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Wolf Distribution and Movements on Caribou Ranges in West-Central Alberta

By

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Abstract

Wolf (*Canis lupus*) predation is thought to be the proximate cause for the decline of threatened woodland caribou (*Rangifer tarandus caribou*) populations in Alberta. Caribou in west-central Alberta are facing increased landuse pressures from resource extraction industries, whose activities may alter the movements and distribution of wolves and ungulates. Thirty-one wolves, from eight wolf packs, were fitted with VHF and GPS radiocollars on two caribou ranges in the Rocky Mountain foothills, near Grande Cache, Alberta (2000-2001). There was a mean of 8 wolves/pack and between 30-39 pack wolves on each of the RedRock/Prairie Creek and Little Smoky caribou ranges. Wolf density averaged 11 wolves/1000 km^2 across caribou ranges, which exceeds the 6.5 wolves/1000km^2 theoretically capable of causing a caribou decline.

Wolves preyed predominately on moose (*Alces alces*), with kill rates averaging one moose every three to five days. When near ungulate killsites, wolves travelled 4.2 times less than when away from them. It follows that this restricted movement may lead to decreased encounter rates with caribou. Deer (*Odocoileus spp.*) are probably an important component of this wolf-prey system but the relationship is currently difficult to quantify.

Information on the response of wolves to forestry activities is scarce, potentially hampering long-term planning for caribou conservation. I found wolves did not use the landscape randomly, and had a significant preference for non-forested natural habitats (shrubs, water) over other habitats. Forest cutblocks were used proportionately more than both forest and non-forested anthropogenic habitats (pipelines, clearings). I found no evidence that wolves either preferred or avoided forest cutblock edges. I conclude by

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discussing specific management implications for assessing predation risk to caribou from wolves in dynamic, forested landscapes.

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Chapter 1. Introduction

The effect of wolf predation (*Canis lupus*) on ungulate populations is central to understanding many predator-prey systems in North America. Wolves have been well studied in relation to common ungulate species such as moose (*Alces alces*) and deer (*Odocoileus spp.*), but new information is needed on wolf interactions with less numerous prey. In west-central Alberta, woodland caribou (*Rangifer tarandus caribou*) occur at low densities and co-exist with the more abundant moose, deer and elk (*Cervus elaphus*). Caribou numbers in this area are declining, with wolf predation thought to be the primary cause (Edmonds 1988). Caribou are listed as threatened under the Alberta Wildlife Act (Edmonds 1998), thus their numbers and habitats must be addressed in land use planning and management (Hervieux et al. 1996). Wolves have not been studied on caribou ranges in west-central Alberta, so it is therefore important to understand the dynamics of wolves in this multi-prey system.

Wolves are thought to be the primary cause for declining woodland caribou numbers in a number of systems (Bergerud and Elliot 1986,1998; Edmonds 1988,1998; Farnell and McDonald 1988; Seip 1991,1992; Thomas 1995; Stuart-Smith et al.1997; Rettie and Messier 1998; James 1999). Caribou may spatially separate themselves from moose, to avoid wolves whose primary prey is moose (Seip 1991; James 1999), and high moose numbers may increase wolf predation risk to caribou (Seip 1992). Contrary evidence has found that caribou can increase concurrently with moose, suggesting increased moose numbers are beneficial for caribou (Farnell et al. 1996,1998; Mech et al. 1998). Within a particular study area, wolf packs may differ with respect to the availability of moose or caribou, and therefore prey on each ungulate species at different rates (Mech et al. 1998;

Hayes and Harestad 2000a,b). In arctic systems, moose can be alternate prey to the more plentiful barren ground caribou (*Rangifer tarandus granti*) (Dale et al. 1994; Ballard et al. 1997).

This chapter provides an overview of North American wolf-ungulate studies, to demonstrate the adaptability of wolves in hunting a diversity of prey. A discussion of wolf social behavior follows, as this can be the main factor in regulating both wolf numbers and territory sizes. Understanding the actual hunting behaviors of wolves is also an important component to studying wolf-prey systems (Weaver 1994). For example, the amount of time wolves spend hunting and consuming a common prey species, such as moose, will affect their chances of encountering less abundant prey, such as caribou. Wolf hunting behaviors, as well as their spatial relationships with ungulates, can change when landscapes are altered by industrial development (e.g., forestry, oil and gas), thus potentially affecting predation risk to caribou, and ultimately affecting caribou populations.

1.1 An Overview of Wolf-Ungulate Studies in North America

Wolf-ungulate systems have been studied in over 30 locations in North America, with most research being designed to determine if wolves are regulating or limiting ungulate populations (e.g., Mech and Karns 1977; Kolenosky 1972; Fuller and Keith 1980; Messier and Crete 1985; Boertje et al. 1995, 1996; Mech 1995a). While it is generally agreed that wolf predation is at least partially responsible for ungulate regulation (Mech 1995a), scientific evidence to the degree of regulation is unclear (Boutin 1992).

The longest running wolf project is a wolf-moose study on Isle Royale, Michigan which began in 1958 and is ongoing (Mech 1966; Peterson 1977; Allen 1979; Peterson 1999). Initial results from this study suggested that wolves were preying primarily on old and young moose, and that wolf numbers cycled with moose densities (Mech 1970). Accumulated data from this study found that years of heavy wolf predation on moose could effect the vegetation growth on the island, suggesting this simple island system was regulated by wolves in a top-down fashion (McLaren and Peterson 1994). The fluctuating cycle of wolf and moose numbers was broken in the mid-1990's when the number of wolves sharply declined, due to disease and inbreeding depression (Peterson 1995). The moose population continued to increase, and eventually crashed from starvation, thus suggesting there is no natural regulation or density dependence of wolves and moose in this system (Peterson 1999). However, the wolf-moose study on Isle Royale is of a closed system, which may be lacking a number of variables that influence population dynamics, when compared with mainland systems (Hayes 1995). Other wolf-moose studies have also examined human consumptive use, but have seldom run for longer than five years (Peterson et al. 1984; Gasaway et al. 1983, 1992; Messier and Crete 1985; Hayes and Harestad 2000a,b).

Long-term wolf and white-tailed deer projects have been conducted in the eastern United States (Mech and Karns 1977; Mech 1991), with some emphasis on hunting issues (Mech and Nelson 2000). In Canada's Algonquin Park, the wolf-deer system has been studied (Theberge 1997; Cook et al. 1999) with reference to excessive harvest rates on wolves migrating outside the Park (Forbes and Theberge 1996; Poszig and Theberge 2000). Studies of wolves interacting with both white-tailed deer and moose have been conducted in Quebec (Messier 1994); and with wolves, white-tailed deer, moose and elk in Manitoba (Carbyn 1983; Paquet 1989).

In the mountains and foothills of western North America, there is a diversity of ungulate prey species for wolves. Wolves prey primarily on elk in or near Banff National Park (Huggard 1993a; Paquet et al. 1996), Jasper National Park (Cowan 1947; Carbyn 1974; Schmidt and Gunson 1985; Weaver 1994; Dekker et al. 1995) the foothills northeast of Jasper Park (Bjorge and Gunson 1989), and in northwestern Montana (Boyd et al. 1994; Kunkel and Pletscher 1999). Weaver (1994) terms these wolves of the mountains and foothills "expanding specialists": they move through the landscape hunting deer while travelling to pockets of the more preferred elk. In the mountains, wolf movements have been documented in relation to bighorn sheep (*Ovis canadensis*) (Stelfox 1969, 1971; Huggard 1993a,b; Weaver 1994), Dall sheep (*Ovis dalli*) (Murie 1944; Sumanik 1987; Barichello et al. 1989; Hayes et al. 1991; Scotton 1998; Mech et al. 1998) and mountain goats (*Oreamnos americanus*) (Festa-Bianchet et al. 1994; Cote et al. 1997).

In other areas, wolves have evolved successful hunting techniques for prey with different body sizes, and various anti-predation tactics. Carbyn et al. (1993) studied wolf-bison (*Bison bison*) interactions in Wood Buffalo National Park, and reported on summer wolf predation of bison calves (Carbyn and Trottier 1987,1988). Observational studies of wolves in the high arctic indicate that in summer the wolves prey primarily on muskoxen (*Ovibos moschatus*) (Mech 1995b, 1997). Livestock depredation by wolves has been reported on cattle (*Bos taurus*) in Alberta (Bjorge and Gunson 1983,1985), and cattle and dogs (*Canis familiaris*) in British Columbia (Tompa 1983) and Minnesota (Fritts 1982; Fritts and Paul 1989; Mech et al. 1988).

1.2 Wolf Social Order and Territoriality

1.2.1 Social Structure of a Wolf Pack

A wolf pack is a family of wolves, consisting of a breeding pair and their offspring from the past one to three years (Murie 1944; Mech 1999). The pack remains a social unit throughout the year, with activities led by the breeding pair (Mech 1999). The use of "alpha" to describe the breeding pair may be somewhat misleading, as alpha implies a hierarchy. Mech (1999) concluded from observing a wild wolf pack in the arctic, and in reviewing the literature, that there is no true "pecking order" or hierarchy in a wolf pack. As wolves live in cooperative family units, the only hierarchy is usually just the breeding parents dominating their offspring, which is a widespread behavior in mammals.

Wolves become sexually mature at two to four years old (Mech 1970), and disperse from their natal pack as early as one year old, but mostly between two to three years of age (Gese and Mech 1991). Therefore, there is usually no competition for breeding rites within a pack (Mech 1999). Multiple breedings are known to occur where two or three families (usually related individuals) live as one pack, and in these instances, the term "alpha" may be appropriate as a mother with a litter may socially dominate her daughter who also has a litter (Mech et al. 1998). Pup survival may only be successful in the dominant female's litter, due to the other pack members feeding only her and her pups (Mech et al. 1998).

During winter, it is the breeding pair that initiates all phases of hunting (Peterson 1995; Mech et al.1998). The pups, yearlings and two-year olds within the pack do not have the experience to lead a successful hunt, but may actively help in chasing and subduing prey. In summer, there is a division of labor among the pack, with the breeding male leading the hunting and travelling, and the breeding female responsible for raising the pups (Mech 1995b). In summer, the wolves may hunt as a pack for large ungulates, or hunt singly or in pairs for small prey, such as beaver (*Castor canadensis*) and snowshoe hares (*Lepus americanus*). The wolves will often bring food back to the den in their stomachs, and regurgitate it to feed the breeding female and her pups (Mech et al. 1999). Once the pups are about eight weeks old, they are moved away from the den to a "rendezvous site", which is usually an open meadow near water and shelter (Mech 1970). From here, the pack will operate its hunting efforts, with the intention of returning food to the pups. At times the breeding female will leave the pups with another pack member, and go on hunting forays (Mech 1999). In fall, when the pups are able to travel greater distances, the pack leaves the rendevous site and becomes a mobile hunting pack within its territory (Mech 1970).

1.2.2 Territoriality: Effects on Wolf Numbers and Ungulate Distribution

Wolves are territorial (Mech 1970), except when following migratory caribou (Ballard et al. 1997) or certain populations of migratory white-tailed deer (Theberge 1997; Cook et al. 1999). Territory size varies with wolf pack size, and their prey species and abundance. It may range from less than 300 square kilometers in wolf-deer systems in Minnesota (Mech 1991), to over 1,000 square kilometers in the Yukon, where wolves prey on moose occurring at low densities (Hayes 1995). Wolves actively maintain their territories by scent marking (Rothman and Mech 1979) and howling (Harrington and Mech 1979). Wolves trespassing into another pack's territory are often killed (Mech 1994; Peterson 1995) and this behavior may regulate both wolf abundance (Packard and

Mech 1980) and the spatial dynamics of wolf packs (Mech 1991).

Ungulate distribution can be related to wolf territory borders. Mech (1977) found evidence that the highest density of deer during a population decline was in a narrow area or "buffer zone" between wolf pack territories. The wolves would avoid territory borders to lessen the risk of death from intraspecific strife, thus reducing the predation pressure on deer in the buffer zones. In Minnesota, Mech (1994) found most wolf deaths from conspecifics occurred in buffer zones of about 3.2 kilometers in territory overlap. Deer will use buffer zones during seasonal migrations (Hoskinson and Mech 1976), are known to have higher mortality rates when travelling within a wolf pack territory (Nelson and Mech 1991), and may winter in proportionally higher numbers near wolf territory edges (Rogers et al. 1980).

1.2.3 Effect of Wolf Pack Size and Ungulate Vulnerability on Kill Rates

A wolf pack is defined as two or more wolves that travel together for more than one month (Messier 1994). Hayes (1995) defines small wolf packs as 2-4 wolves, medium packs as 5-8 individuals and large packs as 9-14. Single wolves are difficult to study (Messier 1985; Fuller 1989) and are assumed to represent 10% of the wolf population (Mech 1973). Wolf kill rate is defined as the number of ungulates killed/wolf/day (Hayes 1995), whereas predation rate is defined as the proportion of ungulates, represented by age and sex classes, that are killed by wolves on a daily basis (Messier 1994; Dale et al. 1994). Wolf pack size can affect the rate at which wolves kill ungulates (Fuller 1989). Hayes (1995) found that kill rates of moose can be disproportionate with wolf pack size, where small packs can have higher kill rates than large packs, due to the freezing rate of carcasses (making the meat difficult to consume) and increased loss to scavengers. Single wolves are capable of killing adult moose (Thurber and Peterson 1993, Mech et al. 1998), but this phenomenon has not been well studied.

Wolves may kill less than 10% of moose (Mech 1966; Peterson 1977) and 15% of caribou (Mech et al. 1998) they encounter. Vulnerability of ungulates to predation by wolves can vary with season, snow depth, cover, sex and age characteristics, nutritional state and overall health (Mech 1991, Hayes et al. 2000). Young ungulates are vulnerable to predation throughout their first year of life due to small body size and lack of experience in predator avoidance (Adams et al. 1995a,b; Mech et al. 1998). Male ungulates are often killed by wolves in higher proportions than they occur in the population, due to energy loss during the breeding season from lack of feeding, chasing females and fighting with other males, and increased vulnerability to wolf predation after the breeding season (Mech et al. 1998). Female ungulates are more susceptible to wolf predation in late winter, when they are nutritionally stressed from pregnancy, and deep snow may inhibit their movements (Peterson 1995).

Snow is a seasonal environmental variable that affects wolves' decisions on where and how to search for prey. Varying snow depths can affect ungulate distribution (Edwards 1956) and wolf predation rates (Peterson 1977; Fuller 1991; Huggard 1993c). In winter, wolves will travel in areas of low snow, such as creeks and lakes, coniferous forests and wind swept ridges, as snow depths of >40-50cm can impede their travel (Formozov 1946). Ungulate tracks and snow packed trails made by humans are used for travel by wolves (Mech 1970, Bergerud et al. 1984, Kuzyk and Kuzyk 2001). In Banff, wolves were restricted to elevations less than 1700m, and where snow depths exceeded

40-50cm, they were found to change their direction of travel when encountering human compacted trails or frozen rivers (Paquet et al. 1996). Huggard (1993c) found that ungulate carcasses from road and train accidents might be more available to wolves in deep snow winters, increasing the time wolves spend scavenging.

1.3 Foraging Theory Related to Wolves Preying on Ungulates

Studying the behavior patterns of wolves hunting and killing ungulates is important for understanding wolf-ungulate systems (Weaver 1994). Various theories help guide the understanding of the behavior of wolves preying on ungulates. Predators may have a functional response to their prey, where their consumption rate of prey slows when they become satiated (Solomon 1949). A numerical response of predators occurs when predator numbers change with prey density (Solomon 1949; Holling 1959). Foraging theory suggests a predator's diet, including prey choice, will be the product of many foraging episodes or searches, which attempt to maximize energy gain in a minimal amount of time (Krebs and Davies 1993). Decisions made during a given foraging episode entail costs and benefits to the individual predator, or hunting group (Krebs and Davies 1993).

1.3.1 How Wolves Search for Ungulates

Mech (1970) describes three techniques wolves use to search for prey: 1) direct scenting 2) chance encounter and 3) tracking. Direct scenting accounted for 42 of 51 wolf-moose encounters observed on Isle Royale, Michigan (Mech 1966). Ungulates can be scented by wolves from several kilometers, and when prey are scented, wolves may come to an abrupt stop and attentively face in the direction of the ungulate. They will then form a tight group, have a short interval of social excitement of wagging tails and sniffing noses, then move directly toward the prey (Mech 1970).

Chance encounters occur more often when wolves hunt small ungulates as deer or mountain sheep (Theberge 1997; Hayes et al. 1991). Theberge (1997) found that when hunting deer, wolves will fan out in hopes of surprising one. Murie (1944) and Barichello et al. (1989) report wolves hunting sheep by chance encounter and Cowan (1947) found evidence from snowtracking, that wolves move on open ridges until they "chance" upon elk or deer below, then rush directly downward toward their prey. Mech (1966) reported wolves using "tracking" for only 9 of 51 moose hunting attempts. Wolves followed fresh moose tracks, but usually only once they were approaching a moose, suggesting initial detection was by scent.

1.3.2 How Wolves Pursue Ungulates

Wolf behaviors preceding the actual pursuit of ungulates are first stalking, followed by an encounter (Mech 1970). Wolves likely use stalking to bring them as close as possible to their prey while remaining undetected. Packs and lone wolves use stalking for hunting a variety of ungulates, including moose (Mech 1970), Dall Sheep (Muire 1944) and white-tailed deer (Mech and Karns 1977). Inexperienced wolves may prematurely break away during the stalking sequence and begin to chase the ungulate, spoiling the success of the hunt (Peterson 1995).

The encounter begins when wolves are detected by the ungulate, and the wolves begin moving towards the ungulate. Ungulates respond to wolves stalking them by either: 1) moving towards the wolves, 2) standing ground, or 3) running (Mech 1970). Ungulates "moving towards" wolves occurs infrequently, with examples being cow moose defending themselves and their calves by lashing out with their front hooves at the attacking wolves (Mech 1966), or caribou moving closer to wolves out of curiosity (Mech et al. 1998). A moose will often "stand its ground" when approached by wolves. The wolves may surround the moose for about five minutes "testing" it, to try and detect if it is vulnerable to attack (Mech 1966). Occasionally wolves pay little attention to moose standing their ground, as previous encounters may suggest such moose to be invulnerable prey (Kuzyk 2002). "Running" is the third response of ungulates to approaching wolves, and it is simply the ungulate moving quickly away. Most ungulates that run from wolves are pursued, and the majority of ungulates killed by wolves have run at some point during an encounter (Mech 1970). Chase distances in which wolves are successful in killing their prey average 115m for elk, 159m for deer and 883m for moose (Paquet 1989). Wolves have been known to chase a moose or elk unsuccessfully, then shortly thereafter, kill a deer (Cowan 1947; Carbyn 1974; Weaver 1994).

1.3.3 How Wolves Subdue Ungulates

Contrary to many historical accounts, wolves do not have a standard method of subduing ungulates by "hamstringing", or severing the Achilles' tendon (Mech 1970). When hunting moose, a wolf pack usually chases the moose single file until they begin the attack. The lead wolf, which is almost always one member of the breeding pair, lunges for the rump area and hangs on, slowing the moose. The rump area of the moose provides a good hold for the wolf's teeth, and keeps the wolf out of sight of the moose and out of reach of its hooves. The rump is also big enough to hold several attacking wolves, where their weight, combined with the tearing and dismembering, will eventually slow the moose down (Mech 1970). The moose nose is the second key attack point (Mech 1966). Once the pack slowed down the moose, one wolf (a skilled hunter) will jump for and hang onto the nose of the moose. The "nose wolf" is usually flung from side to side by the moose, and is sometimes trampled, but this action slows and distracts the moose, allowing other pack members to attack the rump, throat and shoulders (Mech 1966). The moose is normally on the ground within a few minutes of the attack, and the wolves begin feeding (Mech 1991).

Caribou are easier for wolves to kill than are most other ungulates, especially calves (Miller et al. 1985). Points of attack are the shoulder and flank area, rather than the rump, and the killing point is often the throat (Mech 1970). Mech et al. (1998) describes wolves pursuing caribou in deep snow by following the caribou trails, and attacking the caribou when they are struggling in the snow. In areas of exceptionally deep snow, usually >100 cm, wolves can make multiple-kills of 2-13 caribou. However, caribou in good condition, travelling in snow less than 40 cm, can often outdistance pursuing wolves (Mech et al. 1998).

1.3.4 Wolf Handling Time and Feeding Activity at Ungulate Carcasses

Handling time can be defined as the amount of time it takes for a wolf, or wolf pack, to totally consume all available biomass from its prey. The rate at which a carcass is handled will depend on prey type, pack size and number of scavengers present. The amount of consumable biomass available from an ungulate (ungulate biomass) is 65% to

75% for moose (Hayes 1995, Peterson 1977), 75% for caribou (Ballard et al. 1987) and 75% for elk (Carbyn 1983). Large ungulates, such as moose, are handled in approximately 48 hours (Peterson 1977), while small ungulates, such as deer, are usually handled in less than 12 hours (Fuller 1989). Ravens can account for high scavenging rates from wolf-killed ungulate carcasses, taking up to 37 kilograms of meat per day (Promberger 1991). Coyotes (*Canis latrans*), foxes (*Vulpes vulpes*) and wolverines (*Gulo gulo*) can also scavenge large amounts of meat from wolf-killed ungulates, but the actual amount of meat taken by these scavengers is difficult to quantify (Mech 1970).

Wolves have a predictable activity pattern when feeding on ungulate carcasses (Mech 1970). These patterns are related to the volume of fresh meat wolves can eat at one time and the amount of rest required to aid digestion. Initially, a wolf pack begins handling an ungulate by feeding at the kill for about one hour, or until each individual has consumed about 3-9 kilograms of meat. The wolves then bed for several hours (Mech 1970). Resting after feeding allows for optimum digestion, and thus more frequent feeding bouts. The wolves generally return to the kill for a second feeding after approximately six hours. As an adult moose is large, in winter there is ample unfrozen meat left for a number of feedings interspersed with rest periods. These feeding-rest periods (one hour feeding followed by six hours of rest) are repeated until the ungulate carcass is either consumed or abandoned. Smaller ungulates such as deer, especially deer fawns, may be totally consumed in one feeding cycle (Fuller 1989).

