21	24	78
Total	9	28	23	31	91

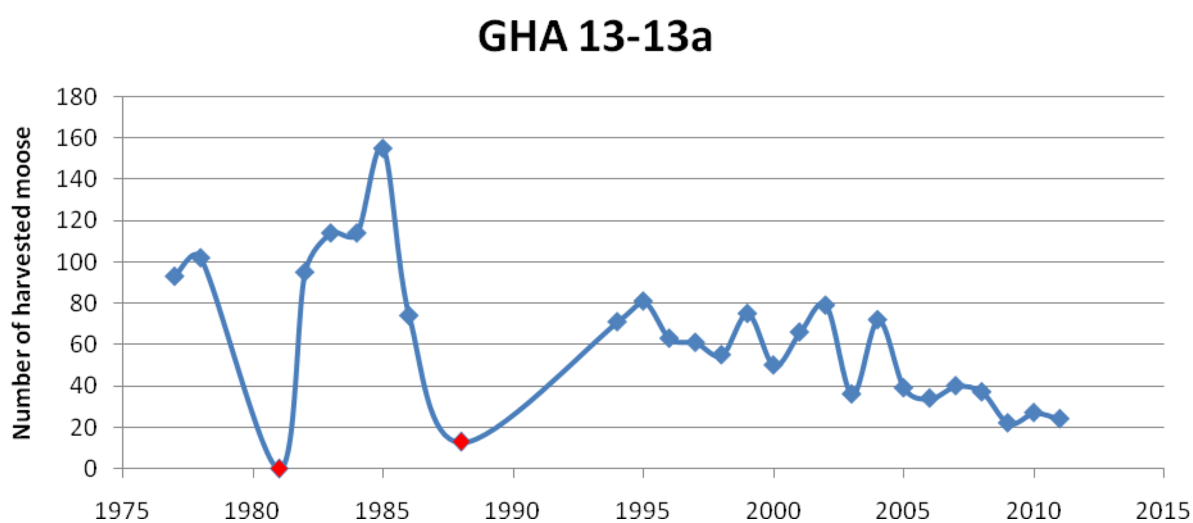


Map A1: GHA 19A and 14A moose survey area

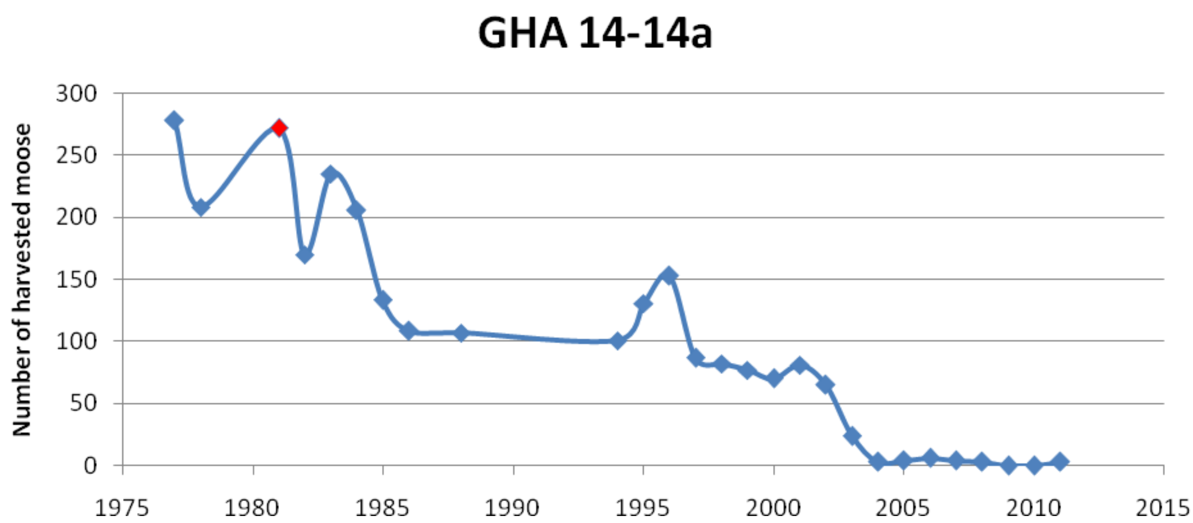
APPENDIX 2: HARVEST NUMBERS PER GHA



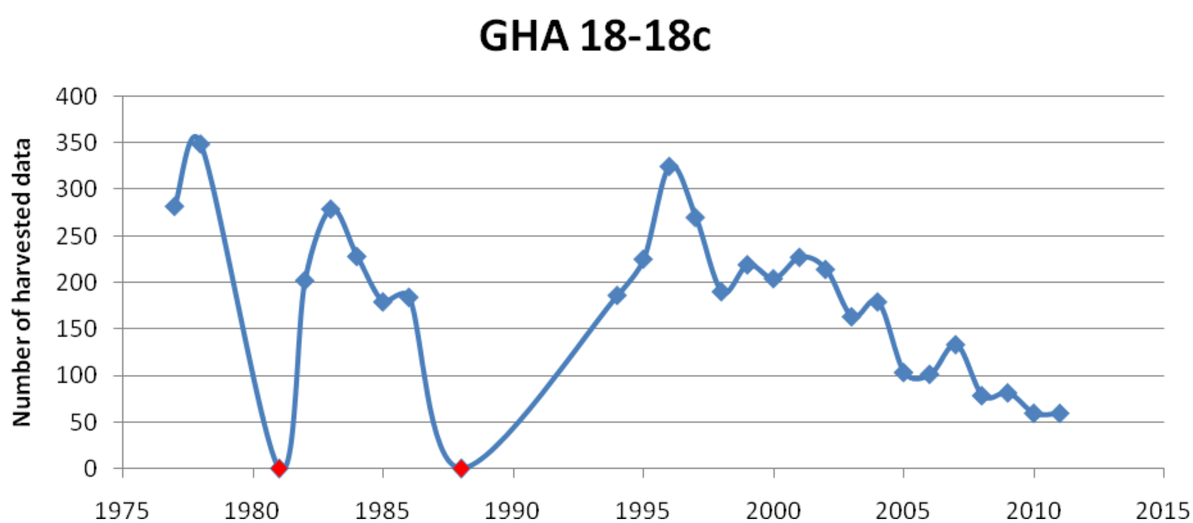
* Year indicated in red had no special season data



