GRAY WOLVES (Canis lupus) MOVEMENT PATTERNS IN MANITOBA: IMPLICATIONS FOR WOLF MANAGEMENT PLANS

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GRAY WOLVES (*Canis lupus*) MOVEMENT PATTERNS IN MANITOBA: IMPLICATIONS FOR WOLF MANAGEMENT PLANS

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Gray Wolf (*Canis lupus*) Movement Patterns in Manitoba: Implications for Wolf Management Plans

(Photo credit to Jerry Lee of Lee's Air Taxi (top left) and Fiona E. Scurrah)

Abstract

In 2010 and 2011, Manitoba Hydro in collaboration with Manitoba Conservation collared 65 gray wolves (*Canis lupus*) as part of a larger multi-year boreal woodland caribou research project. There is insufficient data regarding populations of gray wolves in Manitoba or their movements throughout the province. The objective of this study was to typify wolf movements in Manitoba to provide recommendations for industry and government for the development of policy and integrated resource management plans of this species. Of the 65-collared wolves, 11 were selected to examine their movements in three regions of the Province. It was found that wolf populations overlap one another in the study area, to varying degrees. Their ability to move long distances, creates challenges for resource managers, as most management plans only consider management at a regional scale rather than a multi-jurisdictional level. In addition, this examination of gray wolf movements will assist in understanding their role as predators on the protected boreal woodland caribou and depressed moose populations within the Province.

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Chapter 1: Introduction

Gray wolf (*Canis lupus*) movements or their population dynamics in Manitoba is not well understood or documented. Research on gray wolves in Manitoba has focused on the diet of wolves or on the genetic differentiation of the wolves found in Riding Mountain National Park (Hill, 1979; Aindell, 2006; Stronen et al, 2011; D. Walker personal communication), with some limited research on wolf use of anthropogenic features and natural corridors (Davis, Walker and Kotak, 2010). Research in other jurisdictions primarily focuses on wolf movements in relation to human linear features (Whittington, St. Clair and Mercer, 2004; Heilhecker, Thiel, Hall Jr, 2007; Shepard, Kuhns, Dreslik and Phillips, 2008; Rinaldi, 2011) predator-prey dynamics (Demma, Barber-Meyer, and Mech, 2007; Hebblewhite and Merrill, 2007; Frank, 2008; Metz, Smith, Vucetich, Stahler and Peterson, 2012) or in relation to predator control issues (Kellert, 1985; Van Ballenberghe, 2006; Muisani Anwar, McDermid, Hebblewhite, and Marceau, 2010; Van Ballenberghe, 2011). Other studies have looked at dispersal patterns and dispersal rates of wolves in various jurisdictions and the utilization of developed landscapes such as forest cut areas and as travel corridors (Merrill and Mech, 2000; Jedrezjewski, Schmidt, Theuerkauf, Jedrzejewska and Okarma, 2001; Wabakken, Sand, Kojola, Zimmermann, Arnemo, Pedersen, and Liberg, 2007; Cuicci, Reggioni, Maiorano, and Boitani, 2009; Gula, Hausknecht and Kuehn, 2009; Houle, Fortin, Dussault, Courtois, and Oullet, 2010). The majority of these studies have used GPS tracking collars, which allows for a more complete picture of travel patterns and routes for wolves. In the majority of studies, these wolves were able to navigate and travel in highly fragmented landscapes. The literature suggests that wolves will utilize linear features as their main travel routes in order to move through their territory as well as accessing prey species. While these wolves have adapted to human presence on the landscape by using linear features such as roads as travel corridors, it is unclear as to how much of their travel time is spent using these corridors as travel routes (Merrill and Mech, 2000). Within northern Manitoba a preliminary examination of wolf travel on a linear feature, the Wuskwatim transmission line, indicates that wolves rarely use the transmission line as a travel corridor (Manitoba Hydro, 2012). Research on the eastside of Lake Winnipeg, indicates that transmission lines are not a consistent travel corridor for wolves in the area (Davis et al, 2010). Other studies on transmission line rights-of-way (ROW) indicate that mammalian species will be affected differently by the ROW and larger carnivores, such as wolves, would be detected more frequently on the ROWs (Smith, Aborn, Gaudin and Tucker, 2008).

The ability for wolves to travel long distances and adapt to a changing landscape make it challenging for resource managers to manage wolf populations. In the United States and Europe, the prevailing management strategy for wolf management was eradication of gray wolves on the landscape, to the point of extinction or extirpation. It has not been until relatively recently, in the mid half of the 20^{th} century, that perceptions and policies on how to manage wolf populations has changed (Chapron, Legendre, Ferrière, Clobert and Haight, 2003; Simon, 2009; Wuerthner, 2011; Mech, 2012).

Wildlife resource management is the responsibility of the Wildlife Branch of Manitoba Conservation. The mandate of the branch is to protect wildlife resources for all Manitobans with conservation of species and ecosystems being the underlying tenet (Province of Manitoba, 2012a). The *Wildlife Act*, the *Endangered Species Act* and *Conservation Agreements Act* are the applicable pieces of legislation from which the Wildlife Branch draws their authority to manage wildlife resources within the provincial boundaries. The *Wildlife Act* is the main piece of legislation that lays out the manner by which the province manages wildlife resources as well as research. It is under this Act and its associated regulations that hunting and bag limits, wildlife management areas, any prohibitions on types of hunting, and enforcement actions are defined.

In order to effectively manage wildlife resources there needs to be integrated resource management plans that encompass all interested stakeholders in the process (Wiber, Berkes, Charles, and Kearney, 2004; Marasco, Goodman, Grimes, Lawson, Punt, and Quinn, 2007; Glikman, 2011). Integrated resource management plans ensure that those comments and opinions are heard and incorporated into a final management strategy. Some provincial jurisdictions such as Ontario, manage wolf populations based on an integrated resource management strategy (Ontario Ministry of Natural Resources, 2005a). Ontario recognizes that wolves are an integral component for a healthy and viable ecosystem (Ontario Ministry of Natural Resources, 2005b). The main objective of the management plan is to ensure ecologically sustainable wolf populations within the ecosystems they inhabit. This encompasses biological and ecological benefits along with the cultural, social and economic benefits. Other provinces, like Manitoba have yet to develop or publish a management strategy for wolves; rather they are reactive in nature (Province of Manitoba, 2012b).

Wolf management strategies in the United States and Europe have predominantly been those of eradication. This all or nothing approach resulted in gray wolves disappearing completely in many European countries and the lower 48 states in the United States. In 1974, the United States federally listed the gray wolves on the endangered species list under the *Endangered Species Act* (United States Fish and Wildlife Service, 2012). The federal listing of gray wolves was not without controversy. By 2000, gray wolf populations had increased in many of the states and the US Fish and Wildlife Service attempted to have it reclassified from endangered to threatened. For the next few years, there were numerous court challenges against both reclassifying and then delisting. However, by 2011, the populations of the Western Great Lakes had recovered substantially to warrant them becoming delisted (United States Fish and Game Service, 2012). In those interceding years, between 1974 and 2011, and due in large part to the robustness of the *Endangered Species Act* itself, a recovery strategy was developed and implemented not only at the federal level but also within many states. At the core of these recovery plans and strategies was the commitment to scientific research and proper management of the species. Yet while research is a key component in these plans, this research is directly tied to lands adjacent to national parks with more intensive hunting pressure on wolves found further afield from those locations (Forbes and Theberge, 1996; Theberge, Theberge, Vucetich, and Paquet, 2006; Idaho Department of Fish and Game and Nez Perce Tribe, 2012).

Problem Statement and Objective

Understanding how gray wolves move on the landscape, especially along linear features such as transmission lines, allows corporations such as Manitoba Hydro to develop routing at the planning stage that might mitigate the use of these travel corridors. The primary concern is the potential effect of these features on wolf predation of species such as the threatened woodland caribou. As part of Manitoba Hydro's Bipole III 500kV high voltage direct current environmental assessment, the collecting of telemetry data recording wolf travel movements in relation to transmission line routing was undertaken. The extent and size of wolf home ranges in the Province are critical in understanding how wolves may locate and interact with these features on the landscape. The objective of this study is examining gray wolf movement patterns in and home range size northern Manitoba. It is anticipated that the results of this study will aid in creating more responsive and comprehensive wolf resource management plan as well as aid in the development of recovery strategies for boreal woodland caribou.

Chapter 2: Gray Wolf Ecology

Gray wolves, *Canis lupus*, are the largest member of the Canidae family and are related to coyotes (*Canis latrans*), and foxes (red, *Vulpes vulpes*; gray *Urocyon cinereoargenteus*). In Manitoba, they are also referred to as "timber" wolves (Province of Manitoba, 2012c). Adult gray wolves can measure up to over six feet in length (snout to tail), with females being slightly smaller both in height and weight to their male counterparts. Manitoba gray wolves show a variety of colour phases from pure white animals to pure black and variations between the two colours. They have dense underfur for protection from the cold in the winter, protected by long guard hairs and are well adapted for long distance travel (Michigan Department of Natural Resources, 2008). Gray wolves are found throughout Canada and have not faced the extinction or extirpation that gray wolves faced in the United States.

Gray wolves live in a family pack structure and are very social animals. There is one set of breeding adults or "breeders" (formerly known as the alphas), from which the remainder of the pack are descended. Pack members will be of varying age classes, from the pups to yearlings to sub adults, with each occupying a specific rank within the pack. While the packs are family structures, the only long-term members of the pack are the breeding pair, as the younger wolves will start to disperse from the pack as young as nine months (Mech, 1999). The breeding pair is responsible for the activities of the pack overall and during the reproductive season; the female breeding adult is the most dominant animal in the pack (Mech, 1999; Mech, 2000).

Mortality in wolves is primarily human-induced (i.e. vehicle collisions, hunting), as there is no known predator on wolves, however wolf pups can be susceptible to predation by bears. There are other natural mortality factors including disease, malnutrition, starvation or intraspecific strife (Kuzyk, Kneteman, and Schmiegelow, 2006; Michigan Department of Natural Resources, 2008). Other resource extraction activities on the landscape such as forestry and oil and gas development can alter wolf movements and distributions (Kuzyk et al, 2006) as well as create situations where wolves become habituated to human presence.

Gray wolves generally prey upon ungulates (i.e. hoofed mammals such as deer (*Odocoileus virginianus*), elk (*Cervus canadensis*), moose (*Alces alces*), and caribou (*Rangifer* spp)) but are also known to prey upon smaller species such as beavers (*Castor canadensis*) and snowshoe hares (*Lepus americanus*). Given their status as habitat generalists, they will inhabit areas where there is an abundance of prey whether it is ungulate species or the smaller prey species and have been correlated to seasonality (i.e. in winter months ungulates are the primary prey species whereas in the summer, smaller prey species such as beavers and hares will comprise the main diet of wolves (Fuller, 1989; Schmidt and Mech, 1997). Pack size is sometimes a direct result of the abundance of these prey species, as the larger the prey species, such as moose or elk, the larger the pack required to hunt and take down the animal (Kuzyk, et al., 2006).

Movements by wolves follow two seasonal movement patterns – homesite-based summer movements and nomadic winter movements (Mech and Boitani, 2003a; Demma and Mech, 2009). The den (or what is known as rendezvous site) is the main focal point of summer movement patterns. Adults within the pack will radiate out from this location to seek out prey and return to the den with food in which to feed the pups (Potvin et al, 2004; Mech and Boitani, 2009; Ausband et al, 2010). Data from the studies that have been undertaken, found that den locations tend to be located in meadows or wetland areas (Ausband et al, 2010). Wetlands and meadows provide varying attributes from the ability to conceal the pups to providing a viable water source, which aids in the processing of a high protein diet. Additionally, wetlands generally have small mammal populations, which could be part of the pups' education to hunting of prey (Ausband et al., 2010). In contrast, by late fall the wolves start to move increasingly away from these homesites and begin to work their territory, primarily to ensure no encroachment into the area by other wolves and to possibly to avoid prey behavioural depression (Demma and Mech, 2009). These studies have focused on activities and movement patterns in and around the den site, yet there are few studies that have examined the movement patterns away from the den locations by adult and sub adult wolves.