1.4 Wolf Habitat Use

Where wolves hunt, and how much time they spend handling ungulate carcasses, can be influenced by human use of landscapes. In some forested areas, resource sector (e.g. forestry, oil and gas) activities are causing habitat loss and increased landscape fragmentation, which is effecting the spatial distribution of wolves and their prey (James 1999). In northeastern Alberta, caribou mortalities were closer to linear corridors (e.g. seismic exploration lines, pipelines, roads) than expected by chance (James and Stuart-Smith 2000) and wolves moved 2.8 times faster on linear corridors than in the forest (James 1999). Caribou were found to avoid roads and seismic lines by 250 meters in northeastern Alberta (Dyer et al. 2001), and in west-central Alberta caribou avoided roads by up to 500 meters (Oberg 2001).

Forest harvesting is a dominant industrial feature on the landscape of west-central Alberta, where caribou were found to avoid forest cutblocks by an average of 1.2 kilometers (Smith et al. 2000) and select forests over 80 years old, especially those stands aged 120-160 years (Szkorupa 2002). Forest cutblocks and linear corridors can create a new food source for moose, elk and deer, which in turn may attract wolves, and increase predation risk to nearby caribou. As the forest becomes increasingly altered by forest harvesting and other human activities, it is thought that the caribou's antipredation strategy of spatial separation from wolves will be jeopardized.

1.5 Thesis Overview

The objective of my research is to provide quantitative information on wolf distribution and movements on caribou ranges in west-central Alberta. In Chapter 2, a rationale for wolf research in west-central Alberta is presented, followed by a description of wolf capture techniques, radiocollaring, physical characteristics, territory sizes and ungulate kill rates. Chapter 3 outlines the relationship between wolf travel distances and their ungulates killsites, using location data gathered from wolves instrumented with Global Positioning System (GPS) radiocollars, and killsite information gathered from concurrent aerial monitoring. In Chapter 4, wolf use of forest cutblocks is analysed using GPS location data overlain on forest inventory maps, and discussed in the context of how wolf movements might effect predation risk to nearby caribou. Chapter 5 summarises the thesis results and discusses management implications. Finally, the Appendix includes three naturalist history notes on wolves, recorded during this study, and published in Alberta Naturalist.

1.6 Literature Cited

Adams, L.G., B.W. Dale, and L.D. Mech. 1995(a). Wolf predation on caribou calves in Denali National Park, Alaska. Pages 245-260 *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.

Adams, L.G., F.J. Singer and B.W. Dale. 1995(b). Caribou and calf mortality in Denali National Park, Alaska. Journal of Wildlife Management (59): 584-594.

Allen, D.L. 1979. The Wolves of Minong: their vital role in a wild community. Houghton Mifflin Company, Boston, MA. 499 pp.

Ballard, W.B., J.S. Whitman and C.L. Gardner. 1987. Ecology of an exploited wolf population in south-central Alaska. Wildlife Monographs 114: 49 pp.

Ballard, W.B., L.A. Ayres, P.R. Krausman, D.J. Reed and S.G. Fancy. 1997. Ecology of wolves in relation to a migratory caribou herd in northwest Alaska. Wildlife Monographs 135: 47 pp.

Barichello, N., J. Carey, R. Sumanik, R. Hayes and A. Baer. 1989. The effects of wolf predation on Dall sheep populations in the southwest Yukon. Yukon Fish and Wildlife Branch Report TR-89-3, Whitehorse, Yukon.

Bergerud, A.T., H.E. Butler and D.R. Miller. 1984. Antipredator tactics of calving caribou: dispersion in mountains. Canadian Journal of Zoology (62): 1566-1575.

Bergerud, A.T. and J. Elliot. 1986. Dynamics of caribou and wolves in northern British Columbia. Canadian Journal of Zoology (64): 1515-1529.

Bergerud, A.T. and J. Elliot. 1998. Wolf predation in a multiple-ungulate system in northern British Columbia. Canadian Journal of Zoology (76): 1551-1569.

Bjorge, R.R. and J.R. Gunson. 1983. Wolf predation of cattle on the Simonette River pastures in northwestern Alberta. Pages 106-111. *in* L.N. Carbyn, editor. Wolves in Canada and Alaska: their status, biology, and management. Canadian Wildlife Service Report Series, No. 45, Ottawa, Ontario. 135 pp.

Bjorge, R.R. and J.R. Gunson. 1985. Evaluation of wolf control to reduce cattle predation in Alberta. Journal of Range Management (38): 483-487.

Bjorge, R.R. and J.R. Gunson. 1989. Wolf, *Canis lupus*, population characteristics and prey relationships near the Simonette River, Alberta. Canadian Field-Naturalist (103): 327-334.

Boertje, R.D., D.G. Kelleyhouse, and R.D. Hayes. 1995. Methods for reducing natural predation on moose in Alaska and Yukon: an evaluation. Pages 505-513 *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.

Boertje, R.D., P. Valkenburg, and M.E. McNay. 1996. Increases in moose, caribou, and wolves following wolf control in Alaska. Journal of Wildlife Management (3): 474-489.

Boutin, S. 1992. Predation and moose population dynamics: a critique. Journal of Wildlife Management (56): 116-127.

Boyd, D.K., R.R. Ream, D.H. Pletscher and M.W. Fairchild. 1994. Prey taken by colonizing wolves and hunters in the Glacier National Park area. Journal of Wildlife Management (58): 289-295.

Carbyn, L.N. 1974. Wolf predation and behavioral interactions with elk and other ungulates in an area of high prey diversity. Canadian Wildlife Service Report, Edmonton, Alberta. 234 pp.

Carbyn, L.N. 1983. Wolf predation on elk in Riding Mountain National Park, Manitoba. Journal of Wildlife Management (47): 963-976.

Carbyn, L.N. and T. Trottier. 1987. Responses of bison on their calving grounds to predation by wolves in Wood Buffalo National Park. Canadian Journal of Zoology (65): 2072-2078.

Carbyn, L.N. and T. Trottier. 1988. Descriptions of wolf attacks on bison calves in Wood Buffalo National Park. Arctic (41): 297-302.

Carbyn, L.N., S. Oosenbrug and D. Anions. 1993. Wolves, bison and their dynamics related to the Peace-Athabasca Delta in Canada's Wood Buffalo National Park. Circumpolar Research Series Number 4, Canadian Circumpolar Institute, University of Alberta, Edmonton, Alberta. 270 pp.

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

Cote S.D., A. Peracino and G. Simard. 1997. Wolf, *Canis lupus*, predation and maternal defensive behavior in Mountain Goats, *Oreamnos americanus*. Canadian Field-Naturalist (111): 389-392.

Cowan, I. McT. 1947. The timber wolf in the Rocky Mountain National Parks of Canada. Canadian Journal of Research (25): 139-174.

Dale, B.W., L.G. Adams and R.T. Bowyer. 1994. Functional response of wolves preying on barren-ground caribou in a multiple prey ecosystem. Journal of Animal Ecology (63): 644-652.

Dekker, D., W. Bradford and J.R. Gunson. 1995. Elk and wolves in Jasper National Park, Alberta, from historical times to 1992. Pages 85-94 *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.

Dyer, S.J., J.P. O'Neil, S.M.Wasel and S. Boutin. 2001. Avoidance of industrial development by woodland caribou. Journal of Wildlife Management (65): 531-542.

Edmonds, E.J. 1988. Population status, distribution and movements of woodland caribou in west central Alberta. Canadian Journal of Zoology (66): 817-826.

Edmonds, E.J. 1998. Status of woodland caribou in Alberta. Rangifer Special Issue Number 8: 111-115.

Edwards, R.Y. 1956. Snow depths and ungulate abundance in the mountains of western Canada. Journal of Wildlife Management (20): 158-168.

Farnell, R. and J. McDonald. 1988. Influence of wolf predation on caribou mortality in Yukon's Finlayson caribou herd. Pages 52-70. *in* Proceedings of the third North American Caribou Workshop. Technical Bulletin Number 8. Alaska Department of Fish and Game.

Farnell, R., N. Barichello, K. Egli, and G. Kuzyk. 1996. Population ecology of two woodland caribou herds in southern Yukon. Rangifer Special Issue Number 9: 63-72.

Farnell, R., R. Florkiewicz, G. Kuzyk and K.Egli. 1998. The status of *Rangifer tarandus caribou* in Yukon, Canada. Rangifer Special Issue Number 10: 131-138.

Festa-Bianchet, M., M. Urquhart and K.G. Smith. 1994. Mountain goat recruitment: kid production and survival to breeding age. Canadian Journal of Zoology (72): 22-27.

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

Formozov, A. N. 1946. Snow cover as an integral factor of the environment and its importance in the ecology of mammals and birds. Moscow Society of Naturalists, Moscow, USSR. English translation 1969. Boreal Institute, University of Alberta, Edmonton, Alberta, Occasional Publication (1): 1-141.

Fritts, S.H. 1982. Wolf depredation on livestock in Minnesota. U.S. Fish and Wildlife Service Resource Publication Number 145. 11 pp.

Fritts, S.H. and W.J. Paul. 1989. Interactions of wolves and dogs in Minnesota. Wildlife Society Bulletin (17): 121-123.

Fuller, T.K. and L.B. Keith. 1980. Wolf population dynamics and prey relationships in northeastern Alberta. Journal of Wildlife Management (44): 583-602.

Fuller, T.K. 1989. Population dynamics of wolves in north-central Minnesota. Wildlife Monographs 105: 41 pp.

Fuller, T.K. 1991. Effect of snow depth on wolf activity and prey selection in north central Minnesota. Canadian Journal of Zoology (69): 283-287.

Gasaway,W.C., R.O. Stephenson, J.L. Davis, P.E. Shepherd and O.E. Burris. 1983. Interrelationships of wolves, prey and man in interior Alaska. Wildlife Monographs 84: 50 pp.

Gasaway,W.C. , R.D. Boertje, D.V. Grangaard, D.G. Kellyhouse, 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: 59 pp.

Gese, E.M. and L.D. Mech 1991. Dispersal of wolves (*Canis lupus*) in northeastern Minnesota, 1969-1989. Canadian Journal of Zoology (69): 2946-2955.

Gunson, J.R. 1992. Historical and present management of wolves in Alberta. Wildlife Society Bulletin (20): 330-339.

Harrington, F.H. and L.D. Mech. 1979. Wolf howling and its role in territory maintenance. Behaviour (68): 207-249.

Hayes, R.D., A. M. Baer and D. G. Larsen. 1991. Population dynamics and prey relationships of an exploited and recovering wolf population in the southern Yukon. Yukon Fish and Wildlife Branch Report TR 91-1, Whitehorse, Yukon.

Hayes, R.D. 1995. Numerical and functional response of wolves, and regulation of moose in Yukon. Masters Thesis, Simon Fraser University, Burnaby, British Columbia. 132 pp.

Hayes, R.D., and A.S. Harestad. 2000(a). Demography of a recovering wolf population in the Yukon. Canadian Journal of Zoology (78): 36-48.

Hayes, R.D., and A.S. Harestad. 2000(b). Wolf functional response and regulation of moose in the Yukon. Canadian Journal of Zoology (78): 60-66.

Hayes R.D., A.M. Baer, U. Wotschikowsky and A.S. Harestad. 2000. Kill rate by wolves on moose in the Yukon. Canadian Journal of Zoology (78): 49-59.

Hervieux, D., J. Edmonds, R. Bonar and J. McCammon. 1996. Successful and unsuccessful attempts to resolve caribou management and timber harvesting issues in west central Alberta. Rangifer Special Issue Number 9: 185-192.

Holling, C.S. 1959. The components of predation as revealed by a study of small mammal predation of the European sawfly. Canadian Entomologist (91): 293-320.

Hoskinson, R.L. and L.D. Mech. 1976. White-tailed deer migration and its role in wolf predation. Journal of Wildlife Management (40): 429-441.

Huggard, D.J. 1993(a). Prey selectivity of wolves in Banff National Park. I. Prey species. Canadian Journal of Zoology (71): 130-139.

Huggard, D.J. 1993(b). Prey selectivity of wolves in Banff National Park. II. Age, sex and condition of elk. Canadian Journal of Zoology (71): 140-147.

Huggard, D.J. 1993(c). Effect of snow depth on predation and scavenging by gray wolves. Journal of Wildlife Management (57): 382-388.

James, A.R.C. 1999. Effects of industrial development on the predator-prey relationship between wolves and caribou in northeastern Alberta. Ph.D. Thesis, University of Alberta, Edmonton Alberta. 70 pp.

James, A.R.C. and A.K. Stuart-Smith. 2000. Distribution of caribou and wolves in relation to linear corridors. Journal of Wildlife Management (64): 154-159.

Kolenosky, G.B. 1972. Wolf predation on wintering deer in east-central Ontario. Journal of Wildlife Management (36): 357-369.

Krebs, J.R. and N.B. Davies. 1993. An Introduction to Behavioural Ecology. Blackwell Science Limited, London. 420 pp.

Kunkel, K.E. and D.H. Pletscher. 1999. Species-specific population dynamics of cervids in a multipredator ecosystem. Journal of Wildlife Management (63): 1082-1093.

Kuzyk, G.W. 2002. Female and calf moose remain stationary and non-aggressive when approached by wolves in west-central Alberta. Alberta Naturalist (31): 53-54.

Kuzyk, G.W and K.M. Kuzyk. 2001. Wolf, *Canis lupus*, response to domestic sled dog, *Canis familiaris*, activities in central Yukon. Canadian Field-Naturalist 115(4): *in press.*

McLaren, B.E. and R.O. Peterson. 1994. Wolves, moose, and tree-rings on Isle Royale. Science (266): 1555-1558.

Mech, L.D. 1966. The Wolves of Isle Royale. Fauna of National Parks of the U.S., Fauna Series, Number 7, U.S. Government Print Office, Washington, D.C. 210 pp.

Mech, L.D. 1970. Wolf Ecology and Management of an Endangered Species. University of Minnesota Press. 384pp.

Mech, L.D. 1973. Wolf numbers in the Superior National Forest of Minnesota, U.S. Department of Agriculture and Forest Series Research Paper, Number NC-97, 10 pp.

Mech, L.D. 1977. Wolf-pack buffer zones as prey reservoirs. Science (198): 320-321.

Mech, L.D. 1991. The Way of the Wolf. Voyageur Press, Stillwater, Minnesota, 120 pp.

Mech, L.D. 1994. Buffer zones of territories of gray wolves as regions of intraspecific strife. Journal of Mammalogy (75): 199-202.

Mech, L.D. 1995(a). What do we know about wolves and what more do we need to learn? Pages 537-545 *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.

Mech, L.D. 1995(b). A ten-year history of the demography and productivity of an arctic wolf pack. Arctic (48): 329-332.

Mech, L.D. 1997. The Arctic Wolf-Ten Years with the Pack. Raincoast Books Publishing, Vancouver, British Columbia, 144 pp.

Mech, L.D. 1999. Alpha status, dominance, and division of labor in wolf packs. Canadian Journal of Zoology (77): 1196-1203.

Mech, L.D. and P.D. Karns. 1977. Role of the wolf in a deer decline in Superior National Forest. U.S. Department of Agriculture and Forest Series Research Paper, NC-148. 23 pp.

Mech, L.D. and M.E. Nelson. 2000. Do wolves affect white-tailed buck harvest in northeastern Minnesota? Journal of Wildlife Management (64): 129-136.

Mech, L.D., S.H. Fritts and W.J. Paul. 1988. Relationship between winter severity and wolf depredation on domestic animals in Minnesota. Wildlife Society Bulletin (16): 269-278.

Mech, L.D., P.C. Wolf and J.M. Packard. 1999. Regurgitative food transfer among wild wolves. Canadian Journal of Zoology (77): 1192-1195.

Mech, L.D., L.G. Adams, T.J. Meier, J.W. Burch and B.W. Dale. 1998. The Wolves of Denali. University of Minnesota Press. 225 pp.

Messier, F. 1985. Solitary living and extraterritorial movements of wolves in relation to social status and prey abundance. Canadian Journal of Zoology (63): 239-245.

Messier, F. 1994. Ungulate population models with predation: a case study with North American moose. Ecology (75): 478-488.

Messier, F. and M. Crete. 1985. Moose-wolf dynamics and the natural regulation of moose populations. Oecologia (65): 503-512.

Miller, F.L., A Gunn and E. Broughton. 1985. Surplus killing as exemplified by wolf predation on newborn calves. Canadian Journal of Zoology (63): 295-300.

Murie, A. 1944. The Wolves of Mount McKinley. U. S. National Park Service, Fauna Series 5. Washington, DC. 238 pp.

Nelson, M.E. and L.D. Mech. 1991. Wolf predation risk associated with white-tailed deer movements. Canadian Journal of Zoology (69): 2696-2699.

Oberg, P.R. 2001. Responses of mountain caribou to linear features in a west-central Alberta landscape. Masters Thesis, University of Alberta, Edmonton, Alberta. 126 pp.

Packard, J. M. and L. D. Mech. 1980. Population regulation in wolves. Pages 135-150 *in* M. N. Cohen, R. S. Malpass, and H. G. Klein, editors. Biosocial Mechanisms of Population Regulation. Yale University Press, New Haven, Connecticut.

Paquet, P.C. 1989. Behavioral ecology of sympatric wolves (*Canis lupis*) and coyotes (*C. latrans*) in Riding Mountain National Park, Manitoba. Ph.D. Thesis, University of Alberta, Edmonton, Alberta. 227 pp.

Paquet, P., C.J. Wierzchowski and C. Callaghan. 1996. Effects of Human Activity on Gray Wolves in the Bow River Valley, Banff National Park, Alberta. Chapter 7 *in* Green, J., C. Pacas, L. Cornwell and S. Bayley editors. Ecological Outlooks Project. A cumulative effects assessment and future outlook of the Banff Bow Valley. Prepared for the Banff Bow Valley Study. Department of Canadian Heritage, Ottawa, Ontario. 74 pp.

Peterson, R.O. 1977. Wolf ecology and prey relationships on Isle Royale. U.S. National Park Series Science Monograph Series, No. 11, 210 pp.

Peterson, R.O. 1995. The wolves of Isle Royale: a broken balance. Willow Creek Press, Wisconsin. 190 pp.

Peterson, R.O. 1999. Wolf-moose interaction on Isle Royale: The end of natural regulation? Ecological Applications (9): 10-15.

Peterson, R.O., J. D. Woolington and T. N. Bailey. 1984. Wolves of the Kenai Peninsula, Alaska. Wildlife Monographs 88: 52 pp.

Poszig, D. and J.B. Theberge. 2000. Gray Wolf, *Canis lupus lycaon*, responses to shifts of White-tailed Deer, *Odocoileus virginianus*, adjacent to Algonquin Provincial Park, Ontario. Canadian Field-Naturalist (114): 62-71.

Promberger, C. 1991. Influence of scavengers on the consumption of wolves in the wild. Transaction Congress International Union of Game biologists 20: 396 (English abstract only)

Rettie, W. J. and F. Messier. 1998. Dynamics of woodland caribou populations at the southern limit of their range in Saskatchewan. Canadian Journal of Zoology (76): 251-259.

Rogers, L.L., L.D. Mech, K. Dawson, J.M. Peek and M. Korb. 1980. Deer distribution in relation to wolf pack territory edges. Journal of Wildlife Management (44): 253-258.

Rothman, .R.J. and L.D. Mech. 1979. Scent-marking in lone wolves and newly formed pairs. Animal Behavior (27): 750-760.

Schmidt, K.P. and J.R. Gunson. 1985. Evaluation of wolf-ungulate predation near Nordegg, Alberta: Second Year Progress Report, 1984-1985. Alberta Fish and Wildlife Division Report, Edmonton, Alberta. 53 pp.

Scotton, B. D. 1998. Timing and causes of neonatal Dall sheep mortality in the Central Alaska Range. Masters Thesis, University of Montana, Missoula, Montana. 45 pp.

Seip, D. R. 1991. Predation and caribou populations. Rangifer Special Issue Number 7: 46-52.

Seip, D. R. 1992. Factors limiting woodland caribou populations and their relationships with wolves and moose in southeastern British Columbia. Canadian Journal of Zoology (70): 1494-1503.

Solomon, M.E. 1949. The natural control of animal populations. Journal of Animal Ecology (18): 1-35.

Smith, K.G., E.J. Ficht, D. Hobson, T.C. Sorensen and D. Hervieux. 2000. Winter distribution of woodland caribou in relation to clear-cut logging in west-central Alberta. Canadian Journal of Zoology (78): 1433-1440.

Stelfox, J.G. 1969. Wolves in Alberta: a history 1800-1969. Alberta Lands Forests Parks Wildlife Magazine (12): 18-27.

Stelfox, J.G. 1971. Bighorn sheep in the Canadian Rockies: a history 1800-1970. Canadian Field-Naturalist (85): 101-122.

Stuart-Smith, A.K., C.J. Bradshaw, S. Boutin, D.M. Hebert and A.B. Rippin. 1997. Woodland caribou in relation to landscape patterns in northeastern Alberta. Journal of Wildlife Management (61): 622-633.

Sumanik, R. S. 1987. Wolf ecology in the Kluane region, Yukon Territory. Masters Thesis, Michigan Technological University, Houghton, Michigan. 102 pp.

Szkorupa, T.D. 2002. Multi-scale habitat selection by mountain caribou in west-central Alberta. Masters Thesis, University of Alberta, Edmonton, Alberta, 92 pp.

Theberge, J.B. 1997. Wolf Country. McClelland and Stewart Incorporated, Toronto, Ontario, 306 pp.