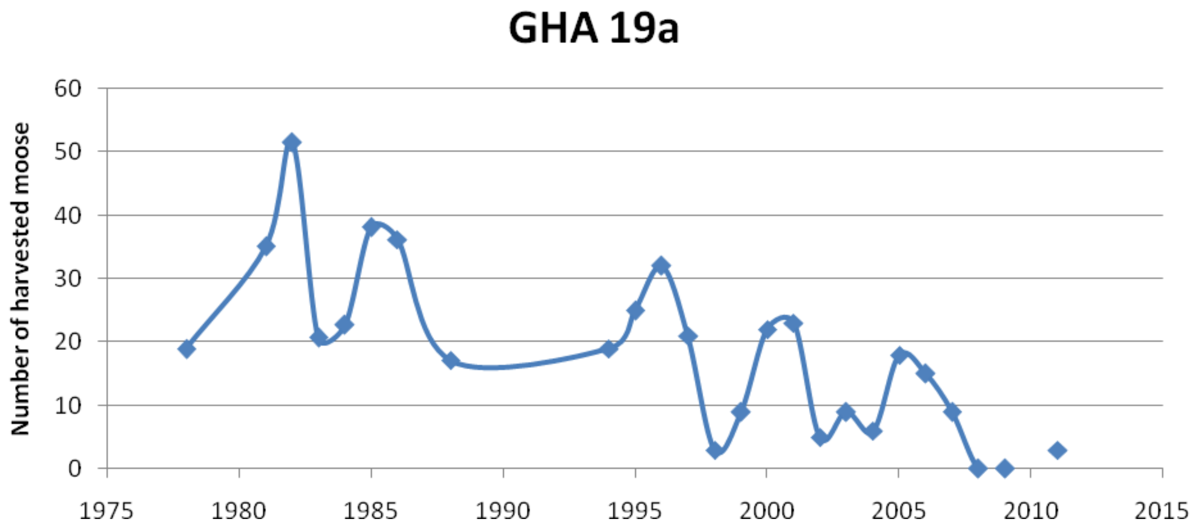
* Year indicated in red had no special season data



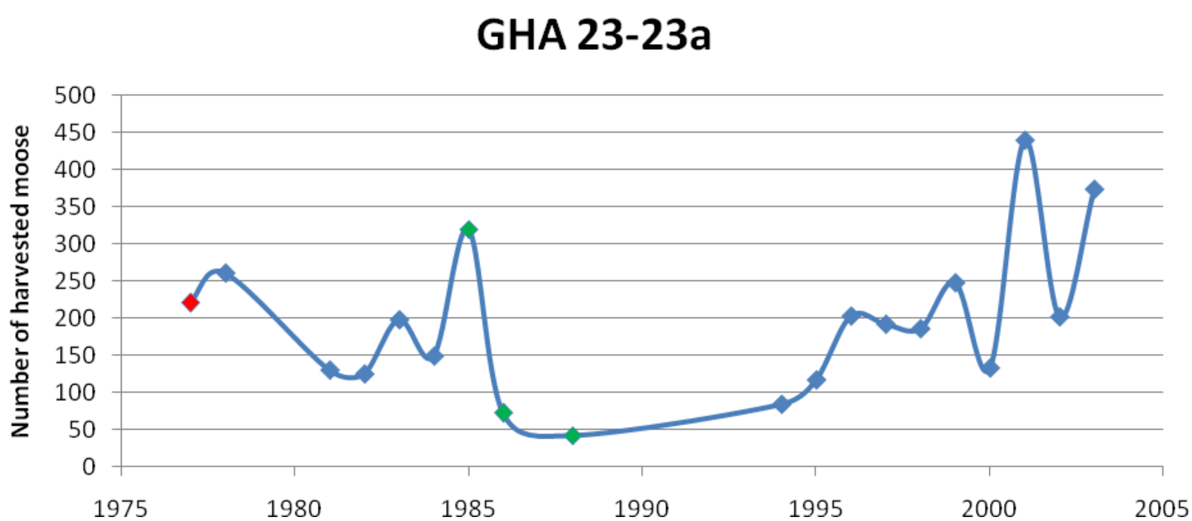
* Year indicated in red had no special season data