Studies focusing on wolves in the summer have generally, focused on the wolf packs use of the den (Ausband et al., 2010; Demma and Mech, 2009; Potvin et al., 2004) and not on the travel or movement patterns of the wolves within the pack in relation to their defined territory. Demma and Mech (2009) undertook a study in northeastern Minnesota to determine the extent of movement by both breeding and non-breeding wolves and to assess whether or not there was a rotational use of the pack's territory. What they found was that through GPS tracking, non-breeding wolves tended to use the homesite less frequently than the breeding wolves. Within the wolf pack's territory there was more than one homesite, with one site being utilized more frequently than the others are. The travel rates of the wolves within the pack varied, but all members of the pack regularly used different portions of the territory on a daily basis, which indicated to them that the wolves were indeed using a rotational foraging strategy.

As the season progress, wolves will begin to move further afield from the summer rendezvous sites to defend or reinforce the packs' territory. However, pack territory defense during the winter months is not necessarily the primary driver for wolf movements during this period. Musiani et al. (2007) suggest that wolves that predominantly inhabit areas with migratory caribou, will abandon that territorial behaviour to migrate with the caribou to their calving grounds. Other studies have focused on predator-prey dynamics and the degree by which prey species are affected by predation over the winter versus during the spring and summer, when neonate predation tends to be significantly higher (Metz et al., 2012; Sand et al., 2012).

Populations of listed species such as boreal woodland caribou are thought to be impacted by increased predation by top predators such as gray wolves. Additionally, Manitoba has seen a significant decline in moose populations in the eastern and western regions of the province, with wolf predation attributed as one of the primary causes of this decline (Province of Manitoba, 2012b). Predators generally select prey that is more vulnerable (i.e. the young, weak) as compared to the average animal within the population which would indicate that predation is not the main driver of a prey species population decline (Sand et al., 2012). Yet it is the most cited reason why listed species, such as boreal woodland caribou, are in decline (Bergerud and Ballard, 1988; Kuzyk et al., 2006; Environment Canada, 2011; Province of Manitoba, 2011).

Jurisdictional responses to decreases in populations of big games species, such as moose, are to institute some form of predator management scenario. As wolves are the apex predator in the ecosystem (Michigan Department of Natural Resources, 2008; Wuerthner, 2011), the responses generally target some form of wolf management, whether it be an increase in bag limits or bounties for hunters and trappers or through other program such as targeted wolf pack culls (Simon, 2009;Wuerthner, 2011). In many instances, however, there is little to no information regarding the wolf populations in the vicinity and these types of reactive management plans do not follow any scientific rigour to ensure that the plan as put in place does not create an imbalance in the system. Yellowstone National Park in the United States is the most cited example of how ecosystems react when the top apex predator is removed from the equation only to be later reintroduced due to the imbalance in the predator prey model. Studies have illustrated that without the wolf in the system, prey species will tend to flourish until they begin to eat themselves out of habitat, which then results in potentially massive die offs due to starvation and disease (Mech, 1970; Ripple and Beschta, 2003; Beyer, Merrill, Varley, and Boyce, 2007; Frank, 2008). Through these studies, it has been shown how integral wolves are to a healthy ecosystem as they influence multiple processes within that ecosystem. Removal of wolves on a large scale will affect all the other components of the system resulting in a trophic cascading effect. This top down cascading effect, can at the onset appear to be beneficial to other species inhabiting the system, yet will shift predation to the meso predators , which will in turn increase in numbers and distribution (Purgh, Stoner, Epps, Bean, Ripple, Laliberte and Brashares, 2009; Beschta and Ripple, 2009). The additional numbers in these meso predators will then increase the rate and number of predation on other smaller prey species, again shifting the ecosystem dynamic. Mech and Boitani (2003b) caution that there is not enough information or data to fully understand the cascading effects of wolves within the ecosystem and that describing any effects as beneficial or positive is a human value judgement. Further, there have been more opinions and papers written, rebutting the 'positive' affects the reintroduction of wolves into the Yellowstone National Park, for example, in terms of the cascading effect (Mech, 2012). Learning from the Yellowstone National Park experience should allow resource managers to better develop and implement wolf management strategies and plans that are not one dimensional in scope (i.e. removal of wolves at all costs). Europe has also had a similar experience with respect to the eradication of wolves in the ecosystem and a recognition that they are an integral part of a viable ecosystem (Wabakken, Sand, Kojola, Zimmermann, Arnemo, Pedersen, and Liberg, 2007; Gula, et al., 2009).

The United Sates under their *Endangered Species Act*, in 1973, listed the gray wolf as endangered in the lower 48 states. The listing of gray wolves was a direct result of the increased various state hunting pressure to rid themselves of the predator that was affecting big game hunting. State wolf management plans then became a necessity due in part to the requirement under the legislation. The vast majority of the plans have as a main driver a research based focus (Wisconsin Department of Natural Resources, 1999; Minnesota Department of Natural Resources, 2001; Michigan Department of Natural Resource, 2008; Alaska Department of Fish and Game, 2011; Wydeven, Wiedenhoeft, Bruner, Thiel, Schultz and Boles, 2011) and the overall objective of maintaining viable wolf populations within their state boundaries. Throughout the years of being federally listed, many states also listed them as either threatened or endangered. In the intervening years since listing, there have been numerous attempts to delist them federally, cumulating in January 2012 with the western great lakes gray wolves officially being delisted from the Federal Endangered and Threatened Species list (US Department of the Interior, 2012). This overlapping of jurisdictions makes it necessary to develop and implement wolf management plans that look to those jurisdictions' management plans and techniques, as actions undertaken in one area may adversely affect the wolf population in another.

Chapter 3: Study Area

Manitoba's landscape comprises of six ecozones – the Southern Arctic; the Taiga Shield; the Hudson Plain; the Boreal Shield; the Boreal Plain and the Prairie. The Northeast (NE) region of Manitoba encompasses the Taiga Shield, the Hudson Plain and the Boreal Shield. The Northwest (NW) region encompasses primarily the Boreal Shield and the Boreal Plain Ecozones. The Eastern (E) region encompasses the Boreal Shield ecozone completely (**Figure 1**).

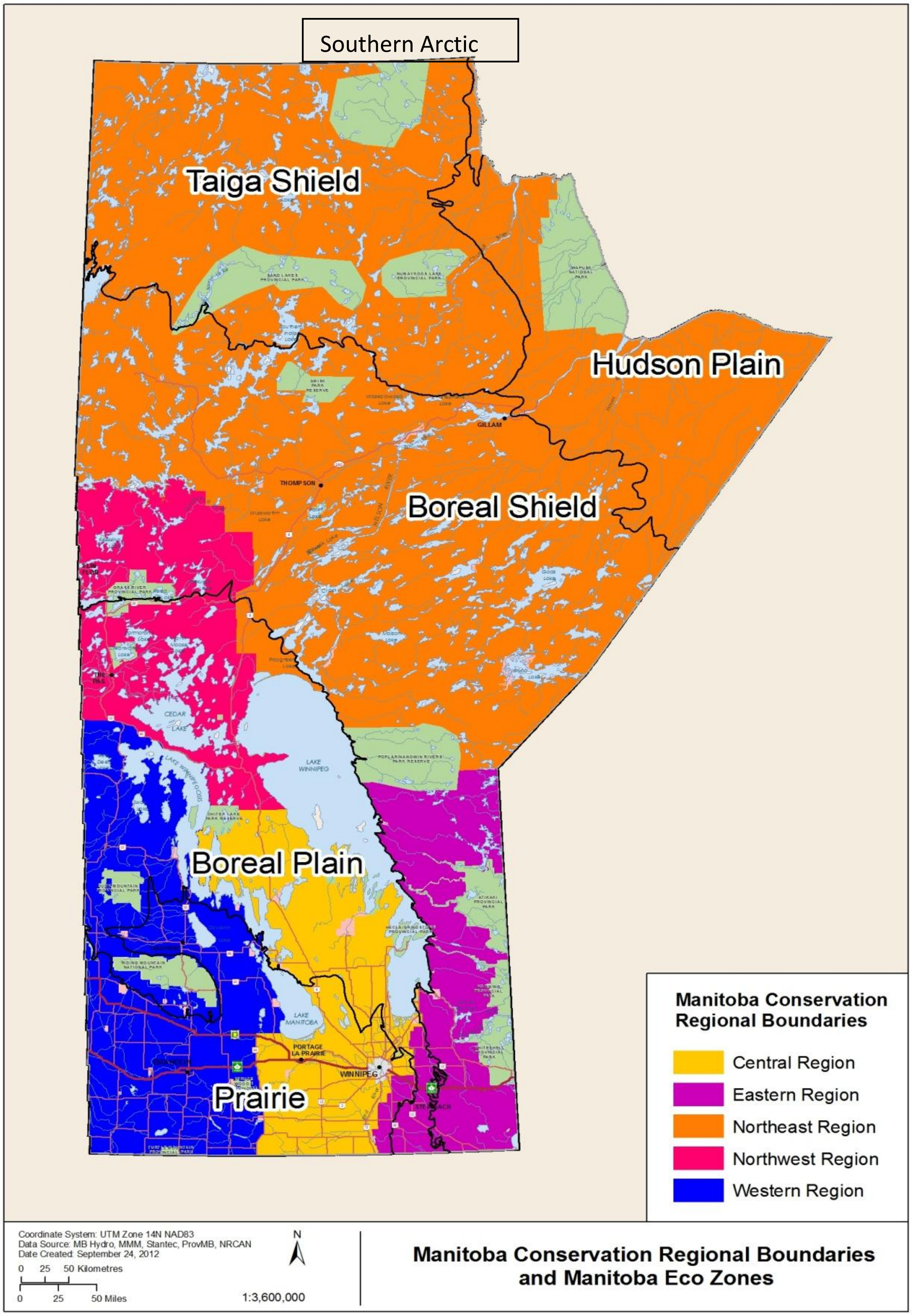

Figure 1: Manitoba Conservation Regions along with Manitoba Ecozones

The Southern Arctic is the northernmost ecozone and is characterized by dwarf birch (*Betula pumila*), willows (*Salix*) and heath species (i.e. low shrub land) along with herb and lichen vegetation (Zoladeski, Wickware, Delorme, Sims and Corns, 1995). The Taiga Shield flanks the Southern Arctic ecozone to the northwest and is characterized by open forested areas, lichen woodlands merging into Arctic tundra at the more northern portion of the ecozone. Towards the central portion of the ecozone, the area is characterized by stunted black spruce (*Picea mariana*); accompanied by alder (*Alnus*), willow (*Salix*) and tamarack (*Larix laricina*) in the fens and bogs (Zoladeski et al., 1995). Found throughout the ecozone in the more upland and along river areas, are open mixed wood stands of white spruce (*Picea glauca*), trembling aspen (*Populus tremuloides*),balsam poplar (*Populus balsamifera*) and white birch (*Betula papyrifera)* (Zoladeski et al., 1995). Permafrost is prevalent in the more northern portions of the ecozone.

The Hudson Plain ecozone is a continuation of the Taiga Shield moving into the southeastern portion of the province. The vegetative cover in this ecozone is dominated by arctic tundra, sedge-moss-lichen and transitions to the edge of the boreal forest in the boreal shield ecozone (Zoladeski et al., 1995). Tree species found in the open woodlands of the Hudson Plain are black spruce and tamarack.