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.

Thurber, J.M. and R.O. Peterson. 1993. Effects of population density and pack size on the foraging ecology of gray wolves. Journal of Mammalogy (74): 879-889.

Tompa, F.S. 1983. Problem wolf management in British Columbia: conflict and program evaluation. Pp 112-119. *in* L.N. Carbyn, editor. Wolves in Canada and Alaska: their status, biology, and management. Canadian Wildlife Service Report Series, No. 45, Ottawa, Ontario. 135 pp.

Weaver, J.L. 1994. Ecology of wolf predation amidst high ungulate diversity in Jasper National Park, Alberta. Ph.D. Thesis, University of Montana, Missoula. 165 pp.

Chapter 2. Wolf distribution, pack composition and prey relationships in west-central Alberta.

2.1 Introduction

Wolf (*Canis lupus*) predation is considered the proximate cause limiting numbers of woodland caribou (*Rangifer tarandus caribou*) (Bergerud 1974, Fuller and Keith 1981, Edmonds 1988, Seip 1992). Caribou are a "threatened" species under the Alberta Wildlife Act and special management considerations are necessary to maintain their numbers and habitat (Edmonds 1998). Caribou ranges in west-central Alberta are coming under increasing pressures from the resource extraction industries, mostly the forestry and energy sectors, resulting in conflicts between land managers (Hervieux et al. 1996). A status report on woodland caribou in Alberta was released in March 2001, outlining the population trends of caribou, and reviewing all caribou research done in the province (Dzus 2001).

West-central Alberta contains three main caribou herds, with the Red Rock/Prairie Creek and Al La Peche herds representing a migratory ecotype, and the Little Smoky herd a boreal or sedentary ecotype (Edmonds 1988). The migratory herds make elevational migrations from the alpine, where they spend the summer and rut, to a forested winter range. However, from the mid-1990's to the present, the Al La Peche herd has spent the entire year in the mountains (Kirby Smith, Alberta Government, personal communication). The mountain herds are thought to number between 600-750 caribou (Edmonds 1998), and the Little Smoky herd which is now thought to number fewer than 100 animals (Dzus 2001).

Caribou studies in west-central Alberta were initiated in the 1970's (Bjorge 1984) and carried out through the 1980's (Edmonds and Bloomfield 1984, Edmonds 1988). In 1986, a government report was released proposing a number of options to slow the decline of caribou numbers, one of which was to reduce wolf numbers (Edmonds 1986). This latter option met with public opposition, and the wolf control plan was not implemented. Caribou studies continued throughout the 1990's in west-central Alberta, dealing mostly with population trends and habitat issues (Hervieux et al. 1996, Smith et al. 2000, Oberg 2001, Szkorupa 2002).

In 1994, the now named Boreal Caribou Research Program initiated a study in northeast Alberta to address the issue of wolf predation risk to caribou on a landscape undergoing increasing industrial development from the oil and gas industry (James 1999). Results from this study found that wolves and moose were spatially separated from caribou by habitat type (James 1999), and suggested that increased fragmentation of the habitat by linear corridors from the oil and gas sector could lead to increased caribou mortality (James and Stuart-Smith 2000). Wolf locations were found to be closer than random to linear corridors and wolves moved up to 2.8 times faster on a linear corridor than when traveling in the forest (James 1999).

A number of wolf studies have been conducted in the foothills and mountains of western Alberta (Stelfox 1969 and Gunson 1992 for reviews), but none of these were directed at wolf movements on caribou ranges. Studies of wolves have occurred in Jasper National Park (Cowan 1947, Carbyn 1974, Weaver 1994), and on the agricultural-forest fringe of western Alberta, dealing with wolf depredation on livestock (Bjorge and Gunson 1983, 1985, 1989). In 1995, a wolf re-introduction program was initiated in the

United States, in which 29 wolves were moved from west-central Alberta to Yellowstone National Park and central Idaho (Kneteman 1995, Fritts et al. 1997). Five wolves from the Berland pack, which overlaps the Little Smoky caribou range, were moved to Yellowstone, where they became progenitors of the Soda Butte pack (Fritts et al. 1997).

In September 1999, the West-Central Alberta Caribou Standing Committee (WCACSC) initiated a wolf study concurrent with new and long term caribou research projects (Edmonds 1998, Smith et al. 2000, Oberg 2001, Szkorupa 2002). Recent advancements in Global Positioning Systems (GPS) radiocollar technology (Rempel et al. 1995) permitted analysis of fine-scale wolf movements in relation to land use developments. The information presented here on wolves in west-central Alberta represents necessary baseline information for resource managers and future wildlife researchers. The objective of this thesis chapter is to detail the following information collected during the wolf study, from December 1999 to May 2001:

1) Outline wolf capture techniques that evolved during this study;
2) Describe physical characteristics and radiocollar deployment of 31 wolves;
3) Detail information of wolf kill rates of ungulates conducted in March 2000;
4) Describe wolf pack sizes and territories overlapping the Red Rock/Prairie Creek and Little Smoky Caribou herd ranges.

2.2 Study Area

The study area is approximately 5,000 square kilometers, located in the foothills of west-central Alberta, near the town of Grande Cache (54N 119W) (Figure 1). The area is classed into subalpine and boreal natural subregions (Beckingham and Archibald 1996), and contains several main rivers and a dendritic pattern of creeks; lakes are scarce. Elevations range from 1300-1800 meters, and the climate is subarctic, with short wet summers and long cold winters. Temperatures average 16C in July and -13.5C in December (Beckingham and Archibald 1996). The area is forested primarily with lodgepole pine (*Pinus contorta*) and some white spruce (*Picea glauca*). The wetland complexes support mostly black spruce (*Picea mariana*) and some tamarack (*Larix laricina*). Some south facing slopes contain aspen (*Populus tremuloides*) and willow (*Salix sp.*).

This area supports a high diversity of large mammals: woodland caribou, moose (*Alces alces*), elk (*Cervus elaphus*), mule deer (*Odocoileus heminous*), white-tailed deer (*Odocoileus virginianus*), bighorn sheep (*Ovis canadensis*), mountain goats (*Oreamnos americanus*) and wild horses (*Equus cabalus*). Wolves, coyotes (*Canis latrans*), grizzly bears (*Ursus arctos*), black bears (*Ursus americanus*) and cougars (*Felis concolors*) also exist throughout the study area.

Major land use activities include logging, oil and gas exploration and development, coal mining, commercial trapping, and public uses such as hunting, fishing, hiking, horse packing and camping (Brown and Hobson 1998). Access is primarily on roads created for resource extraction, pipelines and seismic lines. Further descriptions of the study area can be found in Bjorge (1984), Edmonds (1988) and Smith et al. (2000).

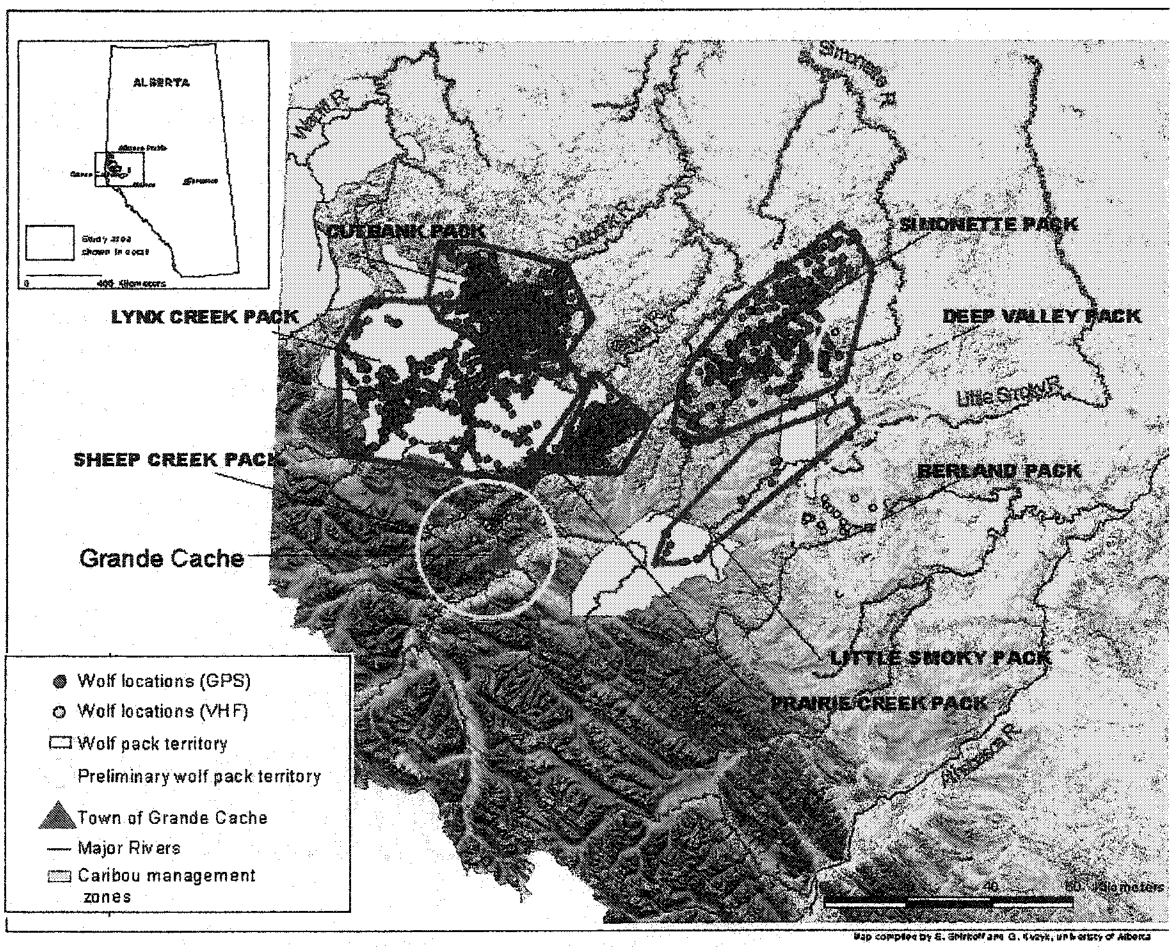


Figure 2-1. Distribution of eight wolf packs on caribou ranges in winters of 2000 and 2001 in west-central Alberta.

2.3 Methods

2.3.1 Bait Sites and Aerial Snowtracking

Following consultation with wolf experts in the Yukon and Alaska, it was decided that ungulate baits would be placed in strategic locations approximately seven to ten days prior to the initiation of the wolf capture operation, to enhance detection of wolves. In December 1999, ungulate carcasses were collected through the Grande Prairie office of Alberta Fish and Wildlife and stored in that compound. On January 12, 2000 two cow moose carcasses were slung with a helicopter to a small lake west of the Narraway River (54 32 58.5 119 55 50.8) and a small bull moose carcass was slung to the confluence of Chicken Creek and the Kakwa River (54 15 09.3 119 28 55.4). A local trapper, Ed Lightfoot, was employed to distribute ungulate baits in the Kakwa River area. He placed a cow elk carcass where the powerline intersects the Kakwa River (54 16 118 54) and moved two deer carcasses up the Kakwa about five kilometers from this location. Four deer carcasses were also secured to a tree on the edge of a large forest cutblock (Dome 2), on the ridge between Prairie Creek and the Kakwa River (54 14 119 02).

Wolves were located by following their trails in the snow from a fixed-wing aircraft, which is a standard technique used in wolf studies (Stephenson 1978, Hayes 1995, Mech et al. 1998). This protocol was successfully used to locate wolves north of Hinton in 1995 for the Yellowstone wolf re-introduction (Bangs and Fritts 1998, Fritts et al. 1997). For this study, a fixed-wing pilot with over 20 years experience in aerial tracking wolves was employed: Denny Dennison of Coyote Air, Teslin, Yukon. Aerial snowtracking of wolves is described in detail below, in conjunction with aerial capture.

2.3.2 Aerial Darting and Netgunning

All wolf capture procedures and wolf handling protocols documented in this report were done in accordance with the University of Alberta Faculty of Agriculture, Forestry and Home Economics Animal Care Committee standards (Protocol # 99-69), subject to the Canadian Council on Animal Care. Aerially darting wolves from a helicopter is a common method of capture for radiocollaring wolves (Mech 1974). Capturing wolves with a net fired from a hand held netgun has been successfully used in other studies, but the wildlife researcher is not usually a part of the capture operation (James 1999). This study combined the methods of darting and netting wolves by employing a capture helicopter pilot and ensuring that the wildlife researchers were part of the capture team. To initially assist with wolf captures for this study, a cooperative program was developed with the Yukon Territorial Government (YTG) and the West Central Alberta Caribou Standing Committee where YTG supplied a wildlife technician with experience in radiocollaring over 200 wolves (Alan Baer, Yukon Territorial Government, Whitehorse, Yukon).

The first phase of the wolf capture operation was conducted from January 20-31, 2000, using a Maule 7 fixed-wing aircraft for snowtracking wolves and a Hughes 500 helicopter for aerial captures. The wolf capture method entailed the pilot in the fixed-wing aircraft flying rivercourses, creeks and bait sites searching for wolves or wolf tracks. If tracks were found, they were followed until the pack was successfully located or the search abandoned due to time restraints. During the time of the airplane search, the helicopter capture crew remained nearby, waiting for radio contact from the airplane. Once a wolf pack was located, the airplane circled well above the pack and directed the helicopter capture crew to the pack's location (see Mech et al. 1998, page 28-33 for details). The helicopter then maneuvered to within 10-15 meters of a wolf and a person with a dartgun fired a 2-3 cc dart into the animal's upper rear leg. Drug dosages of telazol (A.H. Robbins Co., Richmond, Va.), which is a mixture of tiletamine hydrochloride and zolazepam hydrochloride, was administered at 200mg/ml and induction time could take up to seven minutes (Ballard et al. 1991).

The efficiency of aerial darting wolves was reassessed when capture success was hampered by darts missing the wolves, and by long drug induction time due to suboptimal dart placement, which resulted in the wolves moving great distances in thick tree cover before becoming sedated. Darts that missed the wolves were mostly due to the small openings for capture opportunities and lack of snow to slow the wolves. The capture method was subsequently modified; a handheld netgun was used to fire a net over the wolf, the animal was then physically restrained around the neck with a restraining fork, and hand injected with 1-2 ml of 200-400 ml/mg of telazol.

2.3.3 Physical Characteristics and Radiocollaring

Physical measurements of captured wolves were recorded in millimeters with a cloth tape measure, and included total length, chest girth, neck circumference and canine length and width. Wolves were not weighed in this study. It is difficult to accurately age a wolf by cementum analysis (Mech et al. 1998); however, subjective ages between pups and adults can be assigned based on tooth eruption patterns (Van Ballenberghe and Mech 1975). A subjective class of yearlings was also added to this study in an attempt to learn more about the wolf population, with the recognition that there is no definitive way to age yearling wolves (Mech et al. 1998).

Reproductive status of females wolves was determined by bloody vaginal discharge, and breeding condition was also estimated by size of female teats and male testes (Mech et al. 1993). Any physical ailments, wounds or scars were also recorded. Blood samples were taken from each captured wolf for disease antibody testing (Zarnke and Ballard 1987) and DNA analysis (Lehman et al. 1992). Color phases of wolves were recorded as gray, black and white following Dekker (1986), whose classification was modified by adding a category of blue. All wolves were photographed for future reference.

The objective was to place radiocollars on three wolves in each pack. An attempt was made to capture and radiocollar one or both members of the breeding pair of the pack or their pups (<10 months old). Other pack members were not targeted for collaring due to a high chance of their dispersal (Gese and Mech 1991) and high mortality rates of non-breeding wolves (Ballard et al. 1987, Bjorge and Gunson 1989). Members of breeding pairs were to be fitted with GPS (Lotek Engineering, Newmarket Ontario and Televilt GPS-Simplex, Lindesberg, Sweden) or VHF (Lotek Engineering) radiocollars and pups were fitted with VHF collars only. All radiocollared wolves were relocated by aerial radiotracking (Mech 1974) within one to four days of capture to determine if they had rejoined their packs.

2.3.4 Wolf Kill Rates

Wolf kill rates of ungulates were determined by aerially locating radiocollared wolf packs and finding their kills (Mech 1974). Flights were conducted twice daily in hopes of detecting wolf-killed deer (Fuller 1989). When a wolf pack was located, wolves were counted and the area was searched for ungulate carcasses. If an ungulate kill was not immediately found, or all members of a wolf pack were not accounted for, wolf trails were backtracked until an ungulate carcass was found or the pursuit abandoned (Hayes et al. 2000). A kill was assumed to be caused by wolves if there was a blood spoor, disarticulated carcass, and wolf trails indicating a successful chase (Hayes et al. 2000). Wolves were assumed to be scavenging if the carcass was on its sternum (Ballard et al. 1987) or if human sign indicated the ungulate was shot or road-killed.

Dead moose were classified from the air as either adult or calf (Peterson 1977). The amount of meat removed from the carcass was estimated, and the number and behavior of wolves was recorded (Mech 1966). A GPS location of the kill was taken from the aircraft. Each killsite was routinely visited until there was indication the wolves had abandoned the carcass. All wolf-killed ungulates which could not be identified in terms of species, sex and age (adult-calf) from the airplane, and all others that were easily accessible with a helicopter, were later ground inspected.

2.3.5 Wolf Pack and Territory Size

Wolf pack size was recorded in February and March, when pack size would be at a minimum, giving a conservative estimate (Mech 1970). Most packs were intensively monitored during this time, increasing the chances of a good count. The best counts of wolf pack size were made when the wolves were traveling in single file on a linear corridor or river. Lone wolves were assumed to account for 10% of the total population (Fuller 1989).

Wolf territories were calculated by entering wolf GPS and VHF locations (UTM) into a Geographic Information System (GIS) using Arc View software (Environmental Systems Research Institute 1993). A minimum convex polygon was used to calculate a minimum home range for wolf packs (Hooge and Eichenlaub 1997).

2.4 Results

2.4.1 Bait Sites and Aerial Snowtracking

Eight wolf packs were located on two caribou ranges during this study (Table 2-1). Three of eight wolf packs were first located on or near bait sites. The bull moose carcass set on the KakwaRiver/Chicken Creek confluence attracted one wolf pack (Lynx Creek pack), and a lone wolf (who eventually joined the Sheep Creek pack) was captured near the two cow moose carcasses west of the Narraway River. The Prairie Creek pack was first located moving on a powerline, while deer carcasses were being moved with a helicopter near the Dome 2 bait site. Five other wolf packs were initially located by aerial snowtracking. All wolf pack territories are presented in Figure 2-1. Maps of individual wolf pack territories are shown in Appendices 2-1 to 2-6.

Table 2-1. Initial search method and capture locations of wolf packs (n=8) on two caribou ranges in west-central Alberta.

Wolf Pack	Date of Initial Capture	Method	Location of Capture Latitude	Longitude	Caribou Herd Range
Lynx Creek	22-Jan-00	Bait Site	54 14.40	119 27.50	Red Rock/Prairie Creek
Prairie Creek	23-Jan-00	Bait Site	54 12.30	118 52.25	Red Rock/Prairie Creek
Cutbank	24-Jan-00	Aerial Snowtracking	54 31.30	118 59.75	Red Rock/Prairie Creek
Berland	25-Jan-00	Aerial Snowtracking	53 59.29	117 55.46	Little Smoky
Simonette	26-Jan-00	Aerial Snowtracking	54 07.68	118 16.82	Little Smoky
Deep Valley	29-Jan-00	Aerial Snowtracking	54 23.10	117 56.40	Little Smoky
Sheep Creek	30-Jan-00	Bait Site	54 32 58.5	119 55 50.8	Red Rock/Prairie Creek
Little Smoky	16-Feb-01	Aerial Snowtracking	54 04.06	118 09.54	Little Smoky

2.4.2 Aerial Darting and Netgunning

Thirty-one wolves were captured once, and two wolves recaptured once, during this study (Table 2-2). Nine wolves were aerially darted and 24 were netted (two recaptures) with a handheld netgun fired from a helicopter. Netted wolves were physically restrained and hand injected with a syringe containing telazol at a dosage of 1 ml at 185.5-200 mg/ml. Drug dosages were reduced to 1 ml at 100 mg/ml of telazol for wolves other than adult males, captured after March 13, 2000 (Table 2-2). This resulted in a sedation time of less than 30 minutes. This dosage was considered optimal for wolves other than adult males, as most wolves had recovered by the time handling and processing was complete.

Table 2-2. Capture methods and physical characteristics of wolves (n=31) on caribou ranges in west-central Alberta in 2000 and 2001.