* Year indicated in red had no special season data

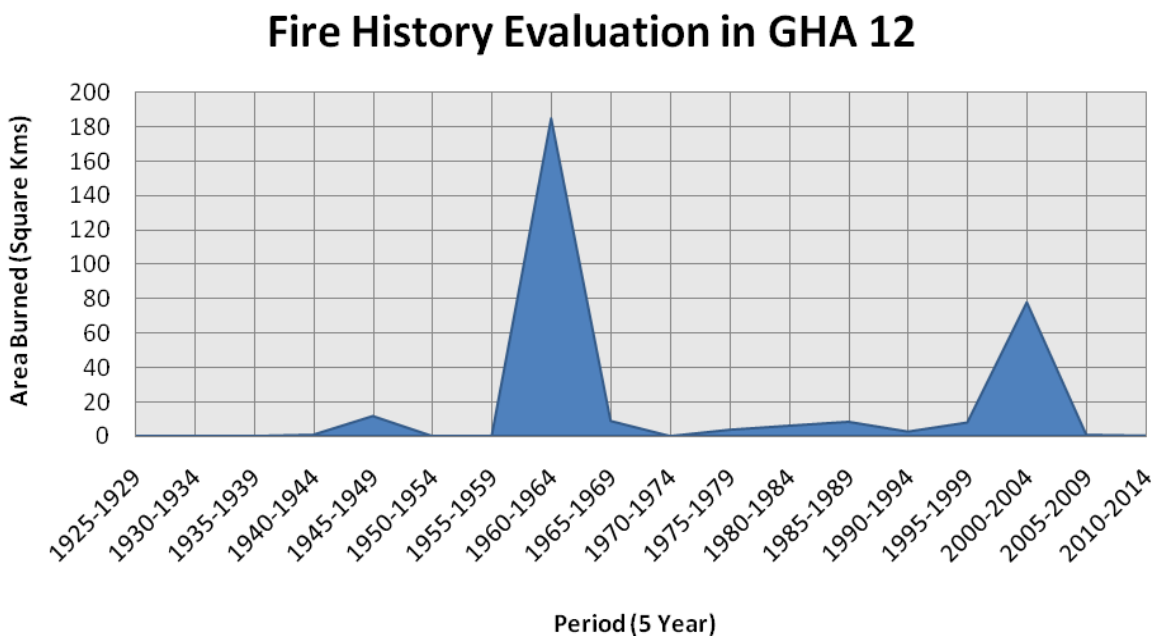


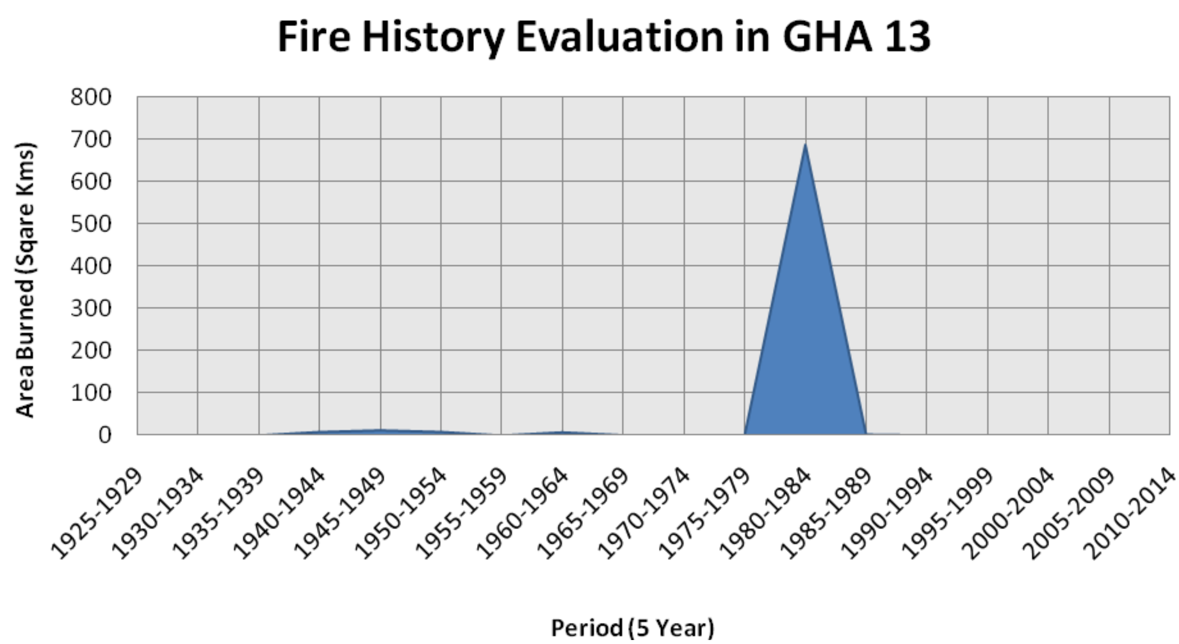
[*] No special season for this GHA

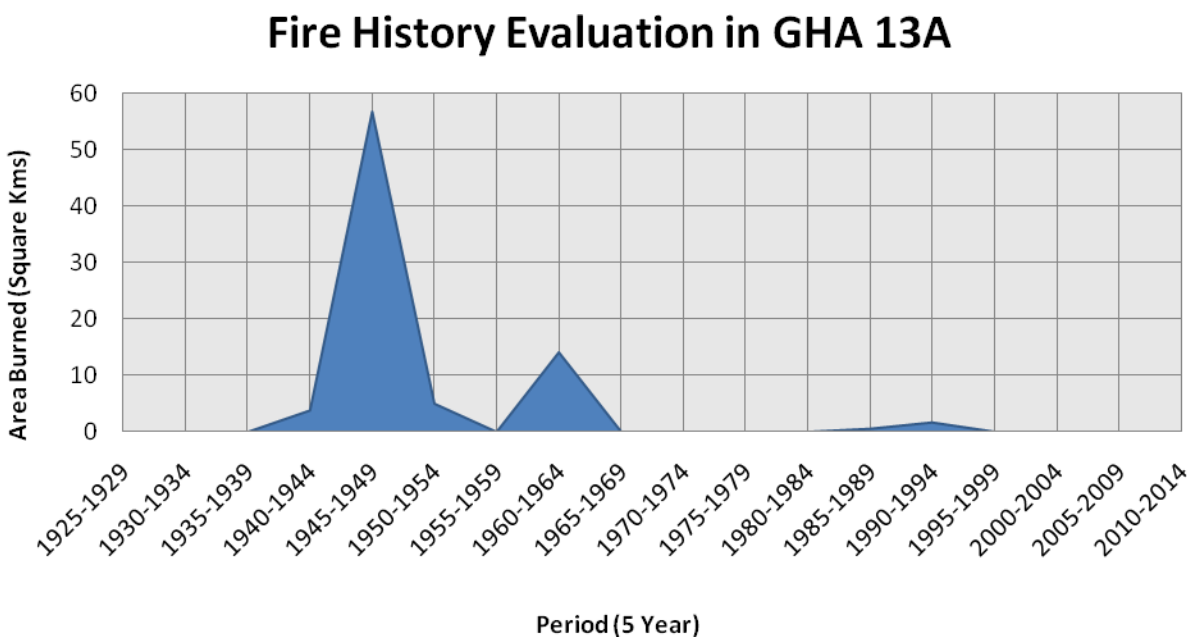


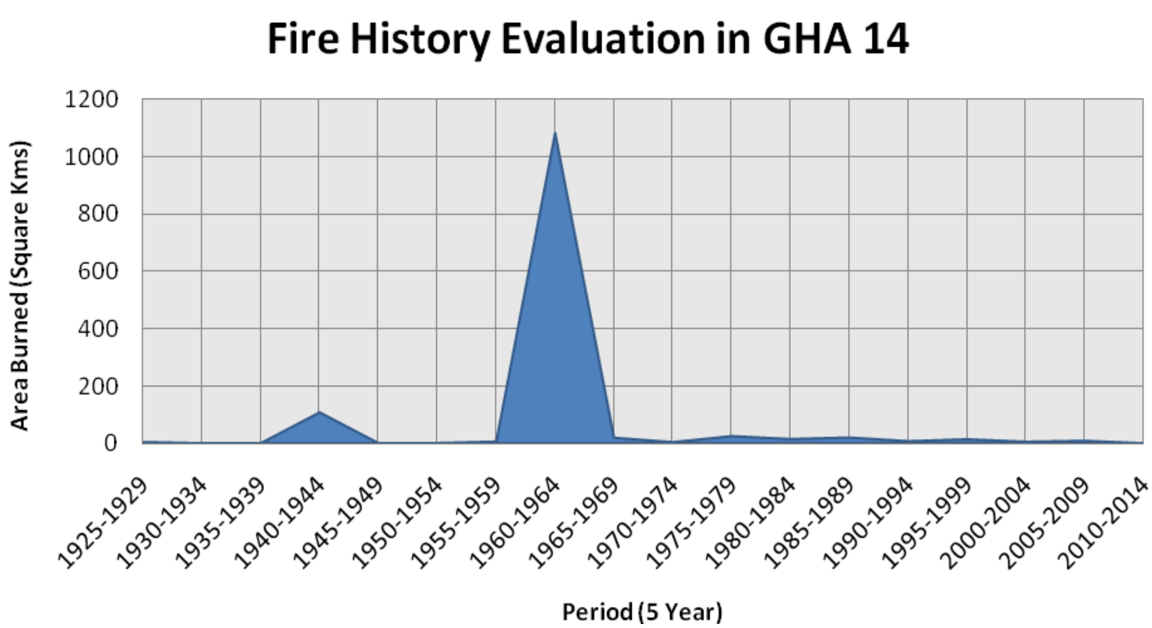
[*] Year indicated in red had no special season data and years indicated in green had an additional landowner season