The Boreal Shield forest is predominantly comprised of closed stands of white spruce, black spruce, jack pine, and tamarack (Zoladeski et al., 1995). Precambrian granite bedrock outcrops are found throughout. As the Boreal Shield moves towards the south, an increase in broadleaf tree species (white birch, trembling aspen and balsam poplar) are found (Zoladeski et al., 1995). The Boreal Plain ecozone is a transition zone between the northern coniferous forest and the mixed deciduous-coniferous forest (Zoladeski et al., 1995). The tree types found in the coniferous forest are primarily black spruce, jack pine, *Abies balsamea* (balsam fir), white spruce and tamarack, whereas the mixed deciduous – coniferous forest comprises of trembling aspen, white birch and balsam poplar. Peatlands, bogs and fens are prevalent throughout the area and the soil is often hummocky (Zoladeski et al., 1995). Fens are typically low-lying marshlands with groundwater and surface water inflows and are used by caribou to access calving complexes within the fens and bogs. These areas are typically not utilized by predators such as wolves and bears as the low laying marshland is difficult terrain for them to traverse. Lichen is found throughout the study area associated with mature jack pine and spruce stands.

Each ecozone has its own specific characteristics, they all form part of the boreal forest. For Manitoba, the boreal forest covers the north central portion of the province down to the eastern side of the province and into Ontario. It is also called the northern coniferous forest, and the dominant tree species are black and white spruce, jack pine, polar and has many lowland fens and bogs throughout. It is in the boreal forest where all wolves were collared.

From a wildlife resource management perspective, Manitoba is split into various regions, with a centralized headquarters in Winnipeg. Wildlife resources within the region are managed through wildlife managers who provide input into provincial policies and strategies.

Chapter 4: Methodology

This study utilized GPS tracking collars, deployed on gray wolves through aerial net gunning, to analyze their movement patterns. Telemetry was acquired and analyzed statistically using GIS as described in the following sections.

GPS Tracking Collars

All wolves were captured by a qualified capture company (Heli Horizons) through aerial net gunning under the direction and control of Manitoba Conservation. Manitoba Conservation was responsible for ensuring capture protocols related to time/duration of hazing of an animal and collaring were properly followed (V. Trim, Manitoba Conservation, personal communication). Of all wolves collared there was one mortality but it was inconclusive as to whether or not it was a direct result of capture (i.e. capture myopathy) (D. Hedman, Manitoba Conservation, personal communication). Animals were located by wolf trackers (Alaskan Trackers), flying survey grids to identify potential wolf locations. Once tracks were spotted, direction of movement was determined, pack size was estimated and tracker attempted to identify the alpha male and female. Once visual contact was made, the pack size and location was relayed to the capture crew who would then initiate the capture process (**Figure 2**).

Figure 2: Wolf pack in northern Manitoba (*photo courtesy of Jerry Lee of Lee's Air Taxi*)

During the collaring activities in 2010 and 2011, the Alaskan Trackers provided data on the number of packs and individual wolves observed in the northeastern and northwestern regions of Manitoba (Manitoba Hydro, unpublished data). The number of packs and individual wolves observed increased from the year previous (**Table 1**). The Alaskan Trackers undertook wolf pack point counts for the eastern region of the Province; however, Manitoba Conservation has not made that data available.

Table 1: Wolf pack and population estimates for the NE and NW Regions of Manitoba (Manitoba Hydro unpublished data)

Survey Year	**Number of Packs**	**Number of Wolves**	**Number of Collars Observed**	**Number of Packs With Collars**
2010	11	58	10	6
2011	20	83	27	7

Two types of GPS tracking collars were utilized for this study – Lotek Argos (deployed 2010 and 2011, **Figures 3 and 4**) (Lotek Inc., Newmarket, Ontario) and Advanced Telemetry

System (ATS, Isanti, Minnesota) Iridium (deployed in 2011 and 2012). The Lotek Argos collars were set on a schedule of taking a GPS reading (or “fix) every 4 to 6 hours – dependent on the size of the collar deployed (every 4 hours for the smaller Lotek collars; and every 6 hours for the larger Lotek collars). The fixes are on a 10-day cycle at which time the full data points are downloaded. The ATS collars was set to take fixes every 3 hours and the schedule for downloading is every day, as the data set is sent as an email at a predetermined time. The 2010 and 2011 collar deployments were designed for a 3 year period, and each collar having a small explosive charge (drop off), which at the 3 year completion would detonate and the collar would drop off the animal. In 2012, only ATS collars were deployed and these were placed on a one-year deployment, after which time the collar would be released via drop off.

Figure 3: Wolf collared with a Lotek Argos GPS tracking collar (*Photo by Fiona E. Scurrah*)

Figure 4: Released gray wolf with Lotek Argos GPS tracking collar attached (*Photo by Fiona E. Scurrah*)

In the first year of the project, all Argos collars were functioning well, with a few lost due to wolf interactions (i.e. chewed off by other members of the wolf pack). As the year progressed, the GPS relocation data began to fall off (i.e. transmissions became less and less). In some instances, when tracking the collars from a helicopter through telemetry, the collars were picked up on the telemetry gear, but with no visual confirmation. In the second year of deployment, there was a significant failure on the Argos collars, with GPS data points only being collected for a few months before transmissions ceased. Out of the 65 wolves collared during 2010 and 2011, two collars failed right after deployment due to the wolves chewing the collars off, providing limited telemetry. Of the 63 remaining, some ceased to transmit within a few months while others stayed on for nearly two years. From those functioning collars, eleven were selected based on their overall dispersal patterns. All collars were examined and mapped in the ArcGIS program to determine which ones exhibited long distance travel patterns and from that examination, eleven were chosen for this study. The eleven wolves represent three Manitoba Conservation resource management regions – namely the Northwest Region (NW), the Northeast Region (NE) and the Eastern Region (E) (**Table 2**). Each region is a multi-species prey system, consisting of species such as deer, moose, boreal woodland caribou, beaver and snowshoe hares. Linear features such as roadways, railways, transmission lines, provide the greatest degree of fragmentation in these landscapes.

Table 2: Regional breakdown of the eleven wolves (note: the two unknown sex in the NW region are due to the field data sheets missing data)

Region	**Collar Id**	**Sex**	**Year Collared**
Northeast (NE)	2540	Female	2010
	2612	Male	2010
	2686	Male	2010
	2690	Male	2011
	31155	Male	2011
Northwest (NW)	2614	Male	2011
	31140	Unknown	2011
	31143	Unknown	2011
	31156	Female	2011
Eastern (E)	30253	Male	2011
	30254	Male	2011

Home Range Delineations

Using the Hawth's Tools extension in ArcGIS, minimum convex polygon (MCP) analysis was used to determine home range delineations for the wolves in this study (Beyer, 2004). MCP has generally been an acceptable method of delineating home ranges for a multitude of species that have been equipped with radio telemetry devices (i.e. GPS tracking collars) (Burch et al, 2005; Nilsen, Pedersen, and Linnell, 2008; Laver and Kelly, 2008). The MCP analysis was done within the ArcGIS program using the Hawth's tools extension (Beyer, 2004). The MCPs were created using the tool - create minimum convex polygon - within the Hawth's tools extension. By taking the furthest outlying data points, this tool creates the boundary for the home ranges.

Movement Parameters

Within ArcGIS, two different extensions were used to analyze the wolf GPS collar data points to determine total distance traveled, speed, average daily distance, distance from the initial capture location to the final location. ET Geo Wizards 10.0 for ESRI ArcGIS 9.3 was used to sort all the data points – by animal identification (i.e. collar identification) and at a temporal scale (i.e. year/month/day/hour). This extension sorts the data as defined above and creates a new field from which to work (i.e. ET_id).The ET_Id field is then populated using the field calculator in ArcGIS using FID+1, which allows for the data to then be sorted utilizing the one field. The Biogeography tools extension (ESRI http://arcscripts.esri.com/details.asp?dbid=15828) creates the movement paths by connecting all the data points within the dataset as defined by ET_Id field.

Movement parameters were summarized over both the entire study period and seasonally. Where seasonal summaries provided the seasons are defined as spring/summer (October 1st to March 31st) and fall/winter (April 1st to September 30th) of the respective study years.

Distance Calculations

Within the ArcGIS program, length has to be created from the created path file. It is populated by utilizing the calculate geometry tool within ArcGIS. Length is an important aspect of the dataset as determines the distance traveled between GPS fixes (i.e. locations between data points). This was done for individually for each wolf over the defined study duration. The study duration is defined as the time of capture and the wolf being outfitted with a GPS tracking collar to the final date the collar actively transmitted. The study duration ranged from 520 days (high end) to 102 days (low end) (Table 3). The original duration of the study was to be set at three years; however, due to issues with the GPS tracking collars, not all collars functioned for the full three years.

Average daily distance for each animal was calculated by taking the total distance traveled divided by the duration of the study. Seasonal average distances were calculated by taking the movement data separated by season and dividing by the total distance over the total number of days within the study (this varied per animal). This was done for the defined study seasons (i.e. spring/summer and fall/winter).

Speed Calculations

In order to calculate speed for each wolf the average daily distance was calculated (Table 3). Average daily speed was calculated by dividing the average daily distance by the number of hours in the day (24). This provides an insight into how far the wolf has traveled at an hourly rate expressed in km/hr.

Kolmogorov – Smirnov (KS) Test

The Kolmogorov-Smirnov (KS) was used to test the distribution of seasonal movements for normality and was used as a two-sample test to determine whether the movement distributions of the eleven wolves varied between seasons. The KS test is a non-parametric test of equality of two observed statistical distributions (McDonald, 2008). This test makes no assumptions about the data and typifies the distribution of values. Much of the literature suggests that wolf packs will undertake certain movement patterns during certain seasons – i.e. shorter movement patterns during the spring/summer and much longer movement patterns during the fall/winter. The KS test tests whether or not there is a difference in the travel movements of the wolves during the seasons (fall/winter pooled and spring/summer pooled) and whether these movements are normal in their distribution. The null and alternate hypotheses are as follows:

H_0 = the seasonal movement patterns of each wolf in the study will be evenly distributed between the seasons (i.e. travel distances remain the same regardless of season)

H_A = the seasonal movement patterns of each wolf in the study will not be evenly distributed between the seasons (i.e. travel distances are different between fall/winter and spring/summer)

The Kolmogorov-Smirnov (KS) test program found at http://www.physics.csbsju.edu/stats/KS-test.n.plot_form.html

This program automatically provides a test of normality for each input distribution as well a comparison between the distributions. For this analysis, results were considered significant at an alpha of 0.05.

Chapter 5: Results

Wolf Home Range

Telemetry locations for the 11 wolves used in the analysis are provided on **Figure 5** and their home range MCPs are given in **Figure 6**. The largest MCP was 196,020 km^2 (wolf 2686) and the smallest 721 km^2 (wolf 30254). The average home range was 45, 848 km^2 with a standard deviation of 55,972 km^2. In general, MCPs demonstrate considerable overlap between the wolves on the landscape. Seven wolves (wolves 2612, 2614, 2686, 2690, 31143, 31155, and 31156) in the northern regions overlap predominantly in the Harding Lake area, just north of Thompson Manitoba (**Figure 7**). There are two wolves, 2540 and 31140 that are at the outer edges of the northern MCPs that show some overlap with one other wolf adjacent to their individual MCPs. The two wolves in the eastern region, 30253 and 30254, only overlapped with each other and not any other of the wolves in the northern regions. The nature and extent of home range overlap is dependent on wolf movements that were coordinated and individual: some animals travelled with one another for a short period before separating (wolves 31140 and 31143); other individual wolves moved over long distances (wolf 2682, over 8, 460 km from Thompson Manitoba, to Nunavut and eventually Saskatchewan); while others stayed close to their original capture locations (wolves 31155 and 31156).