Wolf ID	Capture Date	Wolf Pack	Capture Method	Collar Type	Sex	Age	Color	Canine Lgth. (cm)	Canine Width (cm)	Total (cm)	Chest (cm)	Neck (cm)	Fate as of May 3 /2001
W1	22-Jan-00	Lynx Creek	Dart	GPS	F	Adult	Black	2.8	1.5	121.5	71	43.5	Malfunction
W2	22-Jan-00	Lynx Creek	Dart	VHF	F	Pup	Black	2.4	1.3	123	70.5	41.6	Alive
W3	22-Jan-00	Lynx Creek	Dart	VHF	M	Pup	Black	2.4	1.3	110	74	47.2	Dead
W4	23-Jan-00	Prairie Creek	Dart	VHF	F	Pup	Black	2.3	1.3	Na	67.5	40	Shot
W5	24-Jan-00	Cutbank	Dart	GPS	M	Adult	Gray	3.2	1.8	144.5	89	49.5	Recollar
W5 (Recap)	17-Feb-01	Cutbank	Net	GPS	"	"	"	"	"	"	"	"	Released collar
W6	25-Jan-00	Berland	Dart	VHF	F	Pup	Black	2	1.2	119.5	65	40	Unknown
W7	26-Jan-00	Simonette	Dart	VHF	M	Pup	Black	2.7	1.4	139	75	50.5	Dead
W8	26-Jan-00	Simonette	Dart	GPS	F	Adult	Gray	2.9	1.5	128.5	73	48.5	Released collar
W9	28-Jan-00	Prairie Creek	Dart	GPS	F	Adult	Black	2.6	1.5	124	77	47.5	Recollar
W9 (Recap)	17-Feb-01	Prairie Creek	Net	GPS	"	"	"	"	"	"	"	"	Alive
W10	29-Jan-00	Deep Valley	Net	VHF	M	Yearling	Gray	2.9	1.8	129	77.6	49	Dead
W11	30-Jan-00	Cutbank	Net	VHF	M	Adult	Gray	2.9	1.7	134.9	81.9	50.9	Alive
W12	30-Jan-00	Sheep Creek	Net	VHF	M	Yearling	Black	2.6	1.6	130	80	53.2	Unknown
W13	31-Jan-00	Simonette	Net	GPS	F	Adult	Black	2.7	1.7	134	78	51	Released collar
W14	11-Mar-00	Cutbank	Net	VHF	F	Adult	White	2.5	1.2	138	81	44	Dead
W15	12-Mar-00	Berland	Net	GPS	M	Adult	Black	2.6	1.6	116.4	82.4	50.2	Malfunction
W16	12-Mar-00	Berland	Net	VHF	F	Pup	Black	2.2	1.2	127.8	69.6	47.2	Unknown
W17	13-Mar-00	Simonette	Net	VHF	F	Adult	Black	2.3	1.4	140.2	78.2	51.2	Shot
W18	13-Mar-00	Prairie Creek	Net	VHF	F	Adult	Blue	2.1	1.7	125.8	74.4	51.8	Alive
W19	15-Feb-01	Cutbank	Net	GPS	F	Yearling	Gray	2	1	138	80	43	Released collar
W20	15-Feb-01	Cutbank	Net	GPS	M	Yearling	White	2.7	1.7	134	85	54	Released collar
W21	15-Feb-01	Cutbank	Net	GPS	F	Adult	Gray	2.2	1.1	124	78	50	Alive
W22	15-Feb-01	Lynx Creek	Net	GPS	M	Adult	Black	3.1	1.7	138	89.2	53.5	Released collar
W23	15-Feb-01	Lynx Creek	Net	VHF	F	Pup	Black	2.6	1.2	123	72.4	43	Alive
W24	15-Feb-01	Lynx Creek	Net	VHF	M	Pup	Black	2.4	1.1	126	76	43	Alive
W25	16-Feb-01	L. Smoky	Net	GPS	M	Yearling	Black	2.6	1.5	126.5	80.3	51	Alive
W26	16-Feb-01	Berland	Net	GPS	M	Adult	Black	2.6	1.5	125.5	79.2	48.5	Unknown
W27	16-Feb-01	Berland	Net	VHF	F	Adult	Black	2.6	1.4	135.5	81.4	48.3	Dead
W28	17-Feb-01	Berland	Net	VHF	M	Adult	White	2.7	1.6	147.1	86.4	50.5	Alive
W29	17-Feb-01	L. Smoky	Net	GPS	F	Yearling	Gray	2.6	1.4	124.6	78.4	49.7	Alive
W30	17-Feb-01	Simonette	Net	GPS	M	Adult	Black	2.3	1.5	143.5	79.2	49.8	Released collar
W31	17-Feb-01	Simonette	Net	VHF	F	Adult	Gray	2.4	1.2	121.1	72.4	44.5	Alive

2.4.3 Physical Characteristics and Radiocollaring

Measurements of physical characteristics and blood samples were taken from all 31 wolves handled in this study (Tables 2-2 and 2-3). Blood samples have been archived with the University of Alberta and will be later analyzed for disease and DNA testing.

Table 2-3. Summary table of wolf sex ratio, age class and color phase of all wolves (n=31) captured in west-central Alberta in 2000 and 2001.

Sex Ratio(n=31)	Age Class(n=31)	Color Phases (n=31)
14 Males	17 adults	19 black (61%)
17 Females	8 yearlings	8 gray (26%)
	8 pups	3 white (11%)
		1 blue (2%)

A total of 16 GPS (14 Lotek and 2 Televilt) and 17 VHF radiocollars were deployed. GPS radiocollars were programmed to take locations ranging from one-half to three hour intervals. All 14 Lotek GPS collars were equipped with remote dropoff units, which were meant to release when a person in an aircraft directed a specific signal at the solenoid release mechanism (Lotek Engineering 2000). Six dropoffs released successfully and five failed. Three of the failed releases were recovered by recapturing the wolves, and two collars later malfunctioned and were never retrieved (Table 2-2).

There were seven mortalities of radiocollared wolves during this study (Table 2-4). Two of these wolves were known to be shot by humans. A female pup (W4) of the Prairie Creek pack was seen feeding on a road-killed moose near Highway 40 on February 10, 2000. Within a couple days, her radiocollar was hanging on the Grande Cache Fish and Wildlife office door, and Fish and Wildlife officers later confirmed that this wolf had been shot by a hunter. The adult female (W17) of the Simonette Pack was shot by hunters on October 8, 2000. Earlier on the same day, the wolf capture crew was radiotracking her and it was thought she was near a hunting camp, possibly feeding on moose remains. When the helicopter went in to retrieve the collar, the hunters were in the process of skinning this wolf.

The remaining five mortalities were of natural or unknown causes. The Deep Valley male (W10) died sometime between January 31 and March 2, 2000. The radiocollar, with no physical remains of the wolf, was found near the edge of a non-active road, in an area with many wolf and moose tracks, indicating a natural mortality. On October 8, 2000 the collar and some carcass remains of the Little Smoky male pup (W7) was found in a shallow slough near a creek away from road access, suggesting a natural death. Radiocollars for the Lynx Creek male pup (W3) and Berland female (W27) were retrieved, with cause of death unknown. On May 3, 2001, the carcass of the Cutbank female (W14) was examined and showed little external damage. It was assumed she was killed by a moose, due to evidence of many broken branches at chest height to a moose and an abundance of moose tracks near the wolf carcass.

Table 2-4. Summary table of 33 radiocollars deployed on 31 wolves in winters of 2000 and 2001 in west-central Alberta.

Capture Method	Collar Type	Fate of 16 GPS collars as of May 3/2001	Fate of all collars on May 3, 2001
22 netted 9 darted	16 GPS 17 VHF	4- remote released with VHF signal 2- remote released with no VHF signal 1- failed dropoff-recaptured with VHF signal 2- failed dropoffs- recaptured no VHF signal 2- malfunctioned-not recovered 1- unknown 4- (2 Lotek and 2 Televilt) remain on wolves	11 active 7 mortalities 7 collars released 4 unknown 2 malfunction

2.4.4 Wolf Kill Rates

Twelve ungulate kills were recorded from four wolf packs, during 9-14 days of monitoring in March 2000 (Table 2-5). Wolf kills inspected consisted of four cow and two calf moose, two deer (unknown species) and one cow elk.

Table 2-5. Ungulate kills of wolf packs in west central Alberta from March 2-15, 2000. (* denotes ground inspection)

Pack	Date	Adult Moose	Calf Moose	Adult Elk	Deer (unknown species)	GPS Location	
						Latitude	Longitude
Lynx Creek	Mar 02-00	1				54 13 00	119 24 56
Simonette	Mar 02-00	1				54 20 27	118 07 58
Cutbank	Mar 03-00		1*			54 26 92	119 26 25
Simonette	Mar 06-00	1*				54 20 04	118 18 78
Cutbank	Mar 05-00	1*				54 26 00	119 17 12
Lynx Creek	Mar 07-00	1*				54 05 95	119 37 73
Prairie Creek	Mar 08-00			1*		54 11 02	118 38 19
Simonette	Mar 09-00				2*	54 20 12	118 24 75
Simonette	Mar 12-00	1*	1*			54 20 86	118 19 22
Cutbank	Mar15-00	1				54 27 77	119 02 94
Totals		7	2	1	2		
Per Pack							
Lynx Creek		2					
Cutbank		2	1				
Prairie Creek				1			
Simonette		3	1		2		

For comparison purposes, wolf pack kill rates recorded from March 2-15, 2000 were extrapolated to a 200-day winter period from October to April (Table 2-6).

Table 2-6. Kill rates of wolf packs in west-central Alberta extrapolated to kills per 200 winter days (October to April).

Wolf Pack	Days Monitored	Moose kills	Deer kills	Ungulate kills per day	Moose kills/ 200 days	Deer kills/ 200 days	Total kills/ 200 days
Lynx Creek	9 (Mar 2-10)	2		1/ 4.5	44		44
Cutbank	14 (Mar 2-15)	3		1/ 4.7	43		43
Simonette	14 (Mar 2-15)	4	2	1/ 1.8	57	29	86

Note: Prairie Creek pack not entered as only 1 elk kill was located deer kills could not be located.

2.4.5 Wolf Pack and Territory Sizes

There were between 54 and 77 (mean =66) wolves, equating to 8.2 wolves/pack, on the Little Smoky and Red Rock/Prairie Creek caribou ranges during this study (Table 2-7).

Table 2-7. Summary of wolf numbers per pack in the Little Smoky (n=4) and Prairie Creek (n=4) caribou ranges in March 2001.

	Estimated pack wolves in late winter	**Estimated pack wolves on Little Smoky caribou range**	**Estimated pack wolves on Red Rock/Prairie Creek caribou range**
Total (Range)	54 to 77	31 to 38	30 to 39
Total (Mean)	66.5	35	35
Mean Pack Size	8.2		

Wolf pack sizes ranged from 4-18 and territory size from 336-2128 km^2 (Table 2-8). Wolf pack and territory size, when combined, equated to an average wolf density of 11 wolves/1000km^2 (Table 2-8). Insufficient VHF locations were acquired from the Deep Valley, Sheep Creek and Berland packs to analyze territory size, due to the infrequent locations or collar malfunction.

Table 2-8. Wolf pack and territory size in relation to caribou ranges in west-central Alberta in late winters of 2000 and 2001.

Wolf Pack	Estimated pack size	Territory size km^2	#GPS locations	Wolves/ 1000 km^2	Approx. Latitude	Territory Center Longitude	Caribou herd
Lynx Creek	12 – 18	2128	3064	7	54 15'	119 30'	RPC
Cutbank	7 – 8	758	661	10	54 28'	119 10'	RPC
Prairie Creek	5 – 6	336	472	16	54 12'	118 53'	RPC
Sheep Creek	6 – 7	-	-	-	53 58'	119 20'	RPC
Simonette	7 – 11	823	913	11	54 20	118 15'	LSM
Little Smoky	7	640	23	11	54 05'	118 15 '	LSM
Deep Valley	9	-	-	-	54 17'	117 50'	LSM
Berland	8 – 11	-	-	-	54 05'	117 35'	LSM
Total (Range)	54 – 77	336-2128		7-16			
Total (Mean)	65.5	937		11			
Mean	8.2						

2.5 Discussion

2.5.1 Bait Sites and Aerial Snowtracking

Ungulate bait sites enhanced wolf capture opportunities for two wolf packs and one lone wolf, and five wolf packs were located using aerial snowtracking. The experience of the fixed-wing aircraft pilot was crucial; there can be as much as a threefold difference in results between experienced and inexperienced observers when locating wolves (Stephenson 1978). A combination of ungulate bait sites and aerial snowtracking by an experienced pilot is recommended as the most suitable method for locating wolves in west-central Alberta.

2.5.2 Aerial Darting and Netgunning

Aerial darting was used successfully to capture nine wolves (Table 2-2) but this method is not recommended as the primary means of wolf capture in this type of terrain. The lack of adequate snow to slow the wolves, and scarcity of large rivers and lakes, made darting difficult. When wolves were successfully steered into an open forest cutblock, the capture opportunities were enhanced, but the overall lack of snow, and many snow-packed trails, enabled the wolves to move at a rapid pace, making darting difficult. Also, drug induction times of up to five minutes made following a darted wolf in thick timber a challenge.

Twenty-four successful wolf captures were made with a net fired from a netgun, the wolf being physically restrained and then hand-injected with telazol. This method is deemed the optimal wolf capture technique under this terrain type and low snow conditions. When tangled in nets, the wolves were distracted and usually remained in a small radius of <10 meters, allowing capture personnel to approach, physically restrain and process the wolf in a confined area. However, adult male wolves were a challenge to capture with a net, as they were often large and tried hard to escape from the net and restraining device. One adult gray wolf of the Prairie Creek pack was never collared in 2000, as he successfully chewed through, or slipped under, six nets before the capture crew could restrain him. Other adult males continually bit at the nets and restraining stick in hopes of being freed. Nevertheless, it is recommended to continue using this netgunning technique for wolves, and to encourage workers to continually modify capture methods to ensure they are the safest and most humane possible. One method discussed, but not tried during this study, was to place a netgunner in the usual position in the back of the helicopter and a darter in the front seat. This technique could increase capture options for large male wolves, by allowing a dart to be shot into the wolf while it is tangled in a net.

Concentration of telazol at 100 mg/ml were effective for sedating physically restrained wolves the size of adult females or smaller, but is not recommended for larger males. Due to the aggressive nature of these wolves, a concentration of 200mg/ml is recommended for a quicker induction time. It is recommended that capture personnel carry two to four syringes with dosages of both 100 and 200 mg/ml of telazol to be prepared for a variety of wolf capture possibilities. These syringes must be carried in a safe manner (e.g. hard plastic syringe containers with lids secured with duct tape).

2.5.3 Physical Characteristics and Radiocollaring

Fourteen male and 17 female wolves were captured during this study (17 adults, 8 yearlings and 8 pups). Black wolves consisted of 61% of the captured sample, which is higher than the 53% reported by Dekker (1986) in Jasper National Park. One of the 31 wolves captured was of the blue color phase, revealing an uncommon characteristic and a similar color to one wolf captured north of Hinton for the Yellowstone re-introduction (Fritts et al. 1997).

Many problems were encountered with GPS radiocollars during this study. On March 12, 2000, the GPS radiocollar from the breeding female of the Simonette pack (W8) was non-functioning, but the wolf pack was seen from the air sleeping near the junction of a linear corridor and creek. This collar was remotely released from the wolf using a signal transmitted from an antennae by a person in the airplane. Remote GPS collar dropoffs failed to work on April 20, 2000 for wolves in the Prairie Creek (W9), Cutbank (W5) and Simonette (W17) wolf packs. These collared wolves were located by radiotracking from a helicopter, and visually followed < 200 meters, at which time several attempts were made to remotely release the radiocollar. It was later determined that the dropoff mechanisms had failed due to internal problems with the release pin. On May 2, 2000, W17, from the Simonette pack, was captured using the netgunning technique and the collar removed. Another attempt was made to recapture the remaining wolves with GPS collars on October 8, 2000. However, the VHF component of the GPS collars had stopped transmitting on all collars, and capture plans were delayed. Failed GPS collars from the Prairie Creek female (W9) and Cutbank male (W5) were eventually recovered from the wolves in February 2001, using the netgunning technique. GPS collars from the

Lynx Creek female (W1) and Berland male (W15) were not recovered during this project. All five GPS remote dropoff mechanisms worked in 2001, and no problems were encountered with the VHF collars during this study.

2.5.4 Wolf Kill Rates

During March 2000, wolves killed an ungulate every 1.8 to 4.5 days, which equates to 44-57 moose per 200-day winter period (Tables 2-5 and 2-6), and is similar to kill rates reported in other studies (see Mech et al. 1998 for a review). The Simonette pack (n=11) had the highest kill rate of four moose and two deer in 14 days, and was observed hunting on several occasions (Kuzyk 2002). One killsite consisted of a cow moose in a cutblock, and its calf about 700 meters away, just inside the forest from the cutblock edge. This pack also killed one cow moose and fed on it for approximately 12 hours, then left the carcass for about 24 hours. During that period, the pack was seen and photographed bedded near three other moose, and later they returned to the original moose carcass.

A confounding factor in extrapolating wolf kill rates of ungulates in west-central Alberta is the difficulty of detecting wolf-killed deer, due to the small size and cryptic color of deer and the short time required for wolves to handle deer carcasses (see also Fuller 1989). All wolf packs followed over the two winters in this study, with the exception of the Berland pack, were observed either hunting deer or at deer kills. During the March 2000 kill rate work, the Prairie Creek pack was seen hunting deer, and was thought to have made deer kills, but those were never detected from the aircraft. This resulted in somewhat ambiguous results, as data indicate this pack killed only one elk in nine days of monitoring (Table 2-5). The importance of deer to wolves in this study area should not be underestimated, and further research to quantify the importance of deer in this wolf-ungulate system should be initiated.

No caribou kills were detected during this study, probably due to the low caribou numbers in the region (Dzus 2001) and the short time in which wolves can handle a carcass (Hayes et al. 2000). Caribou could not be primary prey for wolves in west-central Alberta as for example, there are fewer than 100 caribou in the Little Smoky herd and four wolf packs overlap their range, with each pack killing between 40-85 ungulates each winter (Table 2-6).

Wolf kill rates were not extrapolated to the summer period, as in summer wolves begin hunting singly or in small groups, and it is increasingly difficult to find kills, resulting in a lack of information on this subject (Mech et al. 1998). Also in summer, wolves start competing with bears for ungulate carcasses, as was noted in this study when a grizzly bear was found defending a moose carcass from wolves of the Cutbank pack (Kuzyk et al. 2001).

2.5.5 Wolf Pack and Territory Sizes

An average of 66 wolves were living in eight wolf packs on the RedRock/Prairie Creek and Little Smoky caribou ranges during this study. Late winter wolf pack size ranged from 4-18 members per pack with a mean pack size of 8.2 wolves/pack, which is similar to the mean of 8.7 wolves/pack averaged in five other Alberta wolf studies conducted between 1975 and 1985 (Gunson 1992). The 18 members of the Lynx Creek pack documented in the winter of 2001 is a notable example that large wolf packs can exist on fragmented landscapes (Kuzyk 2001), as pack size can provide an indication of ungulate abundance and human impacts on the landscape (Mech 1995). This observation of a large wolf pack also occurred near the Rocky Mountains, where initiatives are underway to create large carnivore conservation areas. It has been suggested that, for long term conservation of wolves, a landscape should hold five contiguous home ranges to allow for emigration and dispersal (Weaver et al. 1996). Mean wolf territory size determined in this study was 937 km^2, which equates to an area of 4685 km^2 for five wolf territories for optimum wolf conservation as suggested by Weaver et al. (1996).

Wolf territory size can effect wolf density on a larger landscape level, and resultant wolf kill rates on ungulates (Fuller 1989, Schmidt and Mech 1997). Territory size can be small where there is a high concentration of prey, and is often larger when preferred prey is more dispersed, especially large-bodied prey such as moose (Mech 1970). The Prairie Creek pack had the smallest territory size of 336 km^2, creating the highest wolf density of 16 wolves/1000km^2. The largest territory was held by the Lynx Creek pack (2128 km^2) resulting in the lowest wolf density of 7 wolves/1000km^2. The average wolf density in this study area was 11 wolves/1000km^2 (Table 8), well above the 6.5 wolves/1000 km^2 Bergerud and Elliot (1986) suggest can cause a caribou decline. These results further our understanding of wolf pack size and territoriality in this system, which is important for caribou conservation (see Thomas 1995 for a review).

2.5.6 Wolf Packs on the RedRock/Prairie Creek Caribou Range

Lynx Creek Pack (n=12-18)

The Lynx Creek wolf pack had the least amount of industrial activity within its territory of any pack in this study. In the winter of 2000, the Lynx Creek pack consisted of 13 black wolves, and three members were collared. The following year on February 11, 2001 this pack had a minimum of 18 wolves (13 black and 5 gray), and was located well to the north of its usual range centering on the Lynx Creek/Kakwa River confluence (Kuzyk 2001). The GPS collar on a female wolf (W1) malfunctioned early in the study and was never recovered. It is highly possible she remained in the pack, as it would be difficult to see one of many black wolves wearing a black colored collar. As well, because this wolf had been captured once before, she would likely be the first to run into the trees once the helicopter approached. In 2001, an adult male (W22) was fitted with a GPS collar and one female (W23) and one male (W24) pup were each fitted with VHF collars. On May 2, 2001 these two collared males were with a group of five wolves that appeared to be dispersing north of the Cutbank pack's territory. The GPS collar from W22 was remotely released from an airplane and later retrieved with a helicopter.

Cutbank Pack (n=7-8)

This wolf pack lived on the most heavily industrialized landscape of any pack in this study. Capture opportunities were at times optimal due to the high prevalence of open cutblocks, and in 2001 five of eight members were fitted with radiocollars. Observations of radiocollared members of this wolf pack were reported twice by local grader operators. One grader operator also found and returned a wolf GPS collar that was initially remotely released from a helicopter but had taken extended time to drop off. No human-caused wolf mortalities were reported for this pack. However an adult female wolf (W14), thought to be the breeding female in 2000, was found dead on May 3, 2001 with evidence suggesting she was killed by a moose.

Prairie Creek Pack (n=5-6)

This pack was consistently the most difficult on which to deploy radiocollars. The wolves were often found near Highway 40 or the logging activities in the Prairie Creek drainage, and the adults of this pack seem attuned at avoiding people (especially in helicopters). Two malfunctioning GPS collars were recovered from this pack. The adult female (W9) wearing a failed GPS collar was recaptured and fitted with a new Lotek GPS collar in 2001. In 2001, on the second last day of captures a large gray wolf wearing a malfunctioning GPS collar was seen with this pack. During the chase it was assumed that the collar could only belong to the adult male of the Cutbank pack from the previous year; once the wolf was caught, this was found to be the case. This wolf (W5) had changed packs, and in 2001 was established as the new leader of the Prairie Creek pack. This pack also contained the oldest wolf and only blue wolf (W18) radiocollared during the study.