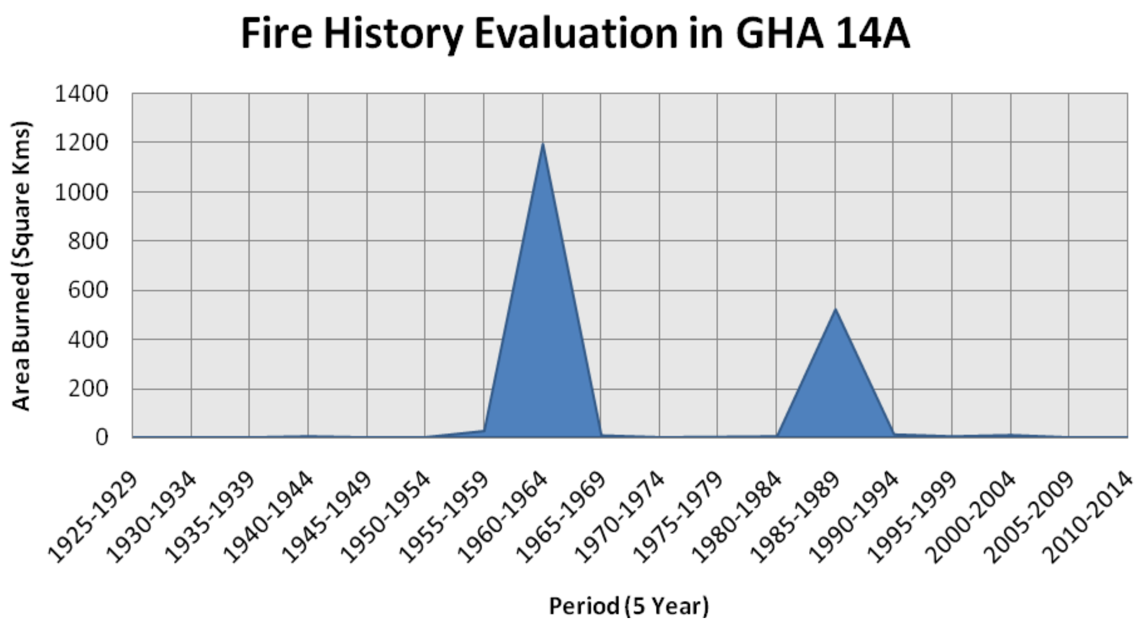
APPENDIX 3: FIRE HISTORY GRAPHS

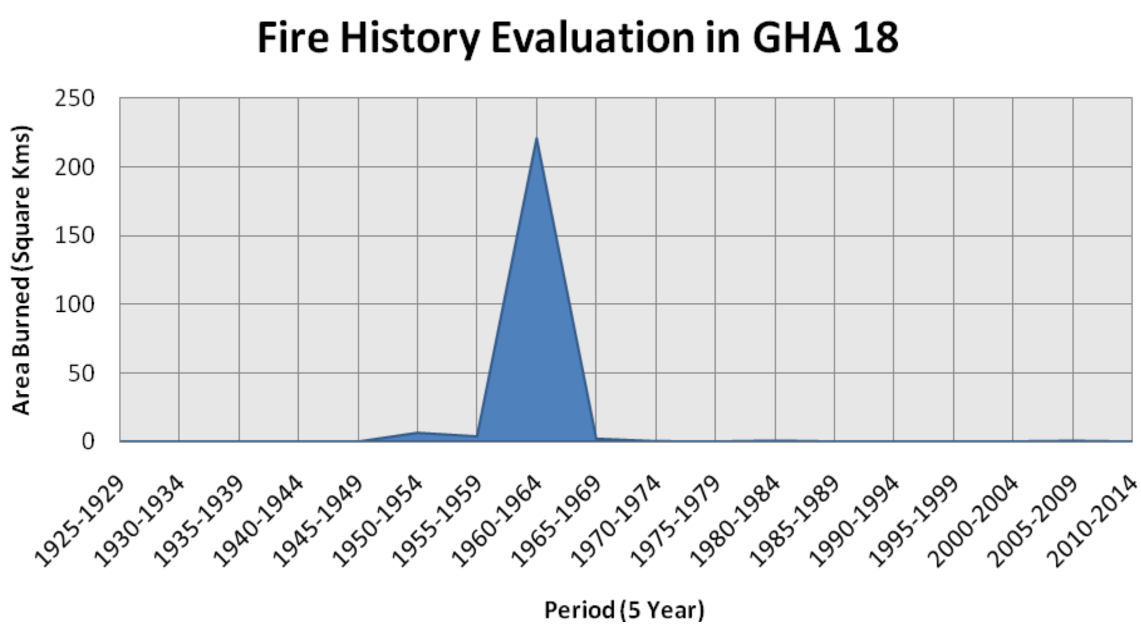


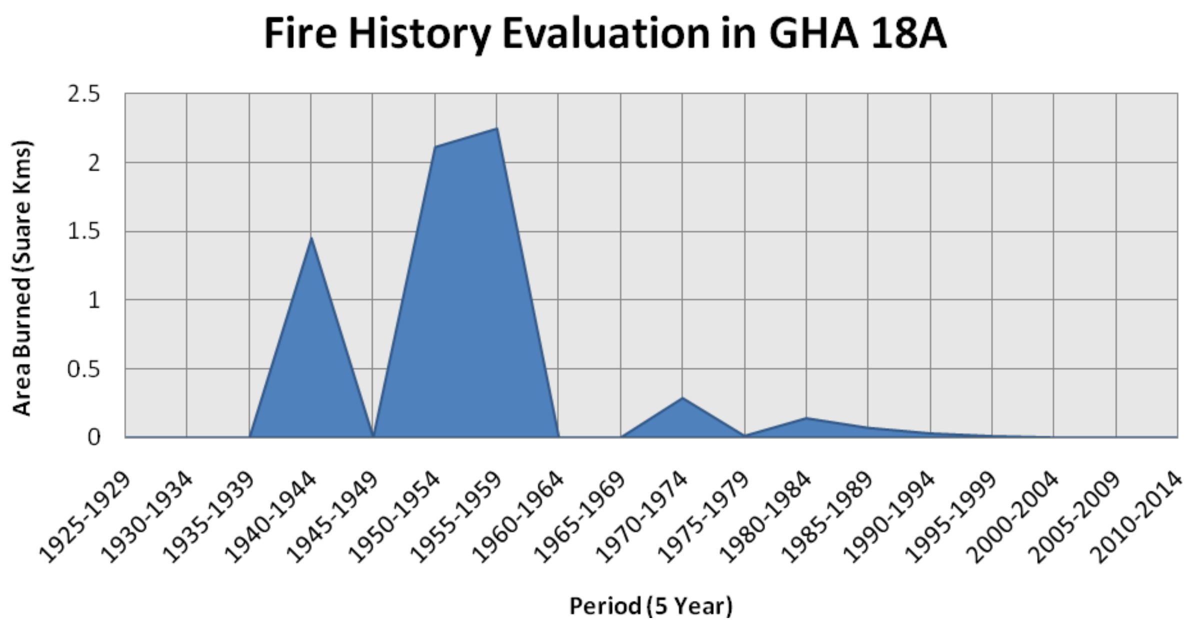


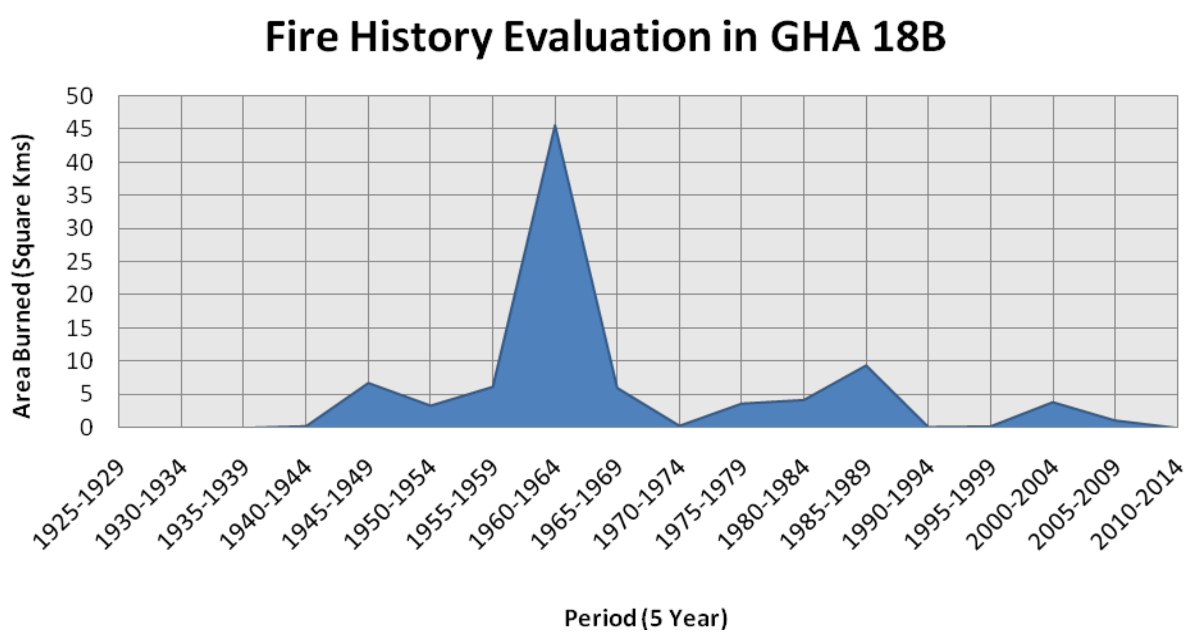

Fire History Evaluation in GHA 13A
Area Burned (Square Kms)
60
50
40
30
20
10
0
1925-1929
1930-1934
1935-1939
1940-1944
1945-1949
1950-1954
1955-1959
1960-1964
1965-1969
1970-1974
1975-1979
1980-1984
1985-1989
1990-1994
1995-1999
2000-2004
2005-2009
2010-2014
Period (5 Year)