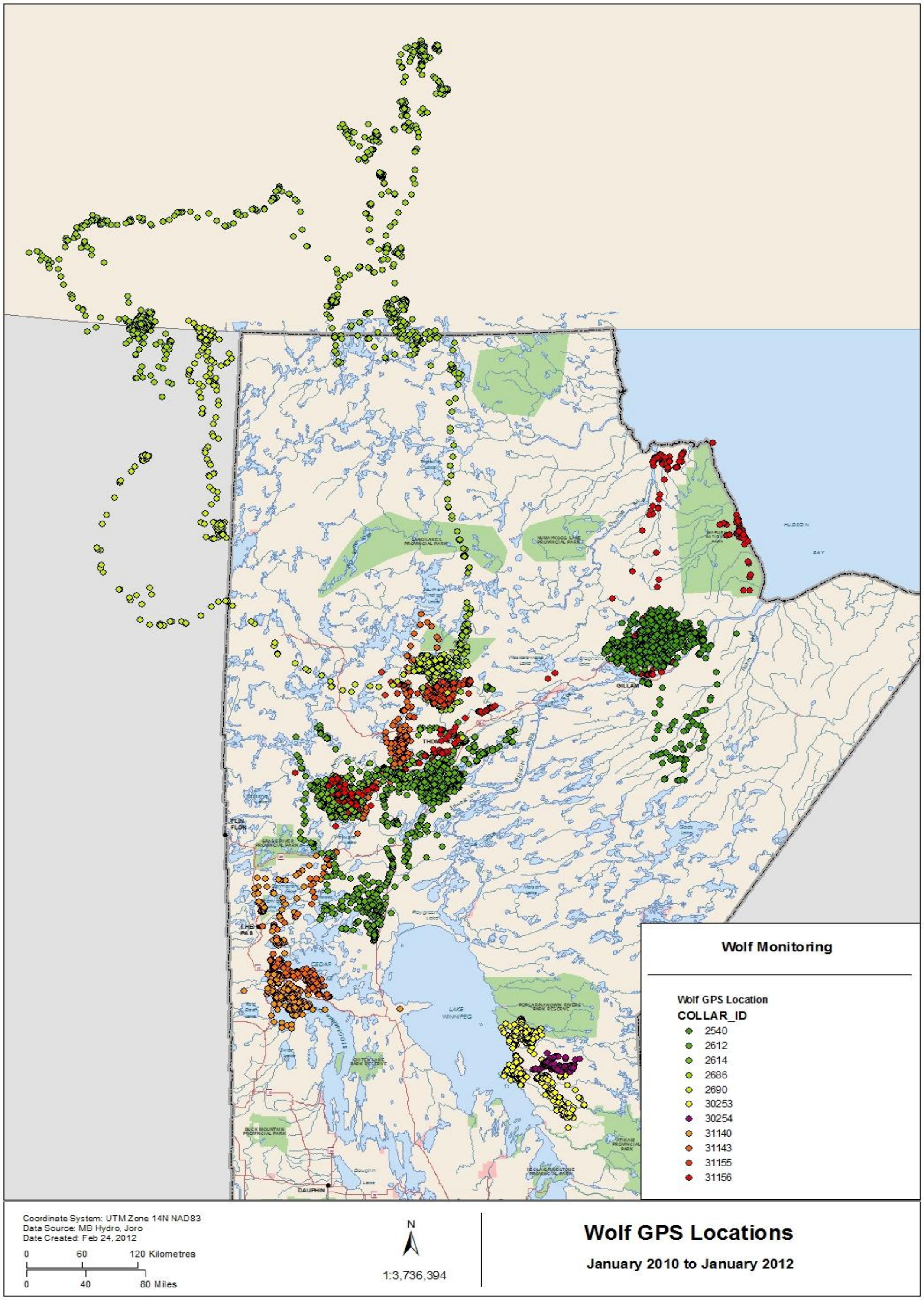

Figure 5: Wolf collar GPS locations

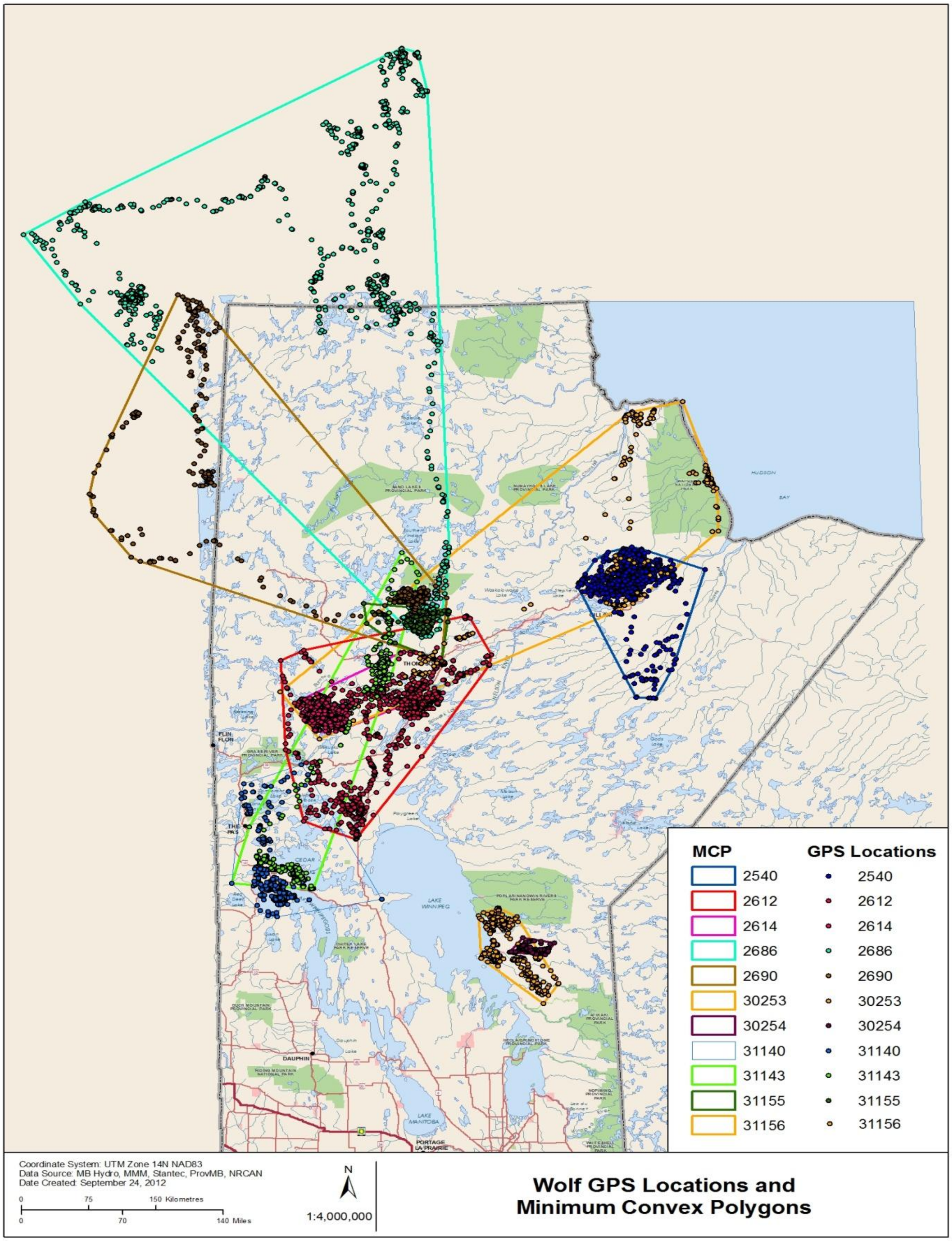

Figure 6: Minimum Convex Polygons (MCP) for home range delineations of 11 collared wolves

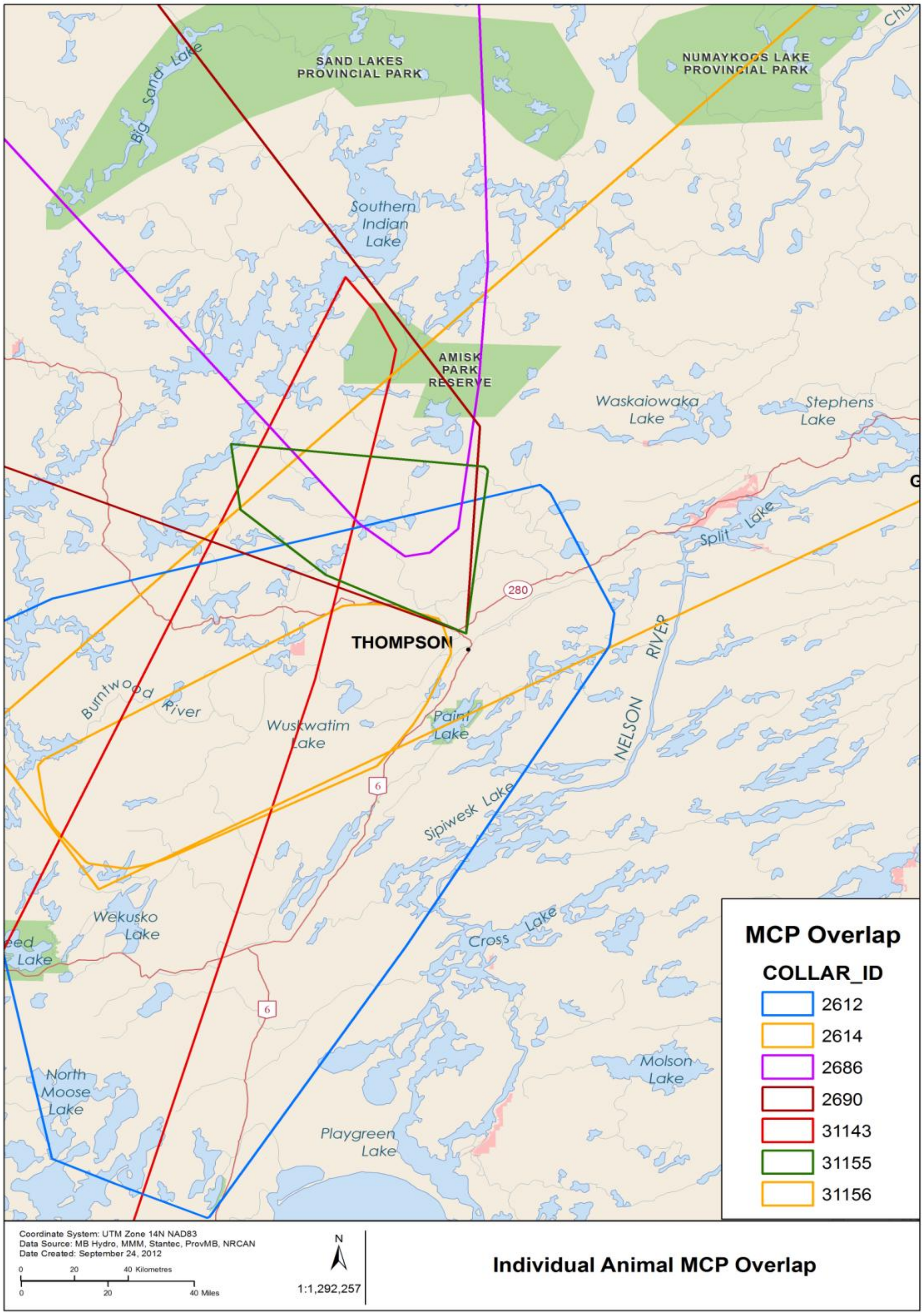

Figure 7: MCP overlaps for northern wolves

Wolf Movements

Duration of monitoring of each wolf varied during the study (Table 3) along with the number of data points collected during the duration of the study. The results for each wolf are summarized individually. Total distances traveled with average daily distances are summarized. Wolves exhibit a range of travel movements over the study period from the shortest distance travelled of 1,470 kilometres travelled (wolf 30254) to the longest distance travelled of 8,460 kilometres (wolf 2686). The shortest movement between telemetry fixes was .000421 kms (wolf 31143) and the longest 197.66 km (wolf 2690). Average distance for all wolves was 2.92 kms with a standard deviation of 5.626 kms.