Sheep Creek Pack (n=6-7)

On January 30, 2000 a young lone wolf was captured and fitted with a VHF collar near a moose bait west of the Narraway River. During the wolf predation rate work in March 2000, he was found alone on the upper Kakwa River, then several days later was found with a pack of 6-7 wolves on Mount Hamel, just north of Grande Cache. This behavior has been recorded in other studies and may have been an example of a young wolf temporarily dispersing from its natal pack (Mech et al. 1998). Studying lone wolves maybe important when assessing predation risk to caribou, as they can favor human-made trails for ease of travel (Kuzyk and Kuzyk 2001). This wolf pack seemed to inhabit the Sheep Creek area up from the confluence of the Smoky River. The collared wolf was last located near Sheep Creek on April 2000. His signal was not heard in February 2001, and due to his age and previous foray, he likely dispersed from the area.

2.5.7 Wolf Packs on the Little Smoky Caribou Range

Simonette Pack (n=7-11)

This pack's territory centered on the upper Simonette River. The Simonette pack had the highest ungulate kill rate recorded in this study (1 ungulate/1.8 days - Table 6) and seemed especially adept at hunting moose. One of the VHF collared wolves (W17) was shot by hunters the morning of the October 8, 2000 capture attempt, and the collar was recovered from the hunters as the wolf was being skinned. Due to collar removals and wolf mortalities, there were no active collars on wolves in 2001 when a pack of 7 wolves was located in the upper Simonette River and assumed to be the same pack as the previous year. An adult male wolf was fitted with a GPS collar and an adult female with a VHF collar. These two collared wolves along with two others, one of which was a black male missing his left front leg from the knee down, appeared to be splitting from the original pack. The female was in estrous when collared, and on the last flight on May

2, 2001, it was assumed she was setting up a new territory on the perimeter of her parents, a behavior called "budding"(Mech et al 1998).

Little Smoky Pack (n=7)

In 2001, a pack of seven wolves was found bedded close to the Little Smoky River near the center of the Little Smoky caribou range. This pack had not been found the previous year, even though the area had been searched extensively because it was thought a pack would inhabit the area. A male yearling was fitted with a GPS collar (Televilt) and later dispersed northeast near the Latronell River. A yearling female wolf was fitted with a Lotek GPS collar and remained in the study area.

Berland Pack (n=8-11)

The Berland pack, whose territory centers on Chase Flats, had two VHF and one GPS collars active on wolves in March 2000. The GPS collar ceased functioning by the fall of 2000, and by February 2001 neither of the VHF collars could be heard. As the VHF collars had been placed on pups, it was presumed those wolves would still have been with the pack, or if they had died of natural causes, that their collars would have been in the area on mortality signal. It is therefore assumed that these two wolves died from human causes and the collars were either destroyed or removed from the study area. In 2001, without the assistance of radiocollars, the Berland pack was found in a similar location near Chase Flats meadows. Due to the GPS collar failure in 2000, and unknown status of wolf (W26), which was GPS collared in 2001, there is no GPS data available for this pack.

Deep Valley Pack (n=9)

A yearling male wolf was collared in this pack in January 2000. His collar was recovered from his mortality site six weeks later, with a moose or wolves presumed to be the cause of death. No further effort was made to locate and recollar this pack.

2.6 Literature Cited

Ballard, W. B., J. S. Whitman and C.L. Gardner. 1987. Ecology of an exploited wolf population in south-central Alaska. Wildlife Monographs 114: 49 pp.

Ballard, W. B., L.A. Ayres, K.E. Roney and T.H. Spraker. 1991. Immobilization of gray wolves with a combination of tiletamine hydrochloride and zolazepam hydrocloride. Journal of Wildlife Management 55(1): 71-74.

Bangs, E.E. and S.H. Fritts. 1998. Reintroducing the gray wolf to central Idaho and Yellowstone National Park. Wildlife Society Bulletin 24(3): 402-413.

Beckingham, J.D. and J. H. Archibald. 1996. Field Guide to the Ecosites of West-central Alberta. Canadian Forest Service, Nortwest Region, Northern Forestry Center, Edmonton, Alberta. 509 pp.

Bergerud, A.T. 1974. The decline of caribou in North America following settlement. Journal of Wildlife Management (38): 757-770.

Bergerud, A.T. and J. Elliot. 1986. Dynamics of caribou and wolves in northern British Columbia. Canadian Journal of Zoology(64):1515-1529.

Bjorge, R.R. 1984. Winter habitat use by woodland caribou in west central Alberta with implications for management. Pp. 335-342 *in* Fish and Wildlife relationships in old-growth forests. W.R. Meehan, T.R. Merrell and T.A. Hanley editors. American Institute of Fishery Research Biology, Juneau, Alaska.

Bjorge, R.R. and J.R. Gunson. 1983. Wolf predation of cattle on the Simonette River pastures in northwestern Alberta. Pages 106-111. *in* L.N. Carbyn, editor. Wolves in Canada and Alaska: their status, biology, and management. Canadian Wildlife Service Report Series, No. 45, Ottawa, Ontario. 135 pp.

Bjorge, R.R. and J.R. Gunson. 1985. Evaluation of wolf control to reduce cattle predation in Alberta. Journal of Range Management (38): 483-487.

Bjorge, R.R. and J.R. Gunson. 1989. Wolf, *Canis lupus*, population characteristics and prey relationships near the Simonette River, Alberta. Canadian Field-Naturalist (103): 327-334.

Brown, W.K. and D.P. Hobson. 1998. Caribou in west-central Alberta – information review and synthesis. Prepared for: The Research Subcommitee of the West-central Alberta Caribou Standing Committee, Grande Prairie, Alberta. 74 pp.

Carbyn, L.N. 1974. Wolf predation and behavioral interactions with elk and other ungulates in an area of high prey diversity. Canadian Wildlife Service Report, Edmonton 234 pp.

Cowan, I. McT. 1947. The timber wolf in the Rocky Mountain National Parks of Canada. Canadian Journal of Research (25): 139-174.

Dekker, D. 1986. Wolf, *Canis lupus*, numbers and color phases in Jasper National Park, Alberta: 1965-1984. Canadian Field-Naturalist 100:550-553.

Dzus, E. 2001. Status of woodland caribou (*Rangifer tarandus caribou*) in Alberta. Environment, Fisheries and Wildlife Management Division, and Alberta Conservation Association, Wildlife Status Report Number 30, Edmonton, Alberta. 47 pp.

Edmonds, E.J. 1986. Draft restoration plan for woodland caribou in Alberta. Alberta Fish and Wildlife Division, Edmonton. 74 pp.

Edmonds, E.J. 1988. Population status, distribution and movements of woodland caribou in west central Alberta. Canadian Journal of Zoology (66): 817-826.

Edmonds, E.J. 1998. Status of woodland caribou in Alberta. Rangifer Special Issue Number 8: 111-115.

Edmonds, E.J. and M. Bloomfield. 1984. A study of woodland caribou (*Rangifer tarandus caribou*) in west central Alberta, 1979-1983. Unpublished report prepared for Alberta Fish and Wildlife Division, Edmonton. 203 pp.

Fritts, S.H., E.E. Bangs, J.A. Fontaine, M.R. Johnson, M.K. Phillips, E.D. Koch and J.R. Gunson. 1997. Planning and implementing a reintroduction of wolves to Yellowstone National Park and central Idaho. Restoration Ecology(5): 7-27.

Fuller, T.K. 1989. Population dynamics of wolves in north-central Minnesota. Wildlife Monographs 105: 41 pp.

Fuller, T.K. and L.B. Keith. 1980. Wolf population dynamics and prey relationships in northeastern Alberta. Journal of Wildlife Management (44): 583-602.

Gese, E.M. and L.D. Mech 1991. Dispersal of wolves (*Canis lupus*) in northeastern Minnesota, 1969-1989. Canadian Journal of Zoology (69): 2946-2955.

Gunson, J.R. 1992. Historical and present management of wolves in Alberta. Wildlife Society Bulletin (20): 330-339.

Hayes, R.D. 1995. Numerical and functional response of wolves, and regulation of moose in Yukon. Masters Thesis, Simon Fraser University, Burnaby, British Columbia. 132 pp.

Hayes R.D., A.M. Baer, U. Wotschikowsky and A.S. Harestad. 2000. Kill rate by wolves on moose in the Yukon. Canadian Journal of Zoology (78): 49-59.

Hervieux, D., J. Edmonds, R. Bonar and J. McCammon. 1996. Successful and unsuccessful attempts to resolve caribou management and timber harvesting issues in west central Alberta. Rangifer Special Issue Number 9: 185-192.

Hooge, P.N. and B. Eichenlaub. 1997. Animal movement extension to arcview version 1.1. Alaska Biological Science Center, US Geological Survey, Anchorage, Alaska.

James, A.R.C. 1999. Effects of industrial development on the predator-prey relationship between wolves and caribou in northeastern Alberta. Ph.D. Thesis, University of Alberta, Edmonton Alberta. 70 pp.

James, A.R.C. and A.K. Stuart-Smith. 2000. Distribution of caribou and wolves in relation to linear corridors. Journal of Wildlife Management (64): 154-159.

Kneteman, J. 1995. Summary report of gray wolf relocation from Alberta to Yellowstone National Park and central Idaho. Alberta Environmental Protection, Wildlife Management Division, Hinton, Alberta. 19 pp.

Kuzyk, G.W. 2002. Female and calf moose remain stationary and non-aggressive when approached by wolves in west-central Alberta. Alberta Naturalist 31(4): 53-54.

Kuzyk, G.W. 2001. Observation of a large wolf pack on a fragmented landscape in west-central Alberta. Alberta Naturalist 31(2): 26-27.

Kuzyk, G.W and K.M. Kuzyk. 2001. Wolf, *Canis lupus*, response to domestic sled dog, *Canis familiaris*, activities in central Yukon. Canadian Field-Naturalist 115(4): *in press.*

Kuzyk, G.W., C. Rohner and J. Kneteman. 2001. Grizzly bear defends moose carcass from wolves in west-central Alberta. Alberta Naturalist 30(4): 75-76.

Lehman, N.E., P. Clarkson, L.D. Mech, T.J. Meir and R.K. Wayne. 1992. A study of genetic relationships within and among wolf packs using DNA fingerprinting and mitochondrial DNA. Behavioral Ecology and Sociobiology (30): 83-94.

Lotek Engineering Inc. 2000. Lotek GPS_2000 small animal GPS location system users manual. Newmarket, Ontario.

Mech, L.D. 1966. The Wolves of Isle Royale. Fauna of National Parks of the U.S. Govt. Printing Office: Faunal Series Number 7. 210 pp.

Mech, L.D. 1970. Wolf. Ecology and Management of an Endangered Species. University of Minnesota Press. 384 pp.

Mech, L.D. 1974. Current techniques in the study of elusive wilderness carnivores. Pages 315-322. *in* Proceedings of the International Union of Game Biologists, Stockholm, Sweden. I. Kjerner and P. Bjurholm. editors. Swedish National Environment Protection Board, Stockholm.

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

Mech, L.D., T.J. Meir and U.S. Seal. 1993. Wolf nipple measurements and as indices of age and breeding status. American Midland Naturalist (129): 266-271.

Mech, L.D., L.G. Adams, T.J. Meier, J.W. Burch and B.W. Dale. 1998. The Wolves of Denali. University of Minnesota Press. 225 pp.

Oberg, P.R. 2001. Responses of mountain caribou to linear features in a west-central Alberta landscape. Masters Thesis, University of Alberta, Edmonton, Alberta. 126 pp.

Peterson, R. O. 1977. Wolf ecology and prey relationships on Isle Royale. U.S. National Park Service Science Monograph Series, Number 11, 210 pp.

Rempel R.S. and A.R. Rodgers. 1997. Effects of differential correction on accuracy of a GPS animal location system. Journal of Wildlife Management (61): 525-530.

Seip, D. R. 1992. Factors limiting woodland caribou populations and their relationships with wolves and moose in southeastern British Columbia. Canadian Journal of Zoology (70): 1494-1503.

Schmidt, P.A and L.D. Mech. 1997. Wolf pack size and food acquisition. The American Naturalist (150): 513-517.

Szkorupa, T.D. 2002. Multi-scale habitat selection by mountain caribou in west-central Alberta. Masters Thesis, University of Alberta, Edmonton, Alberta, 92 pp.

Smith, K.G., E.J. Ficht, D. Hobson, T.C. Sorensen and D. Hervieux. 2000. Winter distribution of woodland caribou in relation to clear-cut logging in west-central Alberta. Canadian Journal of Zoology (78): 1433-1440.

Stelfox, J.G. 1969. Wolves in Alberta: a history 1800-1969. Alberta Lands Forests Parks Wildlife Magazine (12): 18-27.

Stephenson, R.O. 1978. Characteristics of exploited wolf populations. Alaska Department of Fish and Game Federal Aid in Wildlife Restoration, Final Report, Fairbanks, Alaska.

Televilt Postioning AB. 2000. GPS-Simplex and Simpost Manual version 3. Lindesberg, Sweden.

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.

Van Ballenberghe, V. and L.D. Mech. 1975. Weights, growth and survival of timber wolf pups in Minnesota. Journal of Mammalogy (56): 44-63.

Weaver, J.L. 1994. Ecology of wolf predation amidst high ungulate diversity in Jasper National Park, Alberta. Ph.D. Thesis, University of Montana, Missoula. 165 pp.

Weaver, J.L., P.C. Paquet and L.F. Ruggiero. 1996. Resilience and conservation of large carnivores in the Rocky Mountains. Conservation Biology (10): 964-976.

Zarnke, R.L. and W.B. Ballard. 1987. Serological survey of microbial pathogens of wolves in Alaska. Journal of Wildlife Disease (23): 77-85.

Chapter 3. Distances Travelled by Wolves in Relation to Ungulate Killsites

3.1 Introduction

Wolves (*Canis lupus*) travel extensively to locate prey (Mech 1970). When hunting moose (*Alces alces*), wolves often travel 30-50 kilometers per day (Mech 1966, Peterson 1977, Mech et al. 1998). They can move 3.8 kilometers per hour (km/hr) when travelling in the forest in winter (Musani et al. 1998), 8 km/hr when travelling on open expanses of ice (Mech 1966) and 8.7 km/hr when moving on level terrain in summer (Mech 1994). Human infrastructure such as roads and trails can enhance wolf movements (Formozov 1946, Thurber et al. 1994). For example, wolves in winter can move 2.8 times faster on a linear corridor than in the forest (James 1999).

When wolves kill large prey such as moose, they usually spend 2-4 days near the carcass (Peterson 1977, Ballard et al. 1987, Mech et al. 1998, Hayes et al. 2000), whereas deer (*Odocoileus sp.*) carcasses are generally handled in less than 24 hours (Fuller 1989). After feeding on an ungulate carcass, wolves may travel up to several kilometers to rest in open sunny areas, which can optimize digestion (Mech 1970). During one study, wolves were found near moose kills in 21 of 31 days of continuous monitoring (Mech 1966), but fine scale movements near the carcasses were not recorded.

If moose are the main prey of wolves (Mech 1970), and wolves spend about 48 hours handling a moose carcass (Hayes et al. 2000), understanding wolf travel distances in relation to ungulate killsites may be a method to assess predation risk to other prey species. It is hypothesized that woodland caribou (*Rangifer tarandus*) spatially separate themselves from moose to avoid predation by wolves (Bergerud and Elliot 1986, Seip 1992, James 1999). Woodland caribou are threatened in Alberta (Edmonds 1998, Dzus

2001), and wolf predation is often cited as the main cause for caribou declines (Edmonds 1988, James 1999). Thus, increased information on wolf-prey systems is essential for future caribou conservation decisions.

Observational studies of wolves provide useful insight into wolf hunting behavior (Carbyn and Trottier 1988, Mech 1997) but there is little quantitative information on wolf movements near killsites, due to the technical difficulties of collecting such information (Mech 1995). Wolves have traditionally been studied using daily aircraft flights to relocate radiocollared wolf packs, but this technique is limited by daylight and favorable weather (Mech 1995).

The objective of this study is to combine Global Positioning Systems (GPS) radiocollar technology with concurrent aerial observations to provide consistent and finescale information of wolf movements in relation to ungulate killsites. Wolf packs feeding on moose are predicted to spend more time near carcasses than traveling (Mech 1966), which should, theoretically, lessen predation risk to caribou. Wolf packs feeding on deer should spend minimal time at killsites (Fuller 1989), which could result in increased predation risk to caribou.

3.2 Methods

3.2.1 Study Area

The study area is approximately 5,000 square kilometers, located in the foothills of west-central Alberta, near the town of Grande Cache (54N 119W) (Figure 3-1). The area is included in subalpine and boreal natural subregions (Beckingham and Archibald

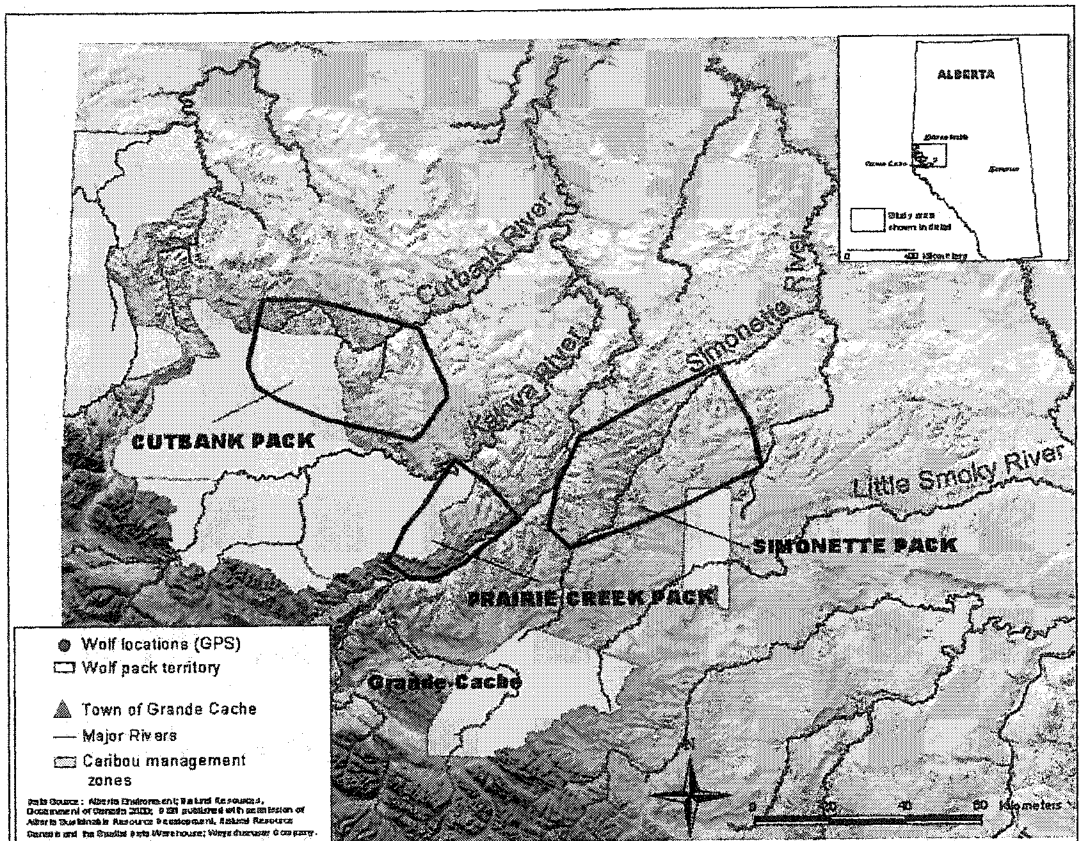


Figure 3-1. Three wolf packs on caribou ranges in west-central Alberta, March 2000.

1996), and contains several large rivers and a dendritic pattern of creeks; lakes are scarce. Elevations range from 1300 - 1800 meters, and the climate is subarctic, with short wet summers and long cold winters. Temperatures average 16° C in July and -13.5° C in December (Beckingham and Archibald 1996). The area is forested, with lodgepole pine (*Pinus contorta*) and white spruce (*Picea glauca*) comprising the dominant tree species. The wetland complexes support mostly black spruce (*Picea mariana*) and some tamarack (*Larix laricina*). Aspen (*Populus tremuloides*) and willow (*Salix sp.*) occur on some south facing slopes.

This area supports a high diversity of large mammals: woodland caribou, moose, elk (*Cervus elaphus*), mule deer (*Odocoileus heminous*), white-tailed deer (*Odocoileus virginianus*), bighorn sheep (*Ovis canadensis*), mountain goats (*Oreamnos americanus*) and wild horses (*Equus cabalus*) are all present. Wolves, coyotes (*Canis latrans*), grizzly bears (*Ursus arctos*), black bears (*Ursus americanus*) and cougars (*Felis concolors*) also exist throughout the study area.

Major land use activities include logging, oil and gas exploration and development, coal mining, commercial trapping, and public uses such as hunting, fishing, hiking, horse packing trips and camping (Brown and Hobson 1998). Access is primarily on roads created for resource extraction, pipelines and seismic lines. Further descriptions of the study area can be found in Edmonds (1988) and Smith et al. (2000).

3.2.2 Wolf Captures and Radiotracking

In January 2000, three wolves from different packs (Simonette, Cutbank and Prairie Creek) were captured and immobilized by helicopter darting (Ballard et al. 1991) or netgunning (Chapter 2) and instrumented with GPS radiocollars (Lotek Engineering 2000). All wolf captures and handling were conducted in accordance with University of Alberta Animal Care Policy, subject to the protocol of the Canadian Council on Animal Care (Number 99-69). GPS collars were programmed to take one location per hour.

From March 2-15, 2000, these radiocollared wolves and their associated pack members were followed by radiotracking from an airplane (Mech 1974). Wolves were relocated twice daily in hopes of detecting wolf-killed deer (Fuller 1989). When a wolf pack was located, the wolves were counted and the area searched for ungulate carcasses. If an ungulate kill or most wolf pack members were not immediately found, wolf trails were then backtracked until an ungulate carcass was found (Hayes et al. 2000).