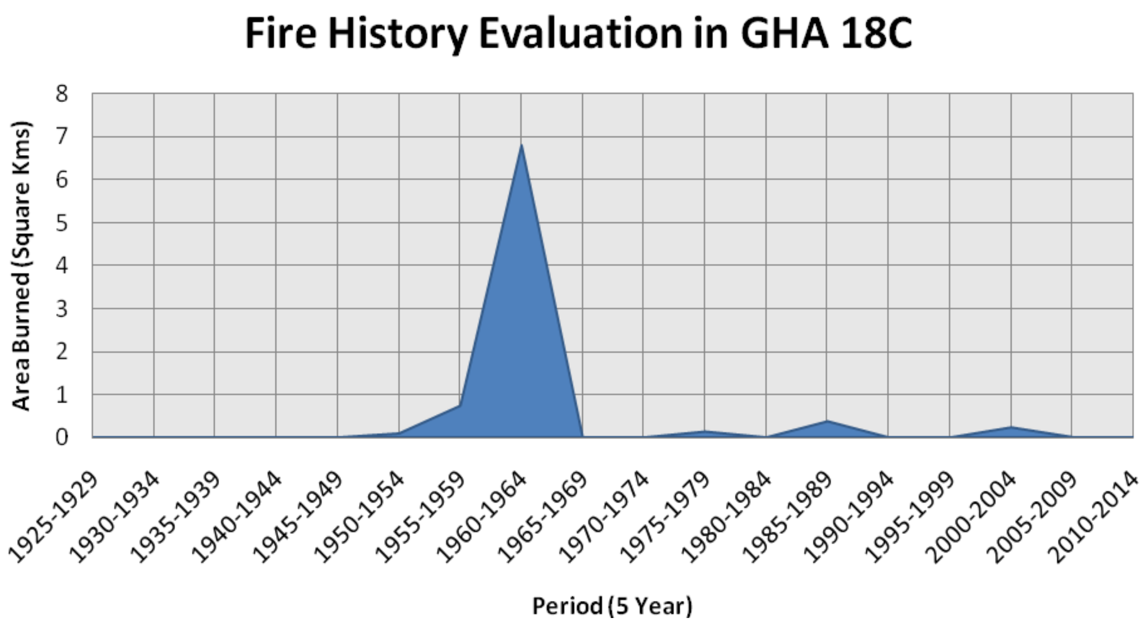

Fire History Evaluation in GHA 14
Area Burned (Square Kms)
1200
1000
800
600
400
200
0
1925-1929
1930-1934
1935-1939
1940-1944
1945-1949
1950-1954
1955-1959
1960-1964
1965-1969
1970-1974
1975-1979
1980-1984
1985-1989
1990-1994
1995-1999
2000-2004
2005-2009
2010-2014
Period (5 Year)

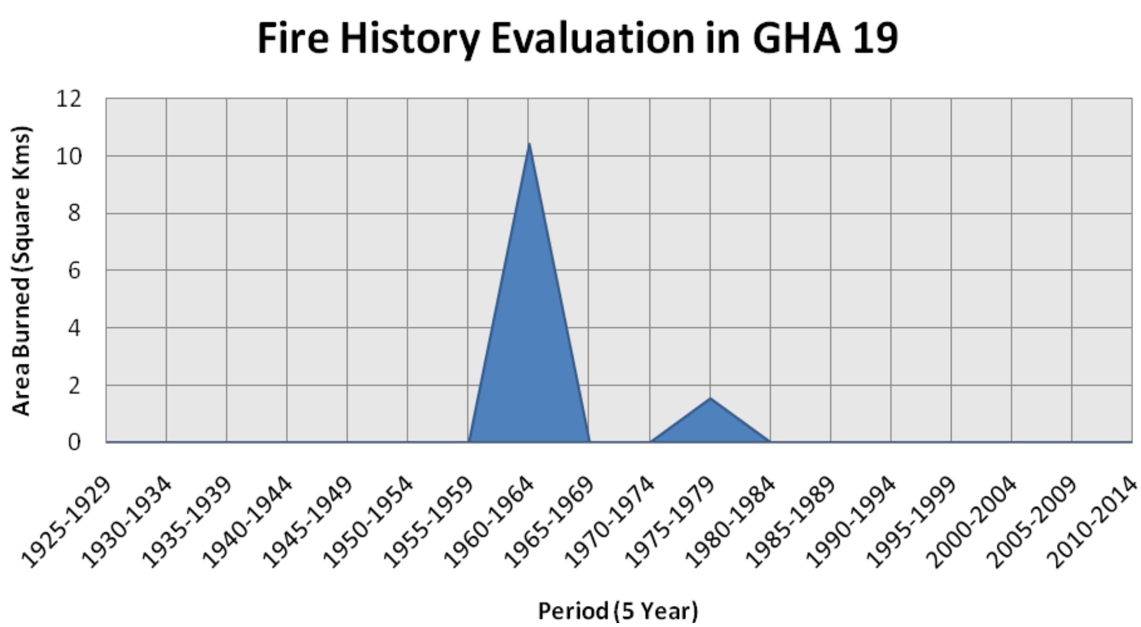

Fire History Evaluation in GHA 14A
Area Burned (Square Kms)
1400
1200
1000
800
600
400
200
0
1925-1929
1930-1934
1935-1939
1940-1944
1945-1949
1950-1954
1955-1959
1960-1964
1965-1969
1970-1974
1975-1979
1980-1984
1985-1989
1990-1994
1995-1999
2000-2004
2005-2009
2010-2014
Period (5 Year)