Table 3: Summary of GPS Wolf Collar Data

Wolf Collar Id	Region	Sex	GPS Study Period Dates (yyyy mm dd)	Duration of Study (number of days)	Number of GPS Locations	Total Distance Traveled (km)	Average Daily Speed (km/hr)	Average Daily Distance (m)	Distance from Capture Location to End Location (km)
2540	Northeast	Female	2010 02 09 to 2011 07 05	511	3795	7489	0.61	14.66	18
2612	Northeast	Male	2010 01 30 to 2011 07 04	520	3744	6926	0.55	13.32	170
2614	Northwest	Male	2011 01 23 to 2011 12 31	342	1680	3670	0.45	10.73	4
2686	Northeast	Male	2010 01 31 to 2011 06 15	135	2988	8460	2.61	62.67	510
2690	Northeast	Male	2011 01 13 to 2011 06 24	159	798	2989	0.78	18.80	297
30253	Eastern	Male	2011 02 01 to 2011 07 20	169	2182	4238	1.04	25.08	11
30254	Eastern	Male	2011 02 01 to 2011 05 14	102	1275	1470	0.60	14.41	16
31140	Northwest	Unknown	2011 01 26 to 2011 07 12	167	635	2466	0.62	14.77	17
31143	Northwest	Unknown	2011 01 26 to 2011 10 20	267	1017	3350	0.52	12.55	268
31155	Northeast	Male	2011 01 13 to 2011 05 09	116	583	1761	0.63	15.18	49
31156	Northwest	Female	2011 01 17 to 2011 10 28	284	812	3141	0.46	11.06	364

Table 4: Wolf Seasonal Travel Rates

	Fall/Winter		Spring/Summer	
Wolf Collar ID	**Total Distance Traveled (km)**	**Average Daily Travel (km)**	**Total Distance Traveled (km)**	**Average Daily Travel (km)**
2540	6260.79	27.10	3763.70	13.59
2612	3073.26	12.81	3853.51	14.43
2614	1794.63	11.36	1875.64	10.31
2686	4510.65	19.19	4538.36	21.01
2690	1061.60	13.79	1927.56	22.95
30253	1642.62	28.32	2596.02	23.60
30254	1086.84	19.07	383.62	9.13
31140	918.87	14.36	1434.04	14.06
31143	955.92	13.09	2025.03	11.38
31155	894.20	11.61	821.58	21.61
31156	1040.33	10.40	1984.19	11.02

Table 4 illustrates the average daily travel rates for each wolf in both seasons. Some wolves' average daily travel distances had > 4 kms difference between seasons (wolves 2612, 2614, 2686, 31140, 31143, and 31156). Wolf 2686 being the longest distance traveller had a slightly higher average daily travel in the spring/summer (21.01 kms) versus the fall/winter (19.19 kms). While the short distance traveller, wolf 30254 had a greater daily average distance traveled in the fall/winter (19.07 kms) versus spring/summer (9.13 kms). Wolf 2540 had one of the highest differences in average daily travel with 27.10 kilometres in the fall/winter versus only 13.59 kilometres in the spring/summer. Wolf 30253 displayed consistent longer average daily distance travels in both fall/winter (28.32 kms) and spring/summer (23.60 kms). In both cases, travel in each season is significantly different. None of the wolves studied exhibited a consistent travel rate in both seasons (i.e. distances traveled varied in both seasons).

The distribution of distances travelled between telemetry fixes departed from that of a normal distribution for eight of the 11 wolves studied (**Table 5**). These results illustrate that the distances moved do not follow a normal distribution. It was observed that distributions departed from normality because of a preponderance of very short movement intervals with a few very large movements. Of the eight wolves, five of them (wolf collars: 2612, 2686, 2690, 31155 and 31156) exhibited less mobility during the fall winter whereas the other three (wolf collars: 30253, 30254 and 31140) were less mobile during the spring/summer.

Table 5: P values and the maximum difference between the cumulative distributions (D)

Wolf Collar ID	**P value**	**D max diff**
2540	0.092	0.126
2612	<<0.001	0.287
2614	0.272	0.106
2686	0.003	0.176
2690	<<0.001	0.341
30253	<<0.001	0.7381
30254	<<0.001	0.71
31140	<<0.001	0.3484
31143	0.901	0.0813
31155	0.011	0.3077
31156	<<0.001	0.3085

In plotting the cumulative fractions, if the data plots along a forty-five degree angle then the data fits with the null hypothesis (expectation under normality). For all of wolves in the study, few of the plotted distributions followed normal expectation. **Figures 10** and **11** provide two examples of the cumulative fraction plots for two of the eleven wolves – one with the P value >.05 (wolf collar 30253) and the other with the P value <.05 (wolf collar 2686). Collar 30253 has a closer fit than collar 2686.Thus the distribution of wolf movements observed in the study, as defined as the distance moved between fixes and stratified by season, were typically not normally distributed. However, movements were highly variable and inconsistent between individuals, as such, movements of each of the wolves will be described below.

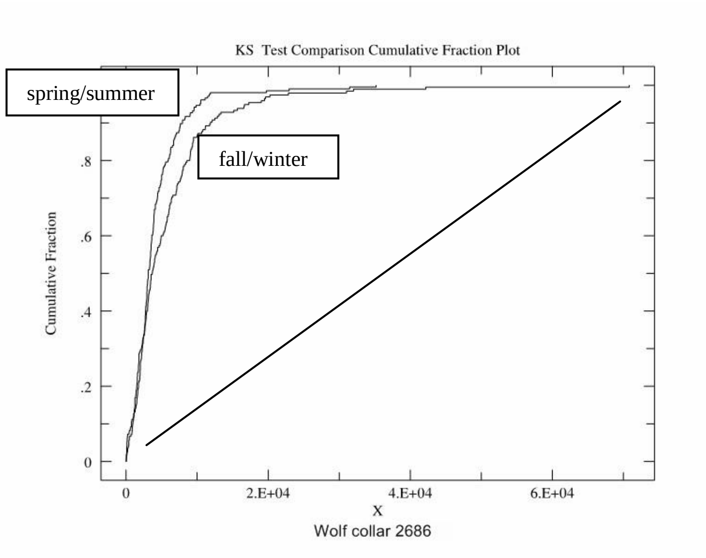

Figure 8: Wolf collar 2686 cumulative fraction plot illustrating the P value <.05

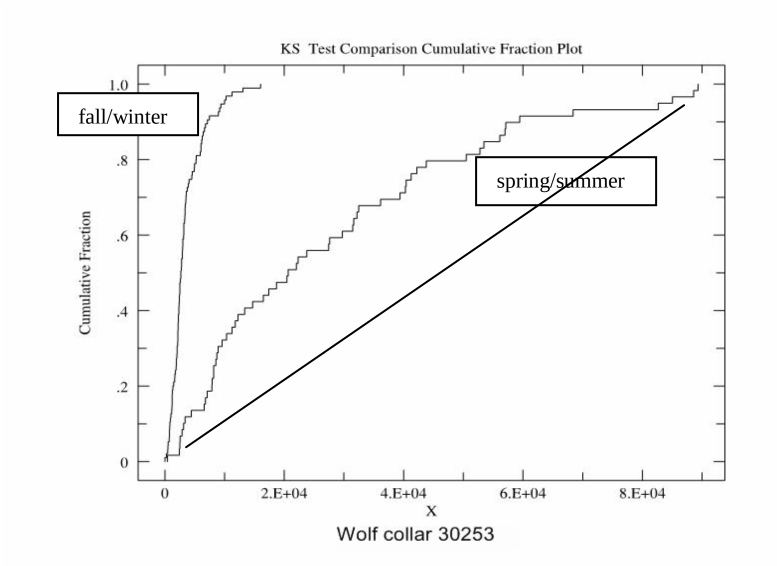

Figure 9: Wolf collar 30253 cumulative fraction plot illustrating the P value >.05

Wolf 2540 (Female)

In analyzing the 3795 GPS relocation data points, this wolf travelled a total distance of 7,489 kms. However, there was only 18kms between the initial site of capture and the final transmission location. This wolf spent most of its time north of the Nelson River (spring/summer), venturing south down the Hayes River during the fall/winter season. The P value between fall/winter and spring/summer was calculated at 0.092. For this wolf, seasonal movements appear to be different, average daily travel in the spring/summer and fall/winter movements were 13.59 km and 27.10 km respectively, indicating that this individual was less mobile in the spring/summer.

Wolf 2612 (Male)

There were 3744 GPS relocations for this wolf. The data points indicate that this wolf undertook a complete circle in the first year it was collared (2010) and then travelled an easterly routing for the remainder of the period. The last transmission for this animal was located on an island in Paint Lake, just south of Thompson. The distance between the initial capture site and the final transmission location was 170kms. The spring/summer movement patterns show this animal was situated mostly in the north of its MCP and the fall/winter movement patterns illustrate movement from the north to the more southern extent of its range. The P value between fall/winter and spring/summer was calculate to be <<0.001. For this wolf, seasonal movements appear to be different, average daily travel in the spring/summer and fall/winter movements were 12.81 km and 14.43 respectively, indicating that this individual was less mobile in the fall/winter.

Wolf 2614 (Male)

This wolf was captured and collared in the Wimapedi area, travelled north to Thompson and then travelled adjacent to PR 391 (highway from Thompson to Lynn Lake). The GPS relocation points illustrate that the wolf only crossed the highway on two occasions. While it had 1680 GPS relocations, there was only a distance of 4kms between its original capture location and the final transmission location. The spring/summer movement patterns show this animal staying close to its original capture location with some movements heading north. The shorter distance movement patterns tend to result in spatial clustering. However, the fall/winter movement patterns exhibit shorter distance movements as well similar to the spring/summer movement patterns, indicating an affinity to a particular area within the landscape. The P value between fall/winter and spring/summer was calculated to be 0.272. For this wolf, seasonal movements appear to be different, average daily travel in the spring/summer and fall/winter movements were 10.31 km and 11.36 km respectively, indicating that this individual was less mobile in the spring/summer.

Wolf 2686 (Male)

Wolf 2686 was collared north of Thompson in the Harding Lake area, travelled north to Nunavut and then into Saskatchewan (**Figure 10**), for a total distance traveled of 8,460kms. This travel route may coincide with the migratory movements of the barren ground caribou, as they travel in both northern Saskatchewan and Manitoba. Barren ground caribou summer ranges are generally just north of the tree line (Frame, Cluff and Hik, 2008), which in reviewing the data points for this animal would coincide with the barren ground migration route. There were 2988 GPS relocation points for this wolf. There was approximately 510 kms from the original collar location to its final transmission location in Saskatchewan. This wolf had movement patterns similar in each season – shorter movements for a couple of months (i.e. February/March) followed by longer movements (i.e. April/May) and then shorter movements (i.e. June) and again longer movements in July. The corresponding P value for this wolf of 0.003. For this wolf, seasonal movements appear to be different, average daily travel in the spring/summer and fall/winter movements were 21.01 km and 19.19 respectively, indicating that this individual was less mobile in the fall/winter.