3.2.3 Wolf Killsites

An ungulate kill was assumed to be caused by wolves if there was evidence of bloodstained snow, a disarticulated carcass and wolf trails indicating a successful chase (Hayes et al. 2000). Wolves were assumed to be scavenging if the carcass was on its sternum (Ballard et al. 1987) or human sign indicated the ungulate had been shot or road-killed. A GPS location was taken from an aircraft when directly over the killsite. Killsites were visited twice daily until the wolves abandoned the carcass. Wolves were classified as being near a kill when all or most members of the pack were seen within one kilometer of the killsite.

Dead moose were classified from the air as adult or calf (Peterson 1977). The amount of meat gone from the carcass was estimated (Carbyn 1983), and the number and behavior of wolves was recorded. All wolf-killed ungulates for which species, sex and age (adult-calf) could not be confirmed from an airplane, and all others that were easily accessible with a helicopter, were later ground-inspected.

3.2.4 Data Analysis

GPS location data were differentially corrected using N4Win Version 2.40 (Lotek Engineering 2000), which reduced location error to 4-5 meters (Rempel et al. 1997). Median travel distances in meters per one-hour interval (m/hr) were classified as killsite or non-killsite by calibrating the GPS data with the field observation data. This was achieved by establishing a median time between each aerial observation in which wolves were either near or away from an ungulate killsite. For example, if a wolf pack was observed traveling at 18:00 hr in the evening, and then relocated near a recent ungulate kill at 08:00 hr the following morning (a time of 14 hours), the travel distances in the first seven hour period were placed in the non-killsite category; and those distances in the remaining seven hour period were placed in the killsite category.

All data were tested for normality prior to analysis, and non-parametric procedures were used where appropriate. All analyses were completed using SYSTAT (Version 8.0, SPSS Inc. 1998). To determine if travel distances differed when wolves were near or away from ungulate killsites, the GPS locations from the collared wolves were pooled and classified into two categories: at or away from an ungulate killsite. A Mann-Whitney U-test was used to test for differences in travel distance between these two categories. To examine variation in travel distances among wolf packs, location data for each pack were similarly divided into two categories (killsite/non-killsite), and analysed separately using Mann-Whitney U-tests.

3.3 Results

The three wolf packs were located at seven ungulate killsites from March 2-15, 2000 (Table 3-1). The Simonette wolf pack made multiple kills at two sites: a cow and calf moose were killed within 500 meters of each other on or near the same day, and the scattered remains of two deer kills were found within 100 meters of each other (Table 3-1). To be conservative, each multiple kill was pooled as one for analysis.

Wolves traveled a median distance of 80 m/hr during 14 consecutive days of monitoring (Table 3-2, Appendix 3-1). They moved a median distance of 45 m/hr when near ungulate killsites, which differed significantly from a median distance of 190 m/hr per hour when they were not near killsites (Mann Whitney U test, $p < 0.0001$; Table 3-2).

Patterns in travel distance varied among wolf packs (Table 3-3, Appendix 3-2). The Cutbank wolf pack, which was only observed on moose kills during the monitoring period, showed a highly significant difference ($p < 0.0001$) in travel distances when at or away from killsites. The Simonette pack, which was found near both moose and deer kills, showed a marginally significant difference ($p < 0.067$) between travel distances at and away from killsites. During aerial monitoring, only one elk kill was recorded for the Prairie Creek pack, and no difference ($p < 0.274$) in travel distances related to killsites was detected (Table 3-3).

Table 3-1. Ungulate killsites of three wolf packs in west-central Alberta from March 2-15, 2000.

Wolf Pack and Size(n)	Adult Moose	Calf Moose	Adult Elk	Deer
Cutbank (n=8)	1	1		
Prairie Creek (n=5)			1	
Simonette (n=11)	3*			1+
Totals	4	1	1	1

* includes one multiple kill of 1 cow and 1 calf moose which is considered 1 kill

\+ includes one multiple kill of 2 deer which is considered 1 kill

Table 3-2. Wolf travel distances (m/hr) at and away from seven ungulate killsites, as determined by one hour GPS locations from three wolves, in separate packs, during March 2-15, 2000, in west-central Alberta.

	All Travel (m/hr)	Travel at Kill (m/hr)	Travel Away from Kill (m/hr)
N of cases	553	288	265
Minimum	0.2	0.2	0
Maximum	6100	2044	6100
Standard Deviation	749	326	963
Median*	80	45	190

*(Mann Whitney U $p < 0.0001$)

Table 3-3. A comparison of median wolf travel distances (m/hr) at and away from ungulate killsites (n= number of GPS locations) for three wolves, in separate packs, during March 2-15, 2000, in west-central Alberta.

Wolf Pack	Travel at Kill (m/hr)	Travel Away from Kill (m/hr)	Mann Whitney U test (p)
Cutbank	37 (n= 135)	148 (n=48)	0.0001*
Prairie Creek	357 (n=36)	338 (n =159)	0.274
Simonette	37 (n=116)	57 (n=57)	0.067

3.4 Discussion

The travel distances of wolves in relation to ungulate killsites is important information when assessing predation risk to caribou. In this study, GPS radiocollar technology allowed wolf travel to be recorded on a relatively continuous (hourly) basis, irrespective of daylight and weather, and accounted for associated feeding, resting and other social behaviors. Further, by combining GPS radiocollar technology with traditional methods used to study wolf kill rates (Mech 1974), a more accurate representation of wolf travel distances was established. Results from this approach found a clear difference in wolf travel distance related to ungulate killsites, which is consistent with both anecdotal information and other research (Mech 1966, Peterson 1977, Hayes et al. 2000).

Wolves traveled 4.2 times less distance when near killsites (45 m/hr) than when away from killsites (190 m/hr). Differences in travel patterns between the three wolf packs studied were presumably due to the different prey species each pack was hunting. The Cutbank pack showed the greatest differences in travel at and away from killsites and was found only at moose kills. In one case, the pack remained near a cow moose carcass for longer than four days, which reduced overall travel time.

The Simonette wolf pack traveled marginally shorter distances when at, than when away, from ungulate kills. This result may be due to a combination of a preference for preying on moose, an overall high kill rate of ungulates (Chapter 2), and partial consumption of prey (Carbyn 1983). As well, this wolf pack made multiple kills of ungulates (e.g. Ballard et al. 1987, Mech et al. 1998), which would reduce their overall travel.

The Prairie Creek pack showed no difference in travel related to ungulate kills, with only one elk kill being documented during aerial monitoring. This wolf pack contained the fewest members (n=5) during the study, and pack size can affect ungulate kill rates (Fuller 1989, Schmidt and Mech 1997, Hayes et al. 2000). Nevertheless, the most probable explanation for these results is that the Prairie Creek pack was preying on deer (Carbyn 1974), as these wolves were observed hunting deer on a number of occasions, although no deer kills were found. Fuller (1989) discusses in detail the logistical problems of determining wolf kill rates of deer, due to the short time frame in which wolves handle deer carcasses and the difficulty in detecting wolf-killed deer from the air. If deer are the main prey for the Prairie Creek pack, then caribou would be at a greater predation risk in this pack's territory than in the territories of packs preying primarily on moose, due to associated increases in travel and encounter rates.

Compared to other wolf packs in the study area, the Prairie Creek pack had the smallest territory (Chapter 2) and traveled the greatest distances (this Chapter). This pack also occupied a caribou winter range (Prairie Creek meadows) which caribou had recently abandoned. The extensive logging in the area (Smith et al. 2000) could favor deer numbers, and thereby influence predation risk to caribou. As this study suggests that wolf packs preying on moose may travel less than do packs feeding on deer, a greater understanding of the role of deer in this wolf-prey system is required.

This study found that wolves traveled a median distance of 0.08 km/hr, which is substantially lower than that reported for wolves travelling in the forest during winter (1.6-6.1 km/hr) (Musani et al. 1998), on iced surfaces (8 km/hr) (Mech 1966), and on tundra during summer (8.7 km/hr) (Mech 1994). This difference could be largely due to this study's data being gathered over several days, and the advantage of continuous (hourly) GPS monitoring. Other studies gathered data while staying in visual or auditory contact with the wolves, and the data-collecting period seldom lasted more than a few hours (Musani et al. 1998, Mech 1994). GPS technology provides the opportunity to collect data more representative of wolves' daily movements. As well, it provides information on travel distances of wolves that includes time spent at known killsites, and accounts for other behaviors such as resting, and stopping at old killsites.

However, these results are lower than those reported by James (1999) for a boreal region of Alberta, where GPS collared wolves moved 0.5 km/hr in the forest and averaged 1.4 km/hr on linear corridors. James (1999) collected GPS locations every five minutes with the objective of establishing wolf speed, whereas in this study the collars obtained hourly locations with the purpose of establishing coarser estimates of wolf travel distances in relation to killsites. Frequency of locations can influence estimation of travel rates due to the linear extrapolation required between time intervals. The wolves in this study were preying primarily on moose, which can greatly limit their movements. However, the wolves remained near a moose carcass for up to fours days, moving little while feeding on the carcass. Furthermore, the boreal region of Alberta has less topographic relief than the foothills of west-central Alberta, which could also account for some difference in wolf travel rates.

The next step in this research is to determine whether ungulate killsites can be inferred from wolf GPS location data. By repeating these study methods, of concurrently determining wolf kill rates of GPS radiocollared wolves, a new technique could be developed to extrapolate killsites of large ungulates (moose and elk) from long-term GPS data sets. The detectable sequence would depend on a wolf pack feeding on a large ungulate (moose or elk) for approximately 48 hours (Mech 1970, Hayes et al. 2000). These ungulates are large enough that a wolf pack could not possibly consume the whole carcass during one feeding, and thus an inferred killsite would not be confused with a simple resting behavior. While feeding on large ungulates, individual wolves return to the carcass in a predictable pattern of about one hour of feeding, followed by about six hours of rest (Mech 1970). The wolves' gut depletion-repletion cycle, and the inherent need for the wolf to maximize food consumption, drive this feeding cycle. If the ungulate is small (e.g. deer, moose calf), or the pack size large (Schmidt and Mech 1997), the consumption of the ungulate would be too rapid (only one gut depletion-repletion cycle), leaving the activity related to the killsite difficult to distinguish from other wolf behaviors, such as simply resting or chewing bones at an old killsite.

This new technique would contribute to a better understanding of wolf behavior and has a number of management applications. Firstly, wolf predation events could be detected during any season or any time of day; such information is currently unavailable. Data on wolf predation during darkness and in the summer months is scarce, due to limitations of gathering data by traditional techniques, where snow and daylight are required components for the research. Sample sizes of wolf-killed ungulates could be increased, which is a constant challenge for wildlife researchers (Marshall and Boutin 1999, Hayes et al. 2000). Another advantage of this new technique is that it would allow ungulate killsites to be spatially referenced to landscape features, providing resource managers with relevant information when planning for caribou conservation. For example, predation risk to caribou from wolves could be assessed by mapping wolf killsites in relation to industrial features such as forest cutblocks and linear corridors.

Finally, this technique of extrapolating behavior patterns from GPS data could be expanded to other large carnivores.

3.5 Literature Cited

Ballard, W.B., J.S. Whitman and C.L. Gardner. 1987. Ecology of an exploited wolf population in south-central Alaska. Wildlife Monographs 114: 49 pp.

Ballard, W.B., L.A. Ayres, K.E. Roney and T.H. Spraker. 1991. Immobilization of gray wolves with a combination of tiletamine hydrochloride and zolazepam hydrocloride. Journal of Wildlife Management (55): 71-74.

Beckingham, J.D. and J. H. Archibald. 1996. Field Guide to the Ecosites of West-central Alberta. Canadian Forest Service, Northwest Region, Northern Forestry Center, Edmonton, Alberta. 509 pp.

Bergerud, A.T. and J. Elliot. 1986. Dynamics of caribou and wolves in northern British Columbia. Canadian Journal of Zoology (64): 1515-1529.

Brown, W.K. and D.P. Hobson. 1998. Caribou in west-central Alberta – information review and synthesis. Prepared for: The Research Subcommitee of the West-central Alberta Caribou Standing Committee, Grande Prairie, Alberta. 74 pp.

Carbyn, L.N. 1974. Wolf predation and behavioral interactions with elk and other ungulates in an area of high prey diversity. Canadian Wildlife Service Report, Edmonton, Alberta. 234 pp.

Carbyn, L.N. 1983. Wolf predation on elk in Riding Mountain National Park, Manitoba. Journal of Wildlife Management (47): 963-976.

Carbyn, L.N. and T. Trottier. 1988. Descriptions of wolf attacks on bison calves in Wood Buffalo National Park. Arctic (41): 297-302.

Dzus, E. 2001. Status of woodland caribou (*Rangifer tarandus caribou*) in Alberta. Environment, Fisheries and Wildlife Management Division, and Alberta Conservation Association, Wildlife Status Report Number 30, Edmonton, Alberta. 47 pp.

Edmonds, E.J. 1988. Population status, distribution and movements of woodland caribou in west-central Alberta. Canadian Journal of Zoology (66): 817-826.

Edmonds, E.J. 1998. Status of woodland caribou in Alberta. Rangifer Special Issue Number 8: 111-115.

Formozov, A. N. 1946. Snow cover as an integral factor of the environment and its importance in the ecology of mammals and birds. Moscow Society of Naturalists, Moscow, USSR. English translation 1969. Boreal Institute, University of Alberta, Edmonton, Alberta, Occasional Publication (1): 1-141.

Fuller, T.K. 1989. Population dynamics of wolves in north-central Minnesota. Wildlife Monographs 105: 41 pp.

Hayes R.D., A.M. Baer, U. Wotschikowsky and A.S. Harestad. 2000. Kill rate by wolves on moose in the Yukon. Canadian Journal of Zoology (78): 49-59.

James, A.R.C. 1999. Effects of industrial development on the predator-prey relationship between wolves and caribou in northeastern Alberta. Ph.D. Thesis, University of Alberta, Edmonton Alberta. 70 pp.

Lotek Engineering Inc. 2000. Lotek GPS_2000 small animal GPS location system users manual. Newmarket, Ontario.

Marshall J.P. and S. Boutin. 1999. Power analysis of wolf-moose functional responses. Journal of Wildlife Management (63): 396-402.

Mech, L.D. 1966. The Wolves of Isle Royale. Fauna of National Parks of the U.S. Govt. Printing Office: Faunal Series Number 7. 210 pp.

Mech, L.D. 1970. Wolf Ecology and Management of an Endangered Species. University of Minnesota Press. 384 pp.

Mech, L.D. 1974. Current techniques in the study of elusive wilderness carnivores. Pages 315-322. *in* Proceedings of the International Union of Game Biologists, Stockholm, Sweden. I. Kjerner and P. Bjurholm. editors. Swedish National Environment Protection Board, Stockholm.

Mech, L.D. 1994. Regular and homeward travel speeds of arctic wolves. Journal of Mammalogy (75): 741-742.

Mech, L.D. 1995. What do we know about wolves and what more do we need to learn? Pages 537-545 *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.

Mech, L.D. 1997. The Arctic Wolf - Ten Years with the Pack. Raincoast Books Publishing, Vancouver, British Columbia, 144 pp.

Mech, L.D., L.G. Adams, T.J. Meier, J.W. Burch and B.W. Dale. 1998. The Wolves of Denali. University of Minnesota Press. 225 pp.

Musiani, M, H. Okarma and W. Jedrzejewski. 1998. Speed and actual distances traveled by radiocollared wolves in Bialowieza Primeval Forest (Poland). Acta Theriologica (43): 409-416.

Peterson, R. O. 1977. Wolf ecology and prey relationships on Isle Royale. United States National Park Series Science Monograph, Number 11, 210 pp.

Rempel R.S. and A.R. Rodgers. 1997. Effects of differential correction on accuracy of a GPS animal location system. Journal of Wildlife Management (61): 525-530.

Schmidt, P.A and L.D. Mech. 1997. Wolf pack size and food acquisition. The American Naturalist (150): 513-517.

Seip, D. R. 1992. Factors limiting woodland caribou populations and their relationships with wolves and moose in southeastern British Columbia. Canadian Journal of Zoology (70): 1494-1503.

Smith, K.G., E.J. Ficht, D. Hobson, T.C. Sorensen and D. Hervieux. 2000. Winter distribution of woodland caribou in relation to clear-cut logging in west-central Alberta. Canadian Journal of Zoology (78): 1433-1440.

Thurber, J.M, R.O. Peterson, T.D. Drummer and S.A. Thomasa. 1994. Gray wolf response to refuge boundaries and roads in Alaska. Wildlife Society Bulletin (22): 61-68.

Chapter 4. Wolf response to forest cutblocks in west-central Alberta

4.1 Introduction

Much of the world's boreal forest is under increased demands from the forest industry, yet there exist little data on how large carnivores (McLellan and Hovey 2001, White et al. 2001), specifically wolves (*Canis lupus*), respond to forest harvesting (Jedrzejewska et al.1994, Kohira and Rexstad 1997, Kunkel and Pletscher 2000). Logging practices can alter the spatial dynamics of wolves and their prey, causing conflict between resource development and wildlife management (Hervieux et al. 1996). In Alberta, woodland caribou (*Rangifer tarandus*) are classed as a threatened species (Edmonds 1998), and wolf predation is considered the proximate cause for their decline (Edmonds 1988). It is therefore important to understand how wolves respond to forest harvesting, as it may effect predation risk to caribou.

Forest harvesting can cause habitat fragmentation and alter predator-prey systems. Predators may follow habitat edges due to ease of travel (Bider 1968). For example, nest predation on birds may be higher near habitat edges than interior sites (Gates and Gysel 1978, Wilcove 1985). As well, when patch size decreases, predator numbers may increase due to increased prey density and diversity (Gates and Gysel 1978, Yahner 1988). Densities of foxes (*Vulpes vulpes*) and coyotes (*Canis latrans*) can increase with increasing landscape fragmentation, and habitat edges are favored for hunting (Oehler and Litvaitis 1996).

Forestry activities have the potential to increase the predation risk to caribou from wolves in three ways. First, caribou are thought to spatially and temporally separate themselves from moose (*Alces alces*) to reduce predation risk from wolves. Moose are the primary prey of wolves, and caribou may seek higher elevations to decrease the chance of being detected by wolves hunting moose in lower level riparian areas (Bergerud and Elliot 1986, Seip 1992). If the spatial separation of caribou and moose is altered by logging roads and forest cutblocks, it has been argued that wolves will have increased access to, and greater encounter rates with caribou, thus causing a caribou decline (Bergerud 1988, Seip 1992). In northeast Alberta, linear developments (roads, seismic lines, trails) were found to affect the spatial separation between caribou and moose, where linear corridors enhanced wolf travel efficiency (James 1999) and caribou mortalities caused by wolves were found closer to linear corridors than expected by chance (James and Stuart-Smith 2000).

Secondly, caribou are thought to reduce spatial overlap from wolves by living in older forests at low densities. Logging can disrupt this anti-predation tactic by decreasing the amount and mean patch size of older forests, resulting in higher caribou densities, and thus increasing chances of detection by wolves (Bergerud 1988).

Thirdly, moose, elk (*Cervus elaphus*) and deer (*Odocoileus spp.*) are attracted to recently logged areas that support high quality regenerating forage (Peek et al. 1976, Tomm et al. 1981, Stelfox et al. 2001). This represents a concentrated prey base for wolves, which may influence how wolves use landscapes. If wolves frequent forest cutblocks searching for moose, elk and deer, and if cutblocks occur near preferred caribou habitats, this may increase predation risk to nearby caribou. Studies examining caribou response to forest cutblocks found that caribou avoided these areas in both summer (Chubbs et al. 1993) and winter (Smith et al. 2000).

As moose appear to be the primary prey of wolves in west-central Alberta (Chapter 2), it is important to understand moose response to forest harvesting. Moose can respond numerically to increased forage availability from logging and fire (Thompson and Stewart 1997), but increased access to logged areas can result in higher rates of human harvest, which may locally limit moose population growth (Timmerman and Buss 1997). A long term study of ungulate response to forest harvesting in the foothills of Alberta (Stelfox et al. 2001) found that available browse for ungulates was 4.5 times greater 10 years after logging than that found in a mature spruce forest (Stelfox 1962). Moose distribution may therefore be determined by a combination of quality of forage in young cutblocks with the availability of nearby security and thermal cover (Stelfox et al. 2001). In Ontario, moose migrated >80 kilometers from cutblocks to reach adequate shelter in late winter (Welsh et al. 1980), and cow moose with calves may select areas with greater shelter away from prime food sources, possibly to protect their calves from predation (Thompson and Vukelich 1981).

In unlogged areas, moose select riparian areas with adequate willow browse, but also require older aged forest for shelter (Peek 1997) and to provide structure for protection from attacking wolves (Mech 1966, Peterson 1995, Stephens and Peterson 1984). Wolves may increase in numbers with the increasing moose (ungulate) densities (Keith 1983, Fuller 1989), but wolf numbers may be stabilized through intraspecific social behaviors and territoriality (Packard and Mech 1980, Mech 1994).

Forest harvesting in west-central Alberta began to increase in the late 1960's and has accelerated in recent years. Energy sector activities (oil and gas exploration and development) are also altering these landscapes, resulting in cumulative land use impacts (Hervieux et al. 1996). For decision making concerning long term caribou conservation, resource managers and land-use planners require new information about how wolves respond to forest harvesting and changing landscape conditions.

I used Global Positioning Systems (GPS) radiocollar technology to examine wolf movements in relation to forest cutblocks in west-central Alberta. I chose to examine fine-scale wolf movements that correspond with Johnson's (1980) third order habitat selection: movements of animals within their home range. I asked two questions. First, do wolves use forest cutblocks preferentially over other habitat types? Second, do wolves prefer cutblock edges? I predicted that wolves would prefer forest cutblocks over other habitats, due to the presumed increased ungulate availability in regenerating forest. I also predicted wolves would prefer forest cutblock edges relative to areas further away from them, due to ungulate use of cutblock edges for feeding and proximity to cover (Stelfox et al. 2001). The cover provided by the forest cutblock edges might also be used by wolves for stalking prey and avoiding human contact.