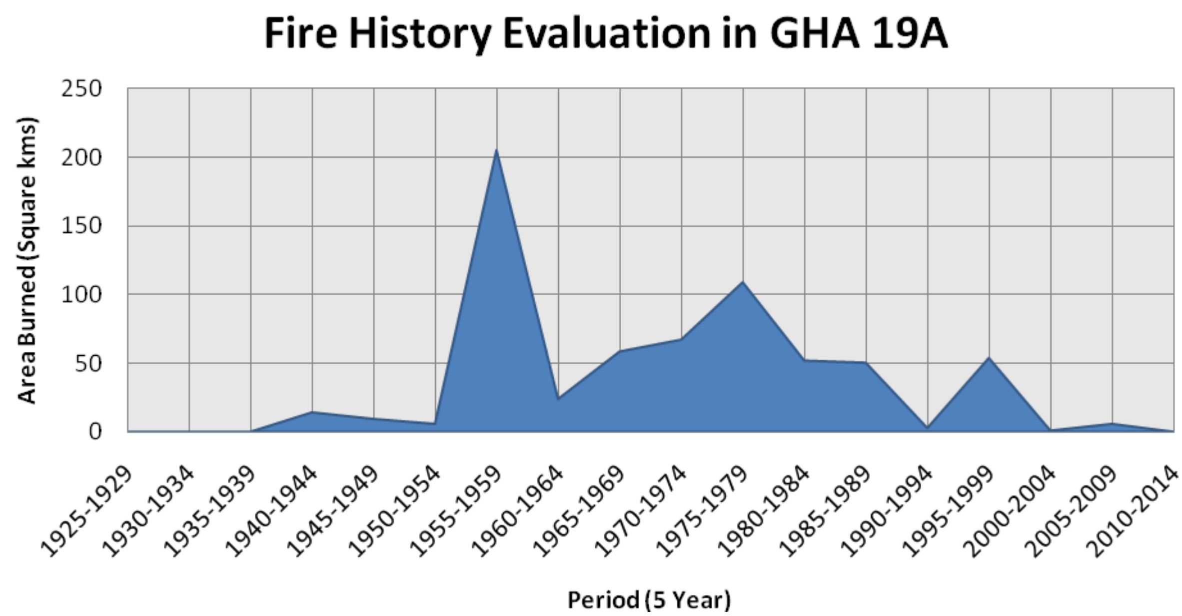

Fire History Evaluation in GHA 18
Area Burned (Square Kms)
250
200
150
100
50
0
1925-1929
1930-1934
1935-1939
1940-1944
1945-1949
1950-1954
1955-1959
1960-1964
1965-1969
1970-1974
1975-1979
1980-1984
1985-1989
1990-1994
1995-1999
2000-2004
2005-2009
2010-2014
Period (5 Year)

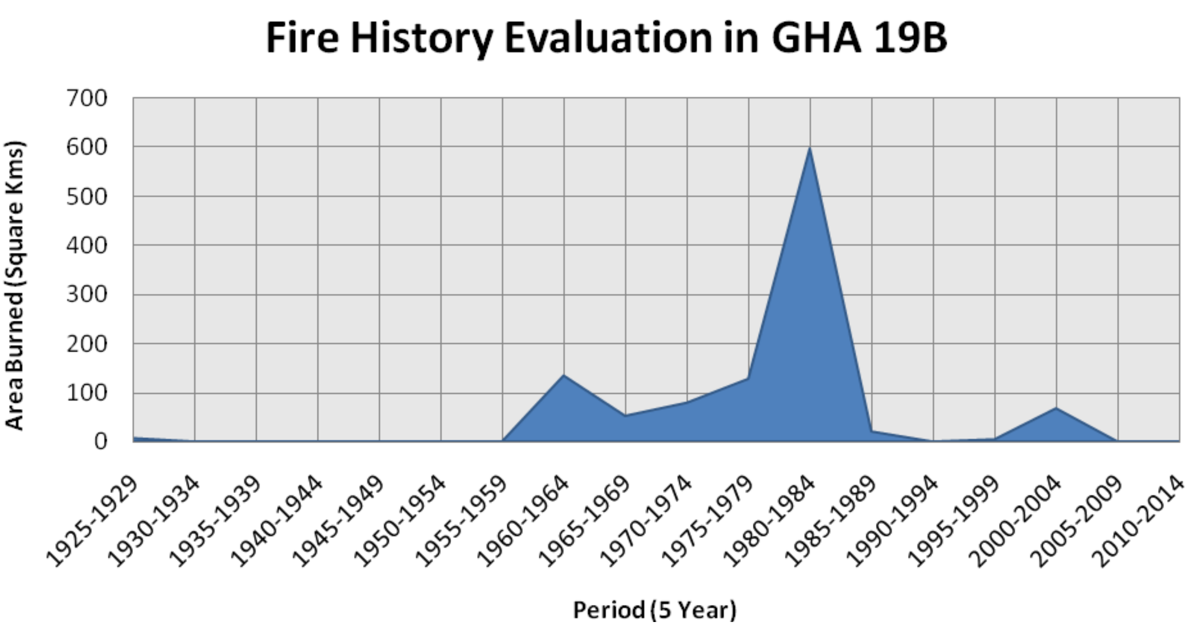

Fire History Evaluation in GHA 18A
Area Burned (Suare Kms)
2.5
2
1.5
1
0.5
0
1925-1929
1930-1934
1935-1939
1940-1944
1945-1949
1950-1954
1955-1959
1960-1964
1965-1969
1970-1974
1975-1979
1980-1984
1985-1989
1990-1994
1995-1999
2000-2004
2005-2009
2010-2014
Period (5 Year)

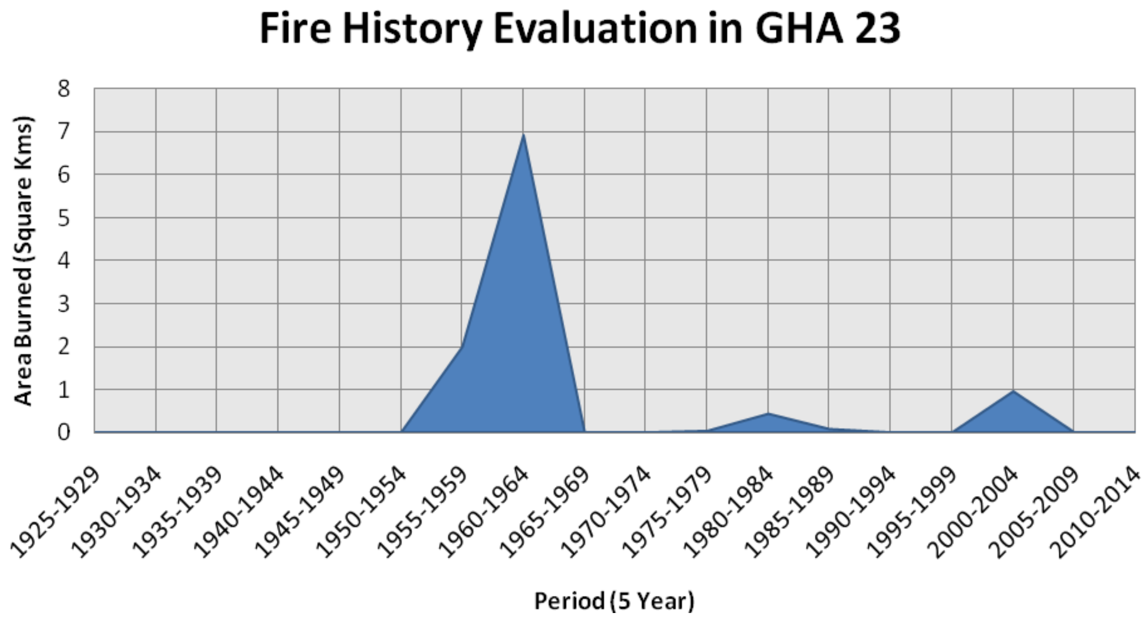

Fire History Evaluation in GHA 18B
Area Burned (Square Kms)
50
45
40
35
30
25
20
15
10
5
0
1925-1929
1930-1934
1935-1939
1940-1944
1945-1949
1950-1954
1955-1959
1960-1964
1965-1969
1970-1974
1975-1979
1980-1984
1985-1989
1990-1994
1995-1999
2000-2004
2005-2009
2010-2014
Period (5 Year)