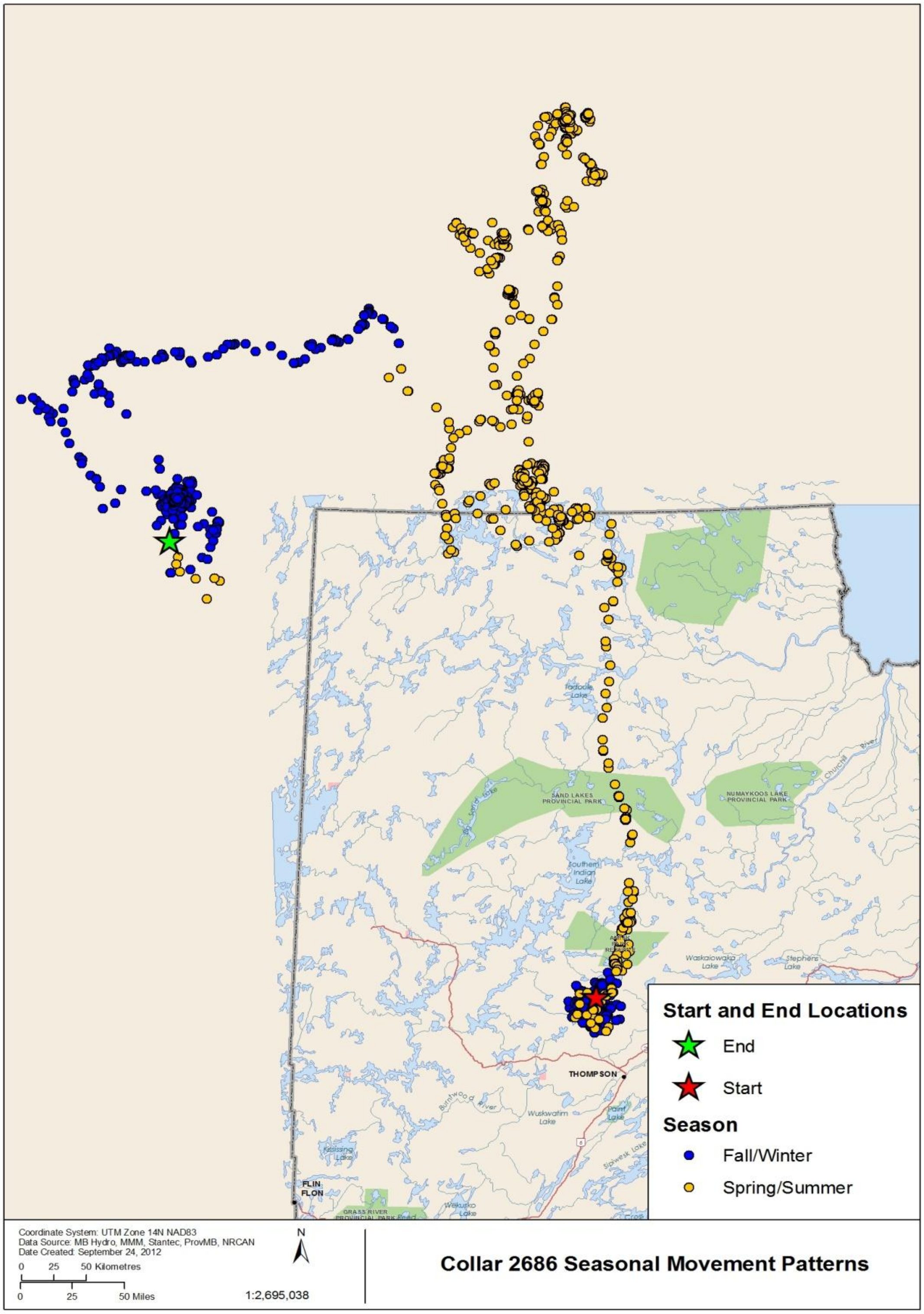

Figure 10: Movement pattern for wolf collar 2686

Wolf 2690 (Male)

This collar had 2234 GPS relocations from its original collaring location in the Wheadon river area in February 2010 to the final transmission in Saskatchewan in June 2011. However, there was a three-month data gap with the relocations over a six-month period indicating that there could be an issue with the collar. Further investigation found that the collar chewed off and it was retrieved. The collar was refurbished and re-deployed in January 2011. The second collaring occurred in the Harding Lake area and the last transmission for this animal was from Saskatchewan. There were 798 GPS relocations for this wolf. In the first collaring, this wolf stayed tight to its original capture location with no significant movement patterns. In the second collaring, this wolf there was shorter fall/winter movements followed by large distance movements during the spring/summer. The calculated P value for this wolf between fall/winter and spring summer was <<0.001. For this wolf, seasonal movements appear to be different, average daily travel in the spring/summer and fall/winter movements were 22.95 km and 13.79 respectively, indicating that this individual was less mobile in the fall/winter.

Wolf 30253 (Male)

This wolf was collared in the eastern region and had 2182 GPS relocations. Analysis of the relocation points indicates that there were only 11kms from its initial collaring location to the final transmission received. As illustrated in **Figure 11**, this wolf inhabited an area where there was limited disturbance (i.e. little to no linear features on the landscape). The majority of the long distance movements for this animal occurred during the fall/winter months, with some shorter movements found in April and June. Spring/summer movements appear to be more consistent and more normally distributed. The calculated P value between fall/winter and spring/summer for this wolf was <<0.001. For this wolf, seasonal movements appear to be different, average daily travel in the spring/summer and fall/winter movements were 23.60 km and 28.32 km respectively, indicating that this individual was less mobile in the spring/summer.

The fall/winter movement patterns indicate traveling along the lake and the lakeshore. It should be noted that the isolated community of Berens River is located at the northeast corner of Lake Winnipeg, where commercial fishing occurs throughout the year, and is within the home range for this wolf.

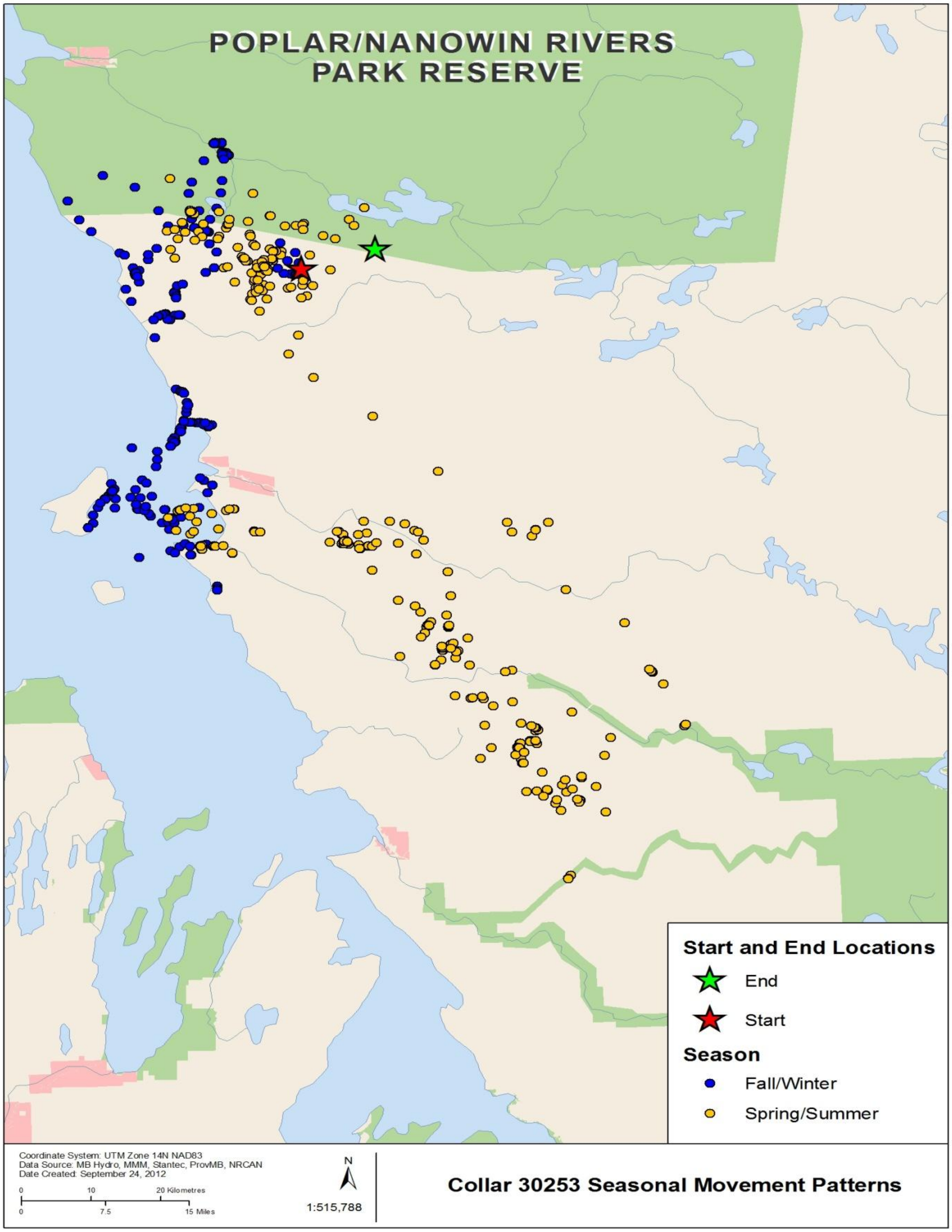

Figure 11: Movement pattern for wolf collar 30253

Wolf 30254 (Male)

There were 1275 GPS relocations for this wolf that was originally collared in the Charron lake area in eastern Manitoba In reviewing the data points there was only 16kms between the original collar location and its final transmission location. This wolf had some overlap in its range with wolf collar 30253. The majority of movements were during the fall/winter, however, it should be noted that it is suspected that the collar failed or was lost during the spring (May). The calculated P value for this wolf for its fall/winter versus spring/summer movement was $<<0.001$. For this wolf, seasonal movements appear to be different, average daily travel in the spring/summer and fall/winter movements were 9.13 km and 19.07 km respectively, indicating that this individual was less mobile in the spring/summer.

Wolf 31140 (unknown) and Collar 31143 (unknown)

Wolves 31140 and 31143 were both collared in the Bog, south of the Pas, Manitoba. Wolf 31140 had 635 GPS relocations, whereas wolf 31143 had 1017 GPS relocations over a ten-month period. Both animals were collared in late January 2011 and in examining the data points, it appears that these two wolves travelled together for approximately five month before separating in May 2011 (**Figure 12**). The analysis of data points for 31140 indicates only a difference of 17kms from its original capture location to the last transmission. Wolf 31140 once separated from wolf 31143, began its journey south back towards its original capture location. The GPS data points for its return trip show that this animal backtracked and went around the lake once it came to a significant linear feature – provincial highway #10. Wolf 31143 the distance between the original collar location and its final transmission location was 268kms. In analyzing the data points, it appears that this wolf travelled north and was on its way back to the original collar location when contact was lost. For both of these wolves, the long distance movements occurred during the spring/summer season. There are shorter distance movements during the spring/summer. The P value for wolf 31140 was <<0.001. For this wolf, seasonal movements appear to be different, average daily travel in the spring/summer and fall/winter movements were 14.06 km and 14.36 km respectively, indicating that this individual was less mobile in the spring/summer. The P value for wolf 31143 was 0.901. For this wolf, seasonal movements appear to be different, average daily travel in the spring/summer and fall/winter movements were 11.38 km and 13.09 km respectively, indicating that this individual was less mobile in the spring/summer.