4.2 Methods

4.2.1 Study Area

The study area is approximately 5,000 square kilometers, located in the foothills of west-central Alberta, near the town of Grande Cache (54N 119W) (Figure 1). The area is situated in subalpine and boreal natural subregions (Beckingham and Archibald 1996), and contains several large rivers and a dendritic pattern of creeks; lakes are scarce. Elevations range from 1300 - 1800 meters, and the climate is subarctic, with short wet summers and long cold winters. Temperatures average 16° C in July and -13.5° C in December (Beckingham and Archibald 1996). The area is forested, with lodgepole pine

(*Pinus contorta*) and white spruce (*Picea glauca*) comprising the dominant tree species. The wetland complexes support mostly black spruce (*Picea mariana*) and some tamarack (*Larix laricina*). Aspen (*Populus tremuloides*) and willow (*Salix sp.*) occur on some south facing slopes.

This area supports a high diversity of large mammals: woodland caribou, moose, elk (*Cervus elaphus*), mule deer (*Odocoileus heminous*), white-tailed deer (*Odocoileus virginianus*), bighorn sheep (*Ovis canadensis*), mountain goats (*Oreamnos americanus*) and wild horses (*Equus cabalus*) are all present. Wolves, coyotes (*Canis latrans*), grizzly bears (*Ursus arctos*), black bears (*Ursus americanus*) and cougars (*Felis concolors*) also exist throughout the study area.

Major land use activities include logging, oil and gas exploration and development, coal mining, commercial trapping, and public uses such as hunting, fishing, hiking, horse packing trips and camping. Access is primarily on roads created for resource extraction, pipelines and seismic lines. Further descriptions of the study area can be found in Edmonds (1988) and Smith et al. (2000).

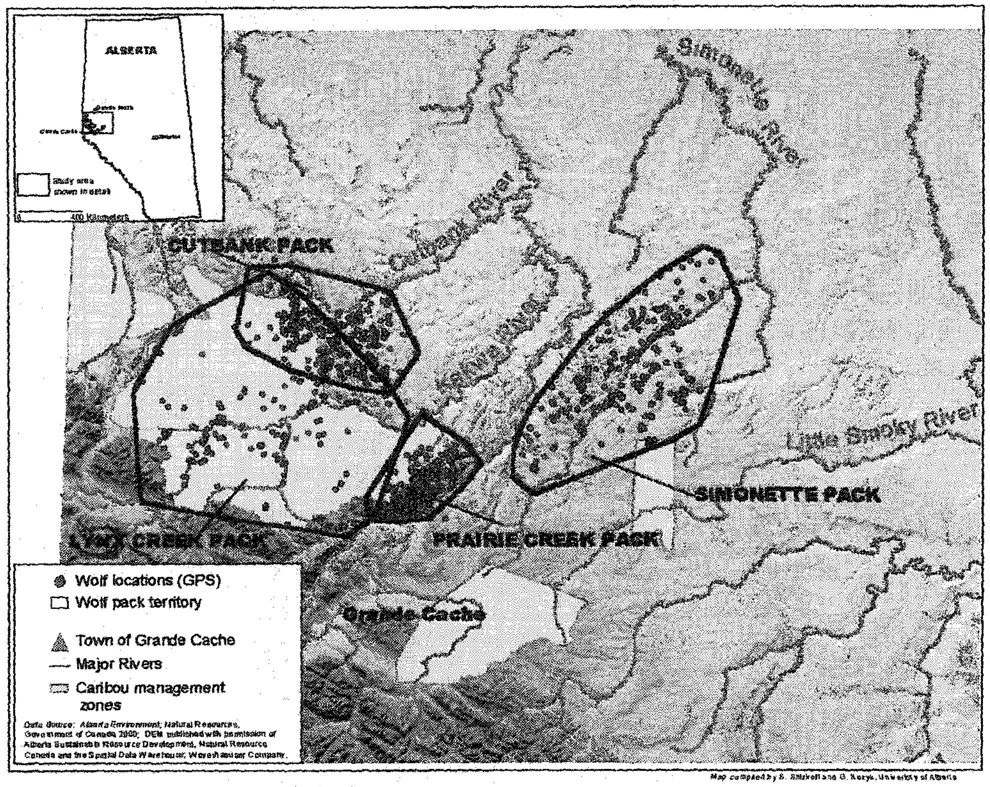


Figure 4-1. Distribution of four wolf packs monitored in winters of 2000 and 2001 in west-central Alberta

4.2.2 Wolf Location Data

Nine wolves in four packs were captured and fitted with GPS radiocollars in winters of 2000 and 2001(Table 4-1). All animal handling was approved by the Faculty of Agriculture, Forestry and Home Economics Animal Care Policy (No. 96-99D), subject to the protocols of the Canadian Council of Animal Welfare. Wolf captures were accomplished by either helicopter darting (Ballard et al. 1991) or netgunning, then physically restraining the wolf with restraining forks, and hand-injecting 1-2 mls of telazol at 200mg/ml (Chapter 2). Wolves were fitted with store aboard GPS collars

(Lotek Engineering Sytems, Newmarket, Ontario). In the winter of 2001, the Prairie Creek and Cutbank packs each had two members instrumented with GPS radiocollars. To avoid pseudoreplication (Hurlburt 1984), location data and associated patterns of habitat use from these individuals were averaged for their respective packs (Table 1).

As this study was designed to understand wolf movements when caribou were on their winter range (Chapter 2), the following criteria were used to select wolf location data:

1) Wolf location data from Jan 31-April 25 in 2000 and 2001 were used for analyses. These dates were used for two reasons: first, most caribou in the study area leave the forests in late winter and spring to calve in the nearby mountains (Edmonds 1988); second, a spring cutoff time also has ecological relevance to wolves. In spring near whelping time, wolves change their hunting patterns by switching from hunting as a pack and preying on ungulates, to hunting alone or in small units in search of smaller prey, with their activities centering on the den and pups (Mech 1970). Therefore a single GPS collared wolf would no longer represent the behavior of their pack, and would not meet the criteria set in the original study design.

2) To provide consistency in GPS collar programming, six-hour locations were chosen (4 per day) as the minimum common sampling unit for analysis. Wolves are very sporadic in their movements, and may travel at rates of about 8 km/hr while hunting (Mech 1966), or relatively short distances when near a killsite (Chapter 3). When near a killsite, they seldom rest in one location for periods longer than six hours (Mech 1970).

3) Wolf locations found outside the calculated pack territories (Chapter 2) were not used. These wolves were assumed to be dispersing from their natal territory and thus behaving differently from their pack (Gese and Mech 1991).

Data were differentially corrected using N4Win Version 2.40 program (Lotek Engineering Inc. 2000) and were therefore accurate within 14 meters, 95% of the time (Lotek Engineering Inc. 2000). Wolf locations with Dilution of Precision (DOP) values greater than 15 were removed from the analysis (<2 % of total locations). High DOP values and collar malfunctions made for unequal locations per wolf pack (range 152 to 279) over the duration of this study (Table 4-1).

Table 4-1. Wolf packs with associated number of GPS locations and area of habitat use (territory size) in west-central Alberta in winters of 2000 and 2001.

Wolf Pack	Wolf	Year	Dates	Number of Locations	Area (km2)
Cutbank	W5	2000	Jan 24-March 16/2000	185	714
Prairie Creek	W9	2000	Jan 28 – April 25/2000	252	286
Simonette	W13	2000	Jan 31-April 25/2000	279	786
***Prairie Creek**	W5 and W9	2001	Feb 18-April 25/2001	231	182
***Cutbank**	W19 and W21	2001	Feb 15-April 25/2001	258	448
Lynx Creek	W22	2001	Feb 15-April 25/2001	247	1848
Simonette	W30	2001	Feb 17-April 4/ 2001	152	398

* Locations were averaged for two collared wolves which belonged to the same pack.

4.2.3 Habitat Classification and GIS Methods

Wolf location data were imported into ArcView Version 3.1 (Environmental Systems Research Institute Inc, Redlands CA). Current, digital forest inventory coverages were obtained from Weyerhauser Canada Limited, Canadian Forest Products and Alberta Government Phase 3. Minimum convex polygons of wolf territories were initially calculated with an animal movement extension in ArcView (Hooge and Eichenlaub 1997) (Chapter 2). Due to a small portion of the GIS coverages missing within each wolf pack territory, territory sizes for this analysis were calculated by summing all the available areas within the GIS layers (Table 4-1).

As wolves live in a defined home range or territory (Mech 1970), each territory was classified into four habitat categories to reflect coarse scale patterns of use. These categories were: 1) forest cutblocks, 2) unharvested forest, 3) non-forest natural (shrubs and water) and 4) non-forest anthropogenic (pipelines, wellsites) (Table 4-2). The area of non-forest natural was divided into "shrub" and "water" classes for descriptive purposes (Table 4-3), but the data were pooled for analysis. As the focus of this study was to determine wolf use of cutblocks, a further analysis was conducted to determine wolf use of cutblock edges. Cutblocks were buffered using specified distances starting from the edge of the forest-cutblock and proceeding into the forest. Locations inside cutblocks were not used in this analysis. Buffer distances were consistent with those studying caribou avoidance of linear features (Dyer et al. 2001, Oberg 2001), starting from the edge of the cutblock to 100 m, 101-250 m, 251-500 m, 501-1000 m and >1000 m. The category of >1000m was also chosen as the furthest distance for comparison to Smith et al. (2000), who found that caribou in west-central Alberta may avoid cutblocks by about 1200m.

4.2.4 Statistical Analysis

Compositional analysis (Aebischer et al. 1993) was conducted by integrating wolf GPS location data and forest inventory data within a GIS (ArcView 3.1) to determine if there was a preference in wolf use of habitat or buffer categories. Aebischer et al. (1993) suggest a minimum of 6 radiotagged animals are required to perform compositional analysis, and replication across years is acceptable. Therefore, my sample of seven wolves over two winters was adequate. Compositional analysis compares the amount of "used habitat" to the amount of "available habitat" and tests whether habitats are preferred or avoided more than expected by random (Johnson 1980). The number of wolf locations in each habitat or buffer category represented used habitat. The available habitat was the total area of each habitat or buffer category (Table 3). If there was no use of a habitat category, 0% use was replaced with 0.001%, as this represented a value lower than the smallest recorded nonzero percentage (Aebischer et al. 1993).

A chi-squared test was used to determine if wolf use of habitat or buffer categories was significantly non-random, then each habitat category was ranked in terms of its use. To determine which habitats were selected over others, a difference for each pair-wise comparison was calculated using log ratios. This compared each habitat category within each wolf pack territory. The means and standard errors for each comparison were calculated across all wolf packs, and the pair-wise differences were tested for significance using a t-test (Aebischer et al. 1993). An alpha level of 0.05 was used. Power was calculated for all chi-squared and t-tests using *G Power (Faul and Erdfelder 1992).

Table 4-2. Description of habitat categories used in compositional analysis for wolf packs in west-central Alberta during late winters of 2000 and 2001.

Habitat 1 **Forest cutblocks**	**Habitat 2** **Unharvested forest**	**Habitat 3** **Non-forest (natural)**	**Habitat 4** **Non-forest (anthropogenic)**
all forest cutblocks	all harvestable forest burn	herbaceous grassland cutbank sand, flooded land closed and open shrub coniferous scrub deciduous scrub brush, windfall open and treed muskeg water	clearing right-of-way industrial pipelines geophysical perennial forest crops*

*Perennial forest crops are denoted as anthropogenic by the forest companies and account for < $0.6 km^2$ of one wolf pack's territory. (Simonette pack – total territory size is 786 km^2).

4.3 Results

4.3.1 Wolf Habitat Use

Territory size for the four wolf packs ranged from 182 – 1848 km^2 (Table 4-1). The availability of each of the four habitat categories varied markedly: the percentage of forest averaged 76.40% (SE 3.90) for all packs, and thus was the most dominant habitat, whereas non-forest anthropogenic averaged only 1.23% (SE 0.25) of available habitat across wolf territories (Table 4-3). Wolves showed a significant deviation from random use of the four habitat types (p= 0.036) and wolves selected non-forest natural (shrubs-water) habitats over both forest (p = 0.005) and cutblocks (p = 0.027) (Table 4-4). No other pair-wise comparisons were significant. However, when ranked in preference by habitat type, forest cutblocks were preferred over both forest and non-forest anthropogenic.

Table 4-3. The percentage of use (GPS locations) and availability (area in km^2) of five habitat categories, for wolf pack territories, in west-central Alberta during late winters of 2000 and 2001.

		Cutblock		Forest		Non-forest* Shrubs		Non-forest* Water		Non-forest Anthro.	
Wolf Pack	**Year**	**Used_1**	**Avail_1**	**Used_2**	**Avail_2**	**Used_3**	**Avail_3**	**Used_4**	**Avail_4**	**Used_5**	**Avail_5**
Cutbank	2000	34.1	28.9	57.8	64.6	7.0	5.4	1.1	0.3	0.0	0.8
Prairie Cr.	2000	11.9	12.5	77.8	80.2	6.7	4.8	1.2	1.0	2.4	1.5
Simonette	2000	21.1	15.9	61.6	78.8	7.5	3.0	2.5	0.6	7.2	1.8
Prairie Cr.	2001	6.3	5.9	81.2	87.1	9.1	4.1	1.7	1.1	1.7	1.8
Cutbank	2001	43.3	35.5	35.7	60.0	20.2	3.4	0.4	0.3	0.4	0.8
Lynx Cr.	2001	0.8	5.4	77.3	85.9	20.2	8.5	0.8	0.1	0.8	0.2
Simonette	2001	16.4	14.0	68.4	78.3	13.2	5.5	0.7	0.5	1.3	1.7
Total	**Mean**	**19.1**	**16.9**	**65.7**	**76.4**	**12.0**	**5.0**	**1.2**	**0.6**	**2.0**	**1.2**
	SE	**5.7**	**4.3**	**6.0**	**3.9**	**2.3**	**0.7**	**0.3**	**0.1**	**0.9**	**0.2**

*Non-forest natural is subdivided into shrub and water categories for descriptive purposes only.

Table 4-4. Results from compositional analysis (p values in parenthesis; + denotes row > column and – column > row) for comparing four habitat categories for four wolf packs in west-central Alberta during late winters of 2000 and 2001.

		1	2	3	4
		Cutblock	Forest	Non-for_natural	Non-for_anthropogenic
1	Cutblock		+(0.947)	-(0.027) *	+(0.902)
2	Forest	-		-(0.005) *	+(0.903)
3	Non-for_natural	+	+		+(0.177)
4	Non-for_anthro.	-	-	-	

* denotes significance at ($p<0.05$).

4.3.2 Wolf Response to Forest Cutblock Edges

The available areas for all distance buffers less than 1000 m were similar, with variation due mostly to dissolving buffers for adjacent cutblocks (Table 4-5). Wolf use of distance buffers did not deviate significantly from random ($p = 0.503$). When buffer distances were compared using compositional analysis, no significant difference was found between distance categories related to forest cutblock edges (Table 4-6). When ranked, the 501-1000 m buffer distance was the most preferred, followed by the 0-100m buffer, with the least preferred being the buffer of >1000 m (Table 4-6).

4.3.3 Power Analysis

The result for *a priori* chi-squared power analysis found that to detect significant wolf habitat preference using a medium effect size (0.5) (Cohen 1988), a sample of 24 wolf packs would be required. *Post hoc* power analysis using the sample of seven wolves (over two winters) and a medium effect size (0.5) for four habitat types, resulted in 0.17 for the chi-squared test, and 0.27 for the t-tests; and for five buffers was 0.20 for the chi-squared tests and 0.29 for the t-tests.

Table 4-5. The total percentage of use (number of GPS locations) and availability (area in km^2) of five buffer categories for four wolf packs in west-central Alberta during late winters of 2000 and 2001.

Buffer	**0 – 100 m**		**101 - 250m**		**251 - 500m**		**501 – 1000m**		**>1000m**	
Total	**Used_1**	*Avail_1*	**Used_2**	**Avail_2**	**Used_3**	**Avail_3**	**Used_4**	**Avail_4**	**Used_5**	**Avail_5**
Mean	16.82	14.47	11.54	13.18	10.96	10.71	16.42	12.72	41.83	48.91
SE	4.69	3.47	2.22	2.71	2.48	1.66	2.99	1.83	12.46	8.76

Table 4-6. Results from compositional analysis (p values in parenthesis; + denotes row > column and – column > row) comparing five buffer distances originating from forest cutblock edges, for four wolf packs in west-central Alberta in late winters of 2000 and 2001.

		1	**2**	**3**	**4**	**5**
		0-100 m	101-250m	251-500m	501-1000m	>1000m
1	0 - 100m		+(0.896)	+(0.975)	-(0.837)	+(0.219)
2	0 - 250m	-		-(0.920)	-(0.737)	+(0.262)
3	0 - 500m	-	+		-(0.813)	+(0.229)
4	0 - 1000m	+	+	+		+(0.163)
5	>1000m	-	-	-	-	

4.4 Discussion

Wolves have been described as habitat generalists (Mech 1970, Mladenoff et al. 1995). On a coarse spatial scale, wolves inhabit large tracts of forest (Mech 1995) and may prefer mixed wood forests over either homogenous coniferous or deciduous forests (Mladenoff et al. 1995, Krizan 1997). Wolves may use forests altered by logging, as these can provide ideal deer habitat, and therefore afford a prey base for the wolves (Mladenoff and Sickley 1998). In this study, GPS radiocollar technology allowed for a more refined examination of wolf habitat preferences and found that wolves do not use the landscape randomly. In general, wolves preferred habitats with young vegetation, in both non-forest natural habitats and forest cutblocks. This is consistent with increased ungulate abundance in areas of young vegetation (Peek et al. 1976, Stelfox et al. 2001), which attract wolves (Bergerud 1988). However, increased road access into these areas may allow humans to impact wolf population growth, from direct or indirect killing (Mech 1995, Mladenoff and Sickley 1998). In this study, the least least preferred habitat of wolves was non-forest anthropogenic (pipelines, right-of- ways), possibly to avoid human contact. Two radiocollared wolves were shot during this study (Chapter 2).

My first prediction that wolves select forest cutblocks was supported in part, as wolves used cutblocks proportionately more than forest or anthropogenic features. However, no significant difference was detected between these categories, and cutblocks ranked second in preference to non-forest natural habitats. Wolves in Ontario were also found to use cutblocks in proportion to their occurrence (Krizan 1997). I had the advantage of GPS radiocollars, compared to the traditional VHF collars used by Krizan (1997), which allowed for a large collection of location data, although my analyses still had low power, due to the sample of wolves collared.

The amount of logged forest differed substantially between wolf packs and may have accounted for variation in wolf use of cutblocks. The Lynx Creek pack had only 5% of its territory as forest cutblocks, which was the least amount among packs. In contrast, the Cutbank pack had the greatest amount of area in forest cutblocks, at 36%. This seven-fold difference in the amount of harvested forest between packs may have influenced habitat preferences. The Lynx Creek pack may not yet be accustomed to regularly using the logged portion of their territory, whereas the Cutbank pack may center more of its hunting activities near cutblocks. Kohira and Rexstad (1997) found no evidence that wolf diets differed between logged and unlogged areas in the coastal rainforests of Alaska. About 6% of that total study area was logged, with the amount of area logged ranging from 1-26% between wolf pack territories. This differs from my study area, where about 17%, or approximately three times as much, area has been logged. Similarily, in southeast British Columbia, researchers did not find evidence that forest harvesting increased the vulnerability of moose to predation by wolves, where at the outset of a long-term study (~10 years) about 13% of the area was logged (Kunkel and Pletscher 2000).

Wolves in this study showed a significant preference for non-forested natural habitats (shrubs/water) over cutblocks and forest. There could be a number of reasons for this selection. Wolves prefer to rest in open areas, and may travel several kilometers to reach such preferred sites (Mech 1970). These areas allow wolves to gain warmth from the sun and provide space to survey their surroundings. After feeding, it is advantageous for a wolf to lay on its side to aid digestion (Mech 1970). The shrubs in these habitats have open crowns, which allow penetration of sunlight and still provide structure for protection from the wind. Wolves in this study area were observed on numerous occasions resting in open meadows, muskegs, hillsides and beaver ponds, often when they were near killsites (Chapter 2, Appendix 1-3).

The shrubs in this non-forest habitat type may also provide forage and cover for ungulates. During this study, wolves made deer kills in shrubby willow areas, and moose, deer and elk kills in or near riparian areas (Chapters 2,3). Elk are primarily grazers, and may be attracted to these shrub patches due to the increased availability of grasses. Bjorge and Gunson (1989), in a nearby wolf study, noted that elk, especially elk calves, can be a preferred prey for wolves in winter. During the limited kill rate work in this study (Chapter 3), only one cow elk kill was documented. In Jasper National Park, wolves hunt deer while moving to pockets of elk (Carbyn 1974, Weaver 1994). It is possible that shrubby areas do represent reliable patches of prey, and the wolves may check them on a regular basis.

Water was also included in this most preferred habitat class. It is common for wolves to use frozen waterways as travel routes (Mech 1991), and in winter wolves may select water to travel on due to the increased abundance of ungulates in nearby riparian areas. Also, wolves frequently kill ungulates on iced surfaces (Mech 1991).