Fire History Evaluation in GHA 18C
Area Burned (Square Kms)
0
1
2
3
4
5
6
7
8
1925-1929
1930-1934
1935-1939
1940-1944
1945-1949
1950-1954
1955-1959
1960-1964
1965-1969
1970-1974
1975-1979
1980-1984
1985-1989
1990-1994
1995-1999
2000-2004
2005-2009
2010-2014
Period (5 Year)


Fire History Evaluation in GHA 19
Area Burned (Square Kms)
0
2
4
6
8
10
12
1925-1929
1930-1934
1935-1939
1940-1944
1945-1949
1950-1954
1955-1959
1960-1964
1965-1969
1970-1974
1975-1979
1980-1984
1985-1989
1990-1994
1995-1999
2000-2004
2005-2009
2010-2014
Period (5 Year)


Fire History Evaluation in GHA 19A
Area Burned (Square kms)
250
200
150
100
50
0
1925-1929
1930-1934
1935-1939
1940-1944
1945-1949
1950-1954
1955-1959
1960-1964
1965-1969
1970-1974
1975-1979
1980-1984
1985-1989
1990-1994
1995-1999
2000-2004
2005-2009
2010-2014
Period (5 Year)


Fire History Evaluation in GHA 19B
Area Burned (Square Kms)
700
600
500
400
300
200
100
0
1925-1929
1930-1934
1935-1939
1940-1944
1945-1949
1950-1954
1955-1959
1960-1964
1965-1969
1970-1974
1975-1979
1980-1984
1985-1989
1990-1994
1995-1999
2000-2004
2005-2009
2010-2014
Period (5 Year)


Fire History Evaluation in GHA 23
Area Burned (Square Kms)
8
7
6
5
4
3
2
1
0
1925-1929
1930-1934
1935-1939
1940-1944
1945-1949
1950-1954
1955-1959
1960-1964
1965-1969
1970-1974
1975-1979
1980-1984
1985-1989
1990-1994
1995-1999
2000-2004
2005-2009
2010-2014
Period (5 Year)

APPENDIX 4: METRIC DEFINITIONS

Area Weighted Mean Patch Fractal Dimension: Area weighted mean patch fractal dimension is the same as mean patch fractal dimension with the addition of individual patch area weighting applied to each patch. Because larger patches tend to be more complex than smaller patches, this has the effect of determining patch complexity independent of its size. The unit of measure is the same as mean patch fractal dimension.

Class area: Sum of areas of all patches belonging to a given class.

Class: A class includes all patches, polygons, contiguous cells or shapes in a theme, a view or a landscape that have the same value for a given attribute.

Edge density: Amount of edge relative to the landscape area.

Landscape Area: The sum of areas, of all patches in the landscape.

Landscape: A landscape includes all patches, polygons, contiguous cells or shapes in a view or a theme.

Mean patch edge: Average amount of edge per patch.

Mean Patch Fractal Dimension: Mean patch fractal dimension is another measure of shape complexity. Mean fractal dimension approaches one for shapes with simple perimeters and approaches two when shapes are more complex

Mean patch size: Average patch size

Mean shape index: sum of each patches perimeter divided by the square root of patch area (km^2) for each class (Class Level) or all patches (Landscape Level), and adjusted for circular standard (polygons), or square standard (grids), divided by the number of patches.

Median patch size: The middle patch size, or 50th percentile. Example: Median Patch size of Conifer Patches

Number of patches: Total number of patches in the landscape if ‘Analyze by Landscape’ is selected, or Number of Patches for each individual class, if ‘Analyze by Class’ is selected.

Patch size coefficient of variance: Coefficient of variation of patches.

Patch size standard deviation: Standard Deviation of patch areas.

Patch: Each individual polygon, contiguous set of cells, or shape is a patch. Each patch has a separate record, or row, in the theme attribute table.

Total edge: Perimeter of patches.

APPENDIX 5: CORRELATION MATRIX

Correlation matrix for the metrics used in this analysis. The only values provided are those correlations that exceed a P-value of 0.05.

	mooseperkm2	ContMatPer	ShrubPer	WetPer	ContUpAWMSI	ContUpMSI	ContUpMPFD	ContUpAWMPFD	ContUpTE	ContUpED	ContUpMPE	ContUpMPS	ContUpNP	ContUpMedPS	ContUpPSCV	ContUpPSSD	RoadLengthKM
ContMatPer	*																
ShrubPer	*	*															
WetPer	-0.73	*	*														
ContUpAWMSI	*	*	*	*													
ContUpMSI	*	*	*	*	*												
ContUpMPFD	*	*	*	*	*	0.9											
ContUpAWMPFD	*	*	*	*	0.94	*	*										
ContUpTE	*	*	*	*	*	*	*	*									
ContUpED	*	*	*	*	*	*	*	*	0.96								
ContUpMPE	*	*	*	*	*	*	*	*	*	*							
ContUpMPS	*	*	*	*	*	*	*	*	*	*	0.83						
ContUpNP	*	*	*	*	*	*	*	*	0.96	0.92	-0.74	*					
ContUpMedPS	*	*	*	*	*	0.76	*	*	*	*	0.71	*	*				
ContUpPSCV	*	*	*	*	0.94	*	*	0.95	*	*	*	*	*	*			
ContUpPSSD	*	*	*	*	0.92	*	*	0.78	*	*	*	0.82	*	*	0.81		
RoadLengthKM	*	*	*	*	*	*	*	*	0.82	0.91	*	*	0.71	*	*	*	
RoadDens	*	*	*	-0.97	*	*	*	*	*	*	*	*	*	*	0.7	*	*