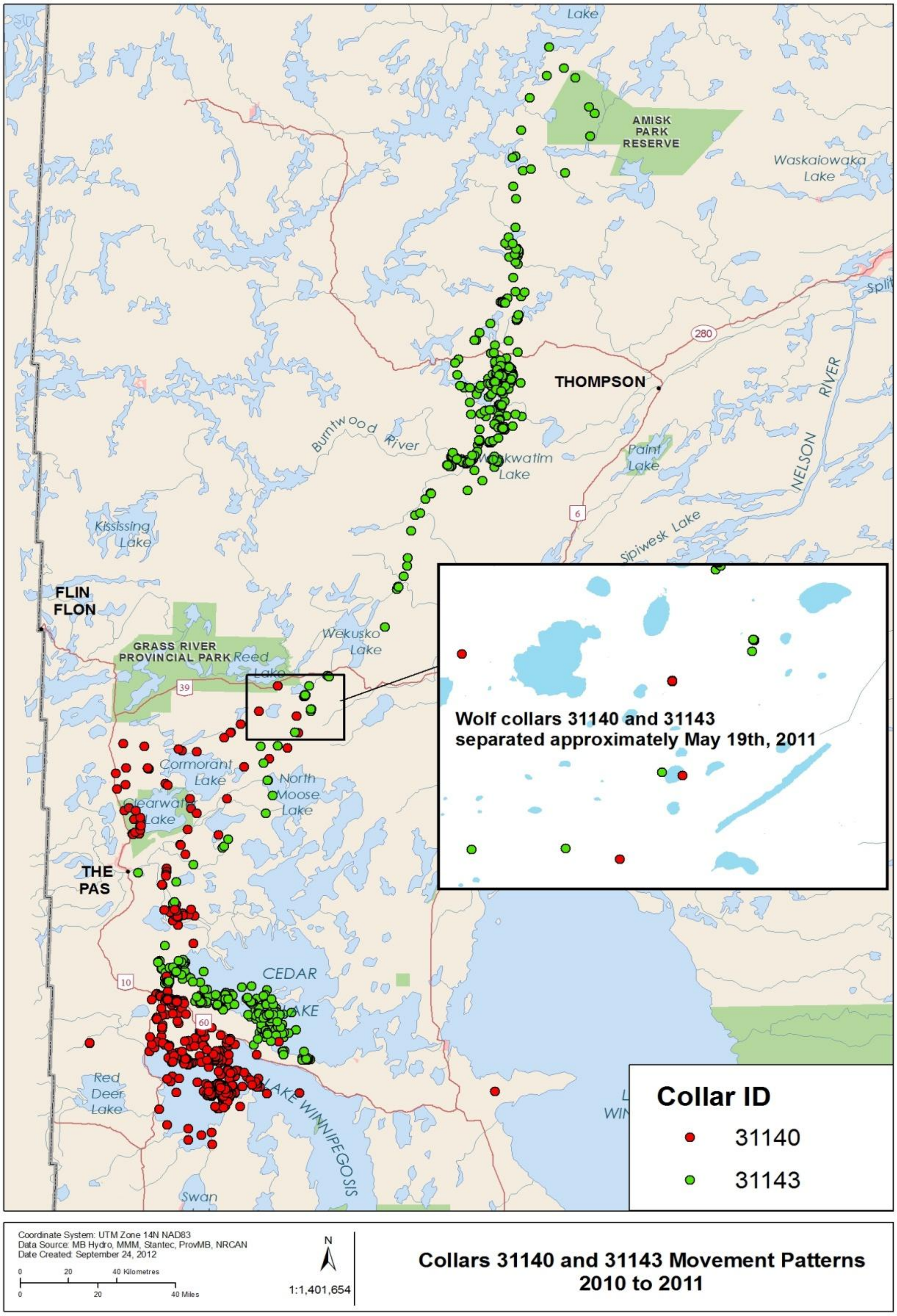

Figure 12: Movement patterns of wolf collars 31140 and 31143

Wolf 31155 (Male)

Capture of this wolf occurred in the Harding Lake area, north of Thompson. There were 583 GPS relocations for this animal. In analyzing the data points, it appears that this wolf initially travelled away from the capture location but was on its way back. There were 49kms from the initial capture site to the last transmission. The two seasons (spring/summer and fall/winter) movement patterns overlap each other and remain within the Harding Lake area, north of Thompson. Long distance movements occurred in both seasons, however, the average daily distance was higher in the spring/summer. It should be noted that there is a boreal woodland caribou population inhabiting this area (D. Leask, personal communication). The calculated P value for this wolf between fall/winter and spring/summer was 0.011. For this wolf, seasonal movements appear to be different, average daily travel in the spring/summer and fall/winter movements were 21.61 km and 11.61 km respectively, indicating that this individual was less mobile in the fall/winter.

Wolf 31156 (Female)

This wolf was captured in the Snow Lake area. It travelled northeast towards Gillam and had 812 GPS relocations. There was 364 kms between its initial capture sites to the last transmission location. Fall/winter movement patterns indicate shorter movements followed by longer distance movements in the spring/summer. In the first winter, this animal stayed within its capture location and then ventured northeast into the Nelson River area, where it stayed for most of the winter until it moved again in the spring to the coast of the Hudson Bay before returning to the Nelson River area. It should be noted that the review of the data points indicates that the last transmission occurred on the tailrace deck at the hydroelectric dam at Long Spruce. The calculated P value for this wolf was $<<0.001$. For this wolf, seasonal movements appear to be different, average daily travel in the spring/summer and fall/winter movements were 11.02 km and 10.40 km respectively, indicating that this individual was less mobile in the fall/winter.

Chapter 6: Discussion

The overlap in MCPs suggests that these wolves may interact throughout their travels to aid each other in the acquisition of prey as suggested by Palacios and Mech (2011). The MCP method provides a general indication of range use, based on the GPS movement data. MCPs for long ranging animals such as gray wolves, need to be viewed with some caution, given their ability to travel considerable distances, their MCP may appear to be quite large when in fact upon further analysis, they are utilizing a significantly smaller portion of their range during key seasons. In addition, the wolves in this study travelled significant distances as they dispersed from the natal pack. Post-natal dispersal movements are often necessary in finding a mate, to establish new packs or in joining other packs (Chaput, Legendre, Ferriere, Clobert and Haight, 2003; Demma and Mech, 2009; Herfindal, 2012). These types of movements are considered critical in enhancing the genetic gene flow between populations (Fritts and Carbyn, 1995; Cuicci et al., 2008). Caution needs to be used in stating unequivocally that the MCP as determined through ArcGIS is the home range for a particular animal, given that wolves can and do travel extensive distances for one reason or another, thus their home range could very well be over exaggerated and prone to bias (Burch, Adams, Follman, and Rexstad, 2005; Nilson, Pedersen and Linnell, 2008; Laver and Kelly, 2008). A better methodology for determining range utilization would be through the kernel density estimator (KDE) which provides a much better insight into how wolves uses their range based on habitat preferences or seasonality (i.e. core area use). While the KDE method would provide a finer scale of habitat use, it also has the propensity to overestimate home range size (Downs and Horner, 2008). The MCP method broadly illustrates the ability for wolves in Manitoba to traverse long distances. The MCP also illustrates that there is overlap within packs and individual animals, indicating some territory sharing. The study by Findo and Chovancova (2004) examining the home range use of two wolf packs in the Slovak Carpathians, used both the MCP and KDE method and concluded that the home range utilization by the wolves was uneven. In addition, there was seasonal variability for range use based on prey availability in spring/summer (April to September) and autumn/winter (October to March) – with the range use decreasing in the spring/summer as denning and pup rearing was the priority to increased range use in the autumn/winter for enhancement of prey capture. This provides an idea of whether or not there is any seasonal correlation in distance traveled. In most instances, there does not appear to be a clearly discernible correlation to distance traveled between seasons.

A further analysis utilizing the GIS data points would visually illustrate the locations and areas in which the wolves were traveling, as seen with wolves 31140 and 31143 (**Figure 12**). Travel distance shown in **Table 3** encompassed the total duration of the study (i.e. data points from multiple years) and may not be a true representation of seasonal movement patterns. Examining travel distances on a year-by-year basis would more than likely provide a truer representation of movement patterns on the landscape. Another aspect of wolf multistage dispersal patterns can be found in the study undertaken by Wabakken et al. (2007). Their study examined the directional and non-directional movement and found differing travel speeds, rates and distances. Summer speeds and directional travel were found to be significantly greater than the non-directional travel in both summer and winter (Wabakken et al., 2007). However, that study only focused on one GPS collared wolf. Utilizing the methodology from this study may provide a clearer insight into how wolves in Manitoba are traveling within their ranges. The MCPs of the northern region wolves indicates that these wolves could possibly be part of a larger meta population, whereas the eastern region wolves could be more aligned with Ontario wolves, given the close proximity of the provincial boundary. As seen in **Figures 10** through **12**, there is definite season variability in movements. In the study by Findo and Chovancova (2004) they found that the spring/summer months (May to October) GPS data points are localized to an area whereas the fall/winter month (November to April) the GPS data points are spread much further throughout the wolves' range. In the case of the wolves in this study, some animals had very little movement between seasons and others had significant movement patterns primarily in either the spring/summer season or fall/winter season. This may be attributable to the study area in Manitoba being much less fragmented by human development and prey availability not limited.

It is suspected though not confirmed, the Lotek collars had issues with the battery packs not being completely watertight, thus if the animal is travelling through water (i.e. swimming through rivers) water would enter into the battery pack and short circuit the electronics making the collar useless for GPS tracking (T. Barker, Manitoba Hydro, personal communication). Other studies have found a poor GPS collar performance on the same collar type which could be attributable to technical issues associated with the collar acquiring fixes in locations with steep terrain, high canopy cover and time of year (D'eon, Serrouya, Smith and Kochanny, 2002; Frair, Nielsen, Merrill, Lele, Boyce, Munro, Stenhouse, and Beyer, 2004; DeCesare, Squires and Kolbe, 2005). The ATS collars appear to be working well, with losses attributed to the wolves themselves chewing the collars off or the wolves being shot (T. Barker, Manitoba Hydro, personal communication).

Whenever a wolf prey species, such as moose, experience a decline in population, the most often cited case for that decline is due to increased predation by wolves (Fuller and Keith, 1981; Bergerud, 1985; Seip, 1992; Van Bellenberghe, 2011). In response to those declines, many jurisdictions institute some form of wolf management plan, which usually results in increasing wolf harvest rates or a bounty on wolves (Van Bellenberghe, 2011; Province of Manitoba, 2012c). However, is this the correct management measure? In many instances, the reactive position of instituting wolf reduction programs, creates additional imbalances within the ecosystem and creates potentially devastating cascading effects (Ripple and Beschta, 2003;Frank, 2008). In 1974, the United States placed gray wolves on the endangered species listing and the primary responsibility for their management resided at the federal government level. As part of the legal requirements associated with the listing under the federal *Endangered Species Act*, appropriate management measures and research priorities are to be developed. This in turn has required the states to follow a similar direction and has resulted in very comprehensive integrated resource management plans for wolf management at the state level. The wolf management plans developed in states such as Michigan, Minnesota, and Wisconsin rely on an integrated approach to wolf management now that the western Great Lakes population of gray wolves is no longer under the federal protection of the *Endangered Species Act*. In order to develop integrated plans, understanding how gray wolves interact on the landscape and within the broader ecosystem is required.

As seen in the Yellowstone experience the total eradication of wolves from the ecosystem produced cascading effects (Ripple and Beschta, 2003). While the re-introduction of wolves back into that landscape was not without controversy, the ability to study those impacts has been significant. The research has provided a unique opportunity to develop adaptive management strategies that do not create an imbalance and alter the predator-prey dynamic of a system.

Manitoba Conservation is the regulatory agency responsible for the management of wildlife resources in the province. Manitoba Conservation suggests that there are approximately

4,000 gray wolves within the provincial boundaries and that the population is a stable (Province of Manitoba, 2012b). Manitoba has not and does not publish a wolf management plan nor is there any published data on what wolf population numbers are in the province and the methodology on how the overall population of gray wolves has been derived. Other jurisdictions in Canada and the United States have active wolf management plans that are routinely reviewed and updated (i.e. Ontario, Alberta, Alaska, Wisconsin, Michigan, Minnesota, and Washington State). British Columbia is currently in the process of developing a wolf management strategy, which is not without its controversy. The current trapping guidelines for wolves include no bag limits and no closed season (Province of British Columbia, 2012). Saskatchewan does not have a wolf management plan but does include wolf harvesting as part of the hunting regulations and in the more northern regions, municipalities are allowed to place harvest wolves to aid in managing the population (Province of Saskatchewan, 2012). European countries such as Italy, Poland, Norway and Finland have developed wolf management plans and strategies aimed at managing population levels of wolves and minimizing potential wolf-human interactions, such as wolf-cattle kills (Chapron et al., 2003; Wabakken et al., 2006Ciucci et al., 2008;). As Chapron et al. (2003) suggests if eliminating individual wolves or packs is required, it should not be at expense of the overall wolf population.

Implementing a reactive management strategy, comprising of increased hunting pressure on a top apex predator in response to declines in prey species, is not good management practice. In interior Alaska in the community of McGrath, moose play a significant role in the subsistence needs of the community (Van Ballenberghe, 2011). A moose survey had placed the population of moose in a significant decline and the immediate response was to implement a wolf reduction program, as the perception was that the main cause of the drastically reduced population was due to wolf depredation. Before the management measure was implemented however, another moose survey was undertaken which resulted in a vastly different population estimate – one that would indeed meet the community subsistence needs. In addition, this survey also illustrated that bears were playing a much more significant role in the reduction of moose calves, in sharp contrast to the community held perception that wolves were the driver of the perceived moose population decline.

The McGrath experience illustrates that any wolf management programs must be scientifically sound with a complete picture of what is happening on the landscape. Predator control alone is not a sound scientific methodology for resource management. Unfortunately, in Manitoba, there is not a comprehensive or integrated approach to resource management. Moose management committees established as a reactive measure well after the fact of moose declines, while robust in terms of membership (i.e. variety of stakeholders form hunter organizations to industry to First Nations), were never really empowered to provide effective dialogue back to the province in terms of assisting in the development of an integrated approach to dealing with the moose crisis in both the western and eastern regions of the province. The initial response by the Wildlife Branch of Manitoba Conservation was an immediate implementation of an increase on the wolf harvest for those regions (Province of Manitoba, 2012c). Given the long distances in movements observed in this study, it is unlikely that extirpation or population reduction can be achieved by these means. It is far more likely that for every removed animal, other animals would simply emigrate from adjacent regions in which the hunting pressure is minimal and pack reproduction is high.

The Province of Manitoba could look to the mid-western states and Ontario for guidance on how to develop an integrated wolf management plan. These management plans place a value on wolves as an integral component of a healthy ecosystem. Public perception and education is also a key element in any management plan that is developed. Wildlife perceptions and beliefs held by groups or individuals shape how they will react to policy and management techniques (Schanning, 2009). If policy decisions or management techniques do not line up with people's belief systems, then those policies will ultimately fail. Society as a whole has change dramatically in their viewpoint of wolves. The early European settlers in North America brought with them their long held beliefs, both symbolic and physical in nature, that wolves were a threat to humans and hence required to be eradicated (Schanning, 2009). It was not until the mid 20th century when bounties on wolves began to be removed in the United States that this view of wolves began to change. Wolf recovery in the United States would probably not be possible without changing people's perceptions of wolves. Schanning (2009) further points out that part of the change was due in large part to having a broader stakeholder group actively engaged in drafting and supporting that recovery planning and strategy. Negative attitudes regarding wolves will continue in part due to embedded cultural and societal viewpoints, but by continued active engagement in managing the species, those attitudes can change.

Chapter 7: Management Implications/Recommendations

Understanding wolf ecology and population dynamics within the Province of Manitoba will require a more integrated approach to resource management. This study has provided a small insight into how wolves are moving on the landscape within the province. Two distinctive dispersal patterns were observed – short distance movements where individuals remained few tens of kilometers from the point they were collard and those that made long-distance dispersal movements often-outside Provincial jurisdictions into neighbouring Provinces or Territories. The long distance wolves tend to emigrate out of the study area, entering in and out of multiple jurisdictions over their lifetime. Although this study had a relatively small sample size, a relatively large proportion of the wolves in this study displayed this behaviour, indicating that this may be a common occurrence (Wabakken et al., 2007; Cuicci et al., 2008; Gula et al., 2009). If this is the general behaviour of wolves in the region, it is also equally likely that wolves in other jurisdictions make similar movements - including movements into Manitoba. Thus, any changes in wolf numbers in Manitoba - such as reduction - might simply result in replacement with additional animals from other jurisdiction undertaking similar movement patterns. Even with an intensive animal reduction programs in place, as wolves are removed from the system additional wolves could be move into the area resulting in a relatively stable population. Wildlife managers need to consider this in development and implementation of wolf management plans. Furthermore, findings from this study suggest that a multi-jurisdictional approach is essentially mandatory for success of any plan. For example, the wolves in Yellowstone National Park are part of ongoing research into wolf/ecosystem dynamics. These wolves have crossed out of the Park boundaries to neighbouring states, such as Wyoming, Idaho and Montana, resulting in some radio collared wolves being killed (The Associated Press, 2012). The wolves are protected while in the boundaries of Yellowstone, but unless there is a cross jurisdictional agreement or buffers implemented with and within adjacent jurisdictions, wolf management plans are generally singular in their jurisdictional focus. The wolves in this study also demonstrate that they can and do cross into adjacent jurisdictions. Of all the jurisdictions wolves in this study have travelled, Ontario is the only one that has in place a wolf management plan. While it draws on the management strategies from its neighbouring US states, there is no mention of intra-provincial management with either Quebec or Manitoba. One of the key implications of this study is that cooperation among Provinces and Territories is a necessary step in predator management and one that has not occurred to date.

While this study has shown that wolves can travel remarkable distances within their territories and beyond, it has opened the door to further research. To this end some guidance can be taken from Wydeven et al (2009) that studied wolf populations that have begun to recover in the Great Lakes Region.. They advise caution in developing wolf management plans that allow the wolves to become game species, or public harvesting as this could be counter to the population goals that have been established. They also recommend that population monitoring and further research should continue. With this in mind, below are recommendations that could be used in the development of an appropriate and manageable wolf management plan and further research for Manitoba wolves.

Integrated Wolf Management Plans

Undertaking a predator management plan (i.e. wolf harvest) in the absence of science is inappropriate. Allowing for an increase in wolf hunting without sound scientific knowledge of wolf population ecology is not a good wildlife management scheme. As shown in the McGrath

Alaska experience, wolf management was not the appropriate response to a perceived moose population decline. Fisheries and Oceans Canada in the early 2000s implemented integrated resource management plans for a variety of fisheries. The intention of integrating the plans was to encompass not only the biological aspects and harvest allocation for a particular species, but also the economic, social and cultural components of those species. Stakeholder participation and to a degree ownership of that fishery are integral elements of the plan. All harvest rates or total allowable catches (TACs) are based in proper scientific stock assessment work. In some cases TACs may decrease but with the establishment of a stakeholder working group to discuss those types of issues can be more effectively managed and issues dealt with. Without that mechanism, confrontations between the regulator and stakeholders would increase.

Management of prey species, such as moose and caribou, need to encompass predator influences – especially apex predators such as wolves – in their management plans. In tying the whole system together, where species interact with other species, the ability to manage at an ecosystem level is increased. Gray wolves can regulate themselves through intra specific strife and territoriality, which needs to be considered when developing management plans. The current philosophy that increases in prey species will in turn increase predator species needs to be re-thought. Moose management for example in Ontario has as one of its core strategies to consider linkages between management objective of wolves and moose to aid in determining population levels that are sustainable (Ontario Ministry of Natural Resources, 2009). Nevertheless, it falls short in the actual implementation – there appears to be no work done to date that links the wolf management plan and the moose management plan to see what if any linkages there are between the two species from a resource management perspective. Other jurisdictions such as Alberta and Saskatchewan have developed integrated resource management plans for large regional and sub regional landscapes where there are number of competing interests (Alberta Sustainable Resource Development, 1996; Province of Saskatchewan, 1998). However, these plans are more of a planning document on how issues such as wildlife resource allocation could be determined. It is interesting to note that bears are the only large predator that warrant a reference in the document in terms of maintaining a set population level in the interests for hunting and encouraging additional "recreational benefits" beyond the current levels (Alberta Sustainable Resource Development, 1996; Province of Saskatchewan, 1998).

GPS Collaring

Maintaining GPS collars on wolves over a longer period will provide a greater degree of understanding of how they interact within the ecosystem. However, as seen with this study, the ability to maintain collars on wolves over the long term is not an easy task. Consideration should be given to a short collaring period (i.e. one year). This would provide a greater degree of accuracy in the data being obtained. In addition having collars set for a shorter duration would open up the possibilities for insights into wolf ecology such as denning and pack dynamics. The downside to GPS collaring is the cost associated with such a program. Collaborating on such a project with industries working or utilizing resources on the landscape provides a more open and transparent process of resource management. As shown with the boreal woodland caribou research currently ongoing in the province, the benefits for both sides are immense.

Collaring by itself does not provide a robust picture of the dynamics on the landscape. In addition to analyzing, the collar data on the ground tracking surveys should be undertaken, especially in summer months, as the high canopy in the boreal forest tends to obscure the ability of the GPS tracking collars to effectively re-locate animals through aerial telemetry work.

Analysis of GPS Relocation Points

Additional analysis of the GPS relocation points needs to be undertaken to determine kill rates, kill sites and rendezvous locations (Vuceith et al., 2011; Metz et al., 2012). The shorter distance movement patterns resulting in spatial clustering could provide insights into locations of denning kill sites and potentially kill rates. While kill rates are not indicative of predation rates, they can provide an insight into the rate by which wolves and/or wolf packs acquire prey (Metz et al., 2012; Vuceith et al., 2011). This type of information can provide an insight into the predator-prey dynamic on the landscape and assist in shaping resource management strategies. However, this analysis has to be done in both summer and winter periods in order to get a full picture of predation rate, given that in the summer months, preference in prey selection is for juveniles (Sand, Wabakken, and Zimmermann, 2008; Merrill, Sand, Zimmermann, McPhee, Webb, Hebblewhite, Wabakken and Frair, 2010). Kill rates in the summer will be higher given the nature of the lifecycle (i.e. pup rearing) and nature of prey availability (i.e. juveniles).Understanding the kill rates for both seasons can assist in developing more accurate population estimates for prey species and thus a more sustainable resource harvest quota.

Locating and determining denning locations and homesites for gray wolves in Manitoba through the GPS data points will aid in creating more credible and reliable population estimates. Understanding how wolf populations are responding to changes on the landscape or in response to prey declines or abundances, will aid in predicting population trends within the wolf population. As part of the recovery, strategies for the gray wolves in the United States include determining the appropriate minimum population level and its associated locale for a healthy wolf population (Fritts and Carbyn, 1995).

Genetic exchanges between populations are also important in determining the overall health of wolf populations in Manitoba. As seen with this study, there are varying degrees of overlap between the individual wolves and their home ranges (MCPs). Having the ability to move between areas allows for increased genetic flow. There are packs in Manitoba that could be considered genetically isolated, predominantly Riding Mountain National Park (Fritts and Carbyn, 1995; Aindell, 2006) that seems to maintain stable population levels. In other areas where it appears that populations are isolated, as seen in some European countries (Italy for example), some wolves have managed to undertake long treks to other countries, suggesting that while the population had become isolated, there is still linkages to its original metapopulation (Ciucci, et al., 2008).

Modelling

Modelling for pack densities will allow for a better understanding of gray wolf densities and their associated territory. Given that conducting wolf population counts is problematic through aerial survey alone, modelling can provide a proxy to determine pack populations especially in areas in which prey species long term health and viability are a concern (i.e. moose, boreal woodland caribou). This type of modelling can be done in conjunction with modelling for habitat use and utilization as shown by Milakovic et al. (2011). Their study examined if vegetation, land cover, habitat-selection for prey played an important role in wolves selecting locations for their lifecycle processes. What they found was that there was a correlation to land cover and habitat that is conducive for prey availability but not necessarily selecting for high prey densities. Given the number of collars currently, collecting data on wolf movements, modelling with a similar set of parameters would enable the resource managers to better understands wolf populations within a multi prey system (i.e. caribou, moose).

Data Acquisition and Publication

Manitoba Conservation needs to publish the results of aerial surveys and population estimates. Undertaking a modelling program to determine wolf density thresholds for areas where prey species are a concern (i.e. sensitive moose and/or caribou habitats) will allow for more effective wolf management programs. Cariappa et al. (2011) took data from northern United States and Canada and modeled the data to determine threshold densities of wolves based on habitat size (i.e. number of wolves per km^2). This allows for a more integrated management plans.

Conclusion

This research has illustrated that there is still much to learn and understand about wolf pack dynamics and populations in Manitoba. The wolves examined in this study had some significant movement patterns on the landscape that were not constrained to one province; rather they span a multitude of jurisdictions (i.e. Saskatchewan, Nunavut). Any development of wolf management plans needs to be an integrated multi-jurisdictional approach. Population declines in large ungulates such as moose and caribou can be influenced by the presence of wolves on the landscape yet they are not the primary driver of those declines. Understanding their role in the ecosystem and how trophic cascades could happen is another important aspect of the development of integrated wolf management plans. Manitoba is uniquely positioned having established partnerships in collaring programs, to embark on a comprehensive and transparent wolf management plan. These partnerships are a key component, just as wolves as an apex predator are key components within the broader ecosystem.

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