My second prediction of wolf preference for forest cutblock edges was not supported. There was no significant difference in wolf preference for any buffer distance categories, nor was the 0-100m buffer class ranked highest. Habitat was not controlled for in the buffer categories, which may have confounded the analysis. The behaviors of wolves, such as feeding at killsites, resting and hunting may also be diluting the effect of any preference or avoidance of cutblock edges. As wolves hunt a diversity of prey, and chase distance varies with each prey type (Paquet 1989), wolves may use cutblock edges for stalking and hunting prey, but would spend more time associated with a carcass, depending on the prey type and the location of the kill. For example, the average chase distance for a moose is 883 m (Paquet 1989). The initiation of the chase would be highly dependent on the initial location of the moose, however, the moose may choose to run to the nearest forest structure to avoid attacking wolves (Stephens and Peterson 1984).

4.4.1 Management Implications

These results present important implications for caribou conservation. Caribou are thought to spatially and temporally separate themselves from moose to reduce predation risk from wolves. Wolves in this study area were found to prefer non-forested natural habitats and cutblocks over forest. By creating forest cutblocks adjacent to preferred caribou habitats, the spatial separation between caribou and wolves may be altered, putting caribou at an increased predation risk from wolves. In the mountains of British Columbia, Seip (1992) found that caribou avoided valley bottoms occupied by moose, and caribou had higher mortality when moose and caribou were in closer proximity. In west-central Alberta, caribou avoided perennial streams (Oberg 2001), potentially to avoid predators, or to find terrestrial lichens on well drained ridges (Edmonds and Bloomfield 1984), variables which are not mutually exclusive. If forest harvesting does encroach on these ridges, the cutblocks may, in turn, attract wolves, putting caribou at increased predation risk.

Caribou are also thought to reduce spatial overlap from wolves by living in old forests at low densities (Bergerud 1988). Logging will decrease the amount and mean patch size of old forest, resulting in higher caribou densities, and thus increasing chances of detection by wolves (Bergerud 1988). The amount of logged forest averaged 17% for all wolf pack territories, and ranged from 6-36% forest between packs (Table 4-3). Caribou may be at increased risk of wolf predation within the Cutbank wolf pack territory (36% logged), but this is less likely in the Lynx Creek pack territory, where only 6% of their territory has been logged. The determining factor may not be the total amount of forest remaining, as cutblocks are regenerated to forest, but the amount of remaining forest that is preferred caribou habitat. In this study area, caribou preferred forests greater than 80 years old, especially those stands aged 120-160 years (Szkorupa 2002), and were found to avoid forest cutblocks by 1200m (Smith et al. 2000). Therefore, it is likely a combination of the amount of old forest retained on caribou ranges, and the spatial relation of old forest to other habitats, that affects predation risk to caribou. If the forest continues to be harvested at present rates, all wolf packs studied will have a substantial amount of logged area within their territories within a relatively short time. This would leave only residual patches of old forest remaining as caribou habitat, and thus it may be the rate of forest harvest that ultimately determines predation risk to caribou from wolves.

Forest harvesting can also attract moose, elk and deer to recently logged areas due to the high quality regenerating forage (Peek et al. 1976, Stelfox et al. 2001), and wolves may then be attracted to such areas in search of prey (Bergerud 1988). Wolves in this study did prefer cutblocks over forest, which re-inforces previous statements suggesting that the juxtaposition of cutblocks with preferred caribou habitats is an important consideration in assessing the predation risk to caribou from wolves. Alternatively, planning cutblocks to be spatially disjunct from preferred caribou habitats, or adjacent to non-forest natural habitats which are most preferred by wolves, may decrease predation risk to caribou.

The next step in research should be to examine fine-scale habitat use of wolves. As the non-forest habitats were the most preferred in this study, it is important to understand the behavior patterns of wolves in these habitats. This could be accomplished by programming GPS radiocollars to take frequent locations (e.g. 1 hour intervals) and combining this with activity data from the collars. It is also important to document the spatial context of these preferred, non-forest habitats on the landscape, and their relationship to preferred caribou habitats. Doing so would help in evaluating the influence of these habitats on wolf predation risk to caribou.

As moose, deer and elk are the primary prey of wolves in this study area, new information is required on how these ungulates use forest cutblocks, as this may ultimately determine how wolves use the landscape. As caribou may avoid cutblocks during both summer (Chubbs et al. 1993) and winter (Smith et al. 2000), there may be temporal and spatial changes associated with use of cutblocks by other ungulates that could not be incorporated here. Finally, I found no significant preference for wolf use of cutblock edges, however this analysis lacked power. This is important information and warrants further study: if wolves do have a preference for cutblock edges, due either to increased ungulate abundance, or for cover when stalking ungulates, then this would have a bearing on the recommended size and placement of cutblocks on caribou ranges.

4.5 Literature Cited

Aebischer, N.J., P.A. Robertson and R.E. Kenward. 1993. Compositional analysis of habitat use from animal radio-tracking data. Ecology (77): 215-227.

Ballard, W. B., L.A. Ayres, K.E. Roney and T.H. Spraker. 1991. Immobilization of gray wolves with a combination of tiletamine hydrochloride and zolazepam hydrocloride. Journal of Wildlife Management (55): 71-74.

Beckingham, J.D. and J. H. Archibald. 1996. Field Guide to the Ecosites of West-central Alberta. Canadian Forest Service, Nortwest Region, Northern Forestry Center, Edmonton, Alberta. 509 pp.

Bergerud, A.T. and J. Elliot. 1986. Dynamics of caribou and wolves in northern British Columbia. Canadian Journal of Zoology (64): 1515-1529.

Bergerud, A.T. 1988. Caribou, wolves and man. Trends in Ecology and Evolution (3): 68-72.

Bider, J.R. 1968. Animal activity in uncontrolled terrestrial communities as determined by sand transect technique. Ecological Monographs (38): 269-308.

Bjorge, R.R. and J.R. Gunson. 1989. Wolf, *Canis lupus*, population characteristics and prey relationships near the Simonette River, Alberta. Canadian Field-Naturalist (103): 327-334.

Carbyn, L.N. 1974. Wolf predation and behavioral interactions with elk and other ungulates in an area of high prey diversity. Canadian Wildlife Service Report, Edmonton, Alberta. 234 pp.

Cohen, J. 1988. Statistical power analysis for behavioral sciences. Earlbaum, Hillside, New Jersey

Chubbs, T.E., L.B. Keith, S.P. Mahoney and M.J. McGrath. 1993. Responses of woodland caribou (*Rangifer tarandus caribou*) to clear-cutting in east-central Newfoundland. Canadian Journal of Zoology (71): 487-493.

Dyer, S.J., J.P. O'Neil, S.M.Wasel and S. Boutin. 2001.Avoidance of industrial development by woodland caribou. Journal of Wildlife Management (65): 531-542.

Faul, F. and E. Erdfelder. 1992. GPOWER: A priori, post-hoc, and compromise power analysis for MS-DOS. Bonn University, Department of Psychology.

Edmonds, E.J. and M. Bloomfield. 1984. A study of woodland caribou (*Rangifer tarandus caribou*) in west central Alberta, 1979-1983. Unpublished report prepared for Alberta Fish and Wildlife Division, Edmonton. 203 pp.

Edmonds, E.J. 1988. Population status, distribution and movements of woodland caribou in west central Alberta. Canadian Journal of Zoology (66): 817-826.

Edmonds, E.J. 1998. Status of woodland caribou in Alberta. Rangifer Special Issue Number 8: 111-115.

Fuller, T.K. 1989. Population dynamics of wolves in north-central Minnesota. Wildlife Monographs 105: 41 pp.

Gates, J.E. and L.W. Gysel. 1978. Avian nest dispersion and fledgling success in field-forest ecotones. Ecology (59): 871-883.

Gese, E.M. and L.D. Mech 1991. Dispersal of wolves (*Canis lupus*) in northeastern Minnesota, 1969-1989. Canadian Journal of Zoology (69): 2946-2955.

Hervieux, D., J. Edmonds, R. Bonar and J. McCammon. 1996. Successful and unsuccessful attempts to resolve caribou management and timber harvesting issues in west central Alberta. Rangifer Special Issue Number 9: 185-192.

Hooge, P.N. and B. Eichenlaub. 1997. Animal movement extension to Arcview. Version 1.1. Alaska Biological Science Center, United States Geological Survey, Anchorage, Alaska.

Hurlburt, S.H. 1984. Pseudoreplication and the design of ecological field experiments. Ecological Monographs (54): 187-211.

James, A.R.C. 1999. Effects of industrial development on the predator-prey relationship between wolves and caribou in northeastern Alberta. Ph.D. Thesis, University of Alberta, Edmonton Alberta. 70 pp.

James, A.R.C. and A.K. Stuart-Smith. 2000. Distribution of caribou and wolves in relation to linear corridors. Journal of Wildlife Management (64): 154-159.

Jedrzejewska, B., H. Okarma, W. Jedrzejewski and L. Milkowski. 1994. Effects of exploitation and protection on forest structure, ungulate density and wolf predation in Bialowieza Primeval Forest, Poland. Journal of Applied Ecology (31): 664-676.

Johnson, D.H. 1980. The comparison of usage and availability measurements for evaluating resource preference. Ecology (61): 65-71.

Keith, L.B. 1983. Population dynamics of wolves. Pages 66-77 *in*. L.N. Carbyn, editor. Wolves in Canada and Alaska: their status, biology, and management. Canadian Wildlife Service Report Series, Number 45. 135 pp.

Kohira, M. and E.A. Rexstad. 1997. Diets of wolves, *Canis lupus*, in logged and unlogged forests of southeastern Alaska. Canadian Field-Naturalist (111): 429-435.

Krizan, P. 1997. The effects of human land development, landscape characteristics, and prey density on the spatial distribution of wolves (*Canis lupus*) on the north shore of Lake Superior. Masters Thesis, Acadia University, Wolfville, Nova Scotia. 109 pp.

Kunkel, K.E. and D.H. Pletscher. 2000. Habitat factors affecting the vulnerability of moose to predation by wolves in southeastern British Columbia. Canadian Journal of Zoology (78): 150-157.

Lotek Engineering Inc. 2000. Lotek GPS_2000 small animal GPS location system users manual. Newmarket, Ontario.

McLellan, B.N. and F.W. Hovey. 2001. Habitats selected by grizzly bears in a multiple use landscape. Journal of Wildlife Management (65): 92-99.

Mech, L.D. 1966. The Wolves of Isle Royale. Fauna of National Parks of the U.S. Govt. Printing Office, Faunal Series Number 7. 210 pp.

Mech, L.D. 1970. Wolf Ecology and Management of an Endangered Species. University of Minnesota Press. 384 pp.

Mech, L.D. 1991. The Way of the Wolf. Voyageur Press, Stillwater Minn., 120 pp.

Mech, L.D. 1994. Buffer zones of territories of gray wolves as regions of intraspecific strife. Journal of Mammalogy (75): 199-202.

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

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

Mladenoff, D.J. and T.A. Sickley. 1998. Assessing potential gray wolf restoration in the northeastern United States: a spatial prediction of favorable habitat and population levels. Journal of Wildlife Management (62): 1-10.

Oberg, P.R. 2001. Responses of mountain caribou to linear features in a west-central Alberta landscape. Masters Thesis, University of Alberta, Edmonton, Alberta. 126 pp.

Oehler, J.D. and J.A. Litvaitis. 1996. The role of spatial scale in understanding responses of medium-sized carnivores to forest fragmentation. Canadian Journal of Zoology (74): 2070–2079.

Packard, J. M. and L.D. Mech. 1980. Population regulation in wolves. Pages 135-150 *in* M. N. Cohen, R. S. Malpass, and H. G. Klein, editors. Biosocial Mechanisms of Population Regulation. Yale University Press, New Haven, Connecticut.

Paquet, P.C. 1989. Behavioral ecology of sympatric wolves (*Canis lupis*) and coyotes (*C. latrans*) in Riding Mountain National Park, Manitoba. Ph.D. Thesis, University of Alberta, Edmonton, Alberta. 227 pp.

Peek, J.M., D.L. Urich and R.J. Mackie. 1976. Moose habitat selection and relationships to forest management in northeastern Minnesota. Wildlife Monographs 48: 65 pp.

Peek, J.M. 1997. Habitat relationships. Pages 351-375 *in* A.W. Franzmann and C.C. Schwartz, editors. Ecology and management of North American moose. Smithsonian Institution Press, Washington, D.C.

Peterson, R.O. 1995. The Wolves of Isle Royale: A Broken Balance. Willow Creek Press, Wisconsin. 190 pp.

Seip, D. R. 1992. Factors limiting woodland caribou populations and their relationships with wolves and moose in southeastern British Columbia. Canadian Journal of Zoology (70): 1494-1503.

Stelfox, J.G. 1962. Effects on big game of harvesting coniferous forests in western Alberta. Forestry Chronicle (38): 94-107.

Stelfox, J.G., J.B. Stelfox, W.C. Bessie and C.R. Clark. 2001. Longterm (1956-1996) effects of clearcut logging and scarification on forest structure and biota in spruce, mixedwood, and pine communities of west-central Alberta. Unpublished report. 220 pp.

Stephens, P.W. and R.O. Peterson. 1984. Wolf-avoidance strategies of moose. Holarctic Ecology (7): 239-244.

Smith, K.G., E.J. Ficht, D. Hobson, T.C. Sorensen and D. Hervieux. 2000. Winter distribution of woodland caribou in relation to clear-cut logging in west-central Alberta. Canadian Journal of Zoology (78):1433-1440.

Szkorupa, T.D. 2002. Multi-scale habitat selection by mountain caribou in west-central Alberta. Masters Thesis, University of Alberta, Edmonton, Alberta, 92 pp.

Thompson, I.D. and R.W. Stewart. 1997. Management of moose habitats. Pages 377-401 *in* A.W. Franzmann and C.C. Schwartz, editors. Ecology and management of North American moose. Smithsonian Institution Press, Washington, D.C.

Thompson, I.D. and M.F. Vukelich. 1981. Use of logged habitats in winter by cow moose with calves in northeastern Ontario. Canadian Journal of Zoology (59): 2103–2114.

Timmerman, H.R. and M.E. Buss. 1997. Population and harvest management. Pages 559-616 *in* A.W. Franzmann and C.C. Schwartz, editors. Ecology and management of North American moose. Smithsonian Institution Press, Washington, D.C.

Tomm, H.O., J.A. Beck and R.J. Hudson. 1981. Responses of wild ungulates to logging practices in Alberta, Canada. Canadian Journal of Forest Research. (11): 606-614.

Weaver, J.L. 1994. Ecology of wolf predation amidst high ungulate diversity in Jasper National Park, Alberta. Ph.D. Thesis, University of Montana, Missoula. 165 pp.

Welsh, D.A., K.P. Morrison, K. Oswald and E.R. Thomas. 1980. Winter habitat utilization by moose in relation to forest harvesting. Proceedings North American Moose Workshop 16: 398-428.

White, T.H., J.L. Bowman, H.A. Jacobson, B.D. Leopold and W.P Smith. 2001. Forest management and female black bear denning. Journal of Wildlife Management (65): 34-40.

Wilcove, D.S. 1985. Nest predation in forest tracts and the decline of migratory songbirds. Ecology (66): 1211-1214.

Yahner, R.H. 1988. Changes in wildlife communities near edges. Conservation Biology (2): 333-339.

Chapter 5. General Conclusions

5.1 Thesis Conclusions

My research has provided original information on wolf physical characteristics, pack and territory sizes, and ungulate killrates in west-central Alberta. There was a mean of 8.2 wolves/pack and between 30-39 pack wolves on each of the RedRock/Prairie Creek and Little Smoky caribou ranges. Wolf density averaged 11 wolves/1000 km^2 across caribou ranges which is higher than the 9 wolves/1000 km^2 reported in other Alberta studies (Gunson 1992). The Prairie Creek wolf pack had the fewest members (5-6), and occupied the smallest territory (336 km^2), but exhibited the highest wolf density (16 wolves/1000 km^2). The neighboring Lynx Creek pack was the largest pack (12-18 members) with the largest territory (2128 km^2), but had the lowest wolf density (7 wolves/1000 km^2). The wolves I studied appeared to prey predominately on moose, with kill rates averaging one moose every three to five days. Deer are probably an important component of the wolf-prey system but this relationship is currently difficult to quantify.

The amount of time wolves spend travelling affects predation risk to caribou. Wolves travelled 4.2 times less when near ungulate killsites than then away from them. Wolves travelled significantly less near moose carcasses than they did compared to carcasses of other ungulate species. Therefore, wolf packs preying on deer may travel more than those packs preying on moose, and have increased chances of encountering caribou.

Wolves did not use the landscape randomly; as they demonstrated a significant preference for non-forested natural habitats (shrubs, water), over both cutblocks and forest. The least preferred habitats by wolves were non-forested anthropogenic habitats (pipelines, clearings). I found no evidence that wolves either preferred or avoided forest cutblock edges.

5.2 Management Implications

If wolves preying on moose travel less than those preying on deer and elk, an abundance of moose in the system may benefit caribou, as wolves will spend a substantial amount of time feeding and resting near moose carcasses, reducing the amount of time they spend hunting, and thus limiting their chances of encountering caribou. These findings are similar to Mech (1966), who found that wolves remained near moose carcasses for 21 out of 31 days of continuous monitoring.

However, there are opposing views to how moose abundance effect caribou. One states that increasing moose numbers will translate into a corresponding increase in wolf numbers, and thus result in more wolves to prey on caribou. Further, caribou will have reduced opportunities to separate spatially from the more abundant moose, and therefore be more susceptible to wolf predation (Bergerud and Elliot 1986, Seip 1992). The alternate view suggests that more moose in the system will benefit caribou, as moose provide biomass (Farnell et al. 1996, Mech et al. 1998) and wolves numbers are self regulated through social behaviors as dispersal and territoriality (Packard and Mech 1980). Hayes and Harestad (2000) found in the Yukon that mean wolf pack size remained similar, despite a two to three-fold increase in ungulate biomass.

Wolves in this study preferred forest cutblocks over both forest and anthropogenic features, although selection for this habitat type was not significant. How cutblocks are developed on caribou ranges may have important consequences for wolf predation risk to caribou. Decisions need to be made on the spatial relationship of cutblocks and other preferred wolf habitats, to those habitats preferred by caribou. Creating aggregated cutblocks away from caribou habitats that receive special management consideration, may attract other ungulates and thus wolves. This would also allow more access to resident hunters and trappers and increase the opportunities to legally harvest wolves.

Although wolf predation may be the proximate cause for caribou declines in west-central Alberta, the ultimate cause for a caribou decline may be the amount of remaining old forest. As the amount of old forest continues to decrease, caribou will be forced to live in residual patches, and may be at increased risk to wolf predation (Bergerud 1988). The amount of natural forest ranged from 60-86% between wolf pack territories in this study area. The threshold amount of forest needed for caribou to avoid population-limiting predation by wolves is presently unknown. I suggest that when considering current wolf (Chapter 2) and caribou numbers (Dzus 2001), this threshold level is probably below the mean value of 76% forest found during this study, the majority which is presently in older age classes.

Non-forested anthropogenic (pipelines, clearings) habitats were the least preferred by wolves in this study. This differs from wolf research in northeastern Alberta, where, at a fine scale using very frequent location data, James (1999) found that wolves preferred linear features such as seismic lines and roads. Future research should analyse wolf habitat use at multiple spatial and temporal scales.

I found wolf densities of 11 wolves/1000 km^2 on caribou ranges in west-central Alberta, which is well above the 6.5 wolves/1000km^2 expected to cause a caribou decline (Bergerud 1988). One management option would be to conduct a wolf control program to increase caribou numbers, but simply reducing wolves to benefit ungulate populations is controversial (Hummel and Pettigrew 1991). I do not recommend a wolf reduction to benefit caribou populations in west-central Alberta, based largely on new biological and social recommendations that have arisen from a recent large-scale wolf reduction program in the Yukon (Hayes et al. in press). Biologically, an acceptable experimental design for a lethal wolf reduction program to benefit ungulate populations suggests wolf numbers must be reduced to at least 20% of their former population level, over the entire study area (including wolf packs on the periphery), for a minimum of five years (Hayes et al. in press). A conservative estimate of wolf numbers from this study found the RedRock/Prairie Creek and Little Smoky caribou ranges to each have about 40 wolves (including non-pack wolves) (Chapter 2). Following the Yukon protocol, a wolf reduction experiment in this study area would entail removing about 60 wolves in the first year, and possibly an additional 20 ingressing wolves per year over the next 4 years: a grand total of 140 wolves.

Reduced wolf numbers could result in increased caribou recruitment, however it might not increase adult survival (Hayes et al. in press). Further, wolves could attain pre-reduction levels within five years (Hayes and Harestad 2000), leading once again to a potential caribou decline. Also, such a reduction has the potential to greatly increase moose numbers (Hayes et al. in press), which is contrary to what some suggest would benefit caribou (Bergerud 1988, Seip 1992), and would likely increase deer and elk numbers as well. Finally, there are the obvious social reasons not to conduct a wolf control – the majority of the public simply does not endorse lethally removing one species for the benefit of another.

5.3 Future Research

An Alberta government policy of 1991 (Information letter 91 – 17) states that caribou, and the supply and integrity of caribou habitat, must be maintained. This policy has often been quoted as the "primary reason" for conducting caribou related research in Alberta. Useful information on caribou has since arisen, and substantial funds have been raised for future research. However, I question if a government policy should be the primary director of future caribou research? I suggest research should have a strong biological rationale, and argue that if predation is the proximate reason for the decline of caribou, then this parameter (predation) should be given far more research priority.

Most published literature on caribou in Alberta states that predation, primarily by wolves, is the cause for caribou declines (Dzus 2001 for a review). Recent estimates suggest there are about 4000-6000 woodland caribou in Alberta (Dzus 2001), with a population structure with an adult sex ratio of 53% females, an 85% parturition rate, and 22% of the original calves surviving to March (Stuart-Smith et al. 1997). To conservatively estimate the impact of predation on caribou calves using the above data (4000 caribou), a simple calculation could assume a possible 2120 female caribou, producing 1802 calves, of which 901 calves (50%) are killed by predators in the first month (Adams et al. 1995), leaving 396 of the original calves remaining by March. Thus predation alone could account for about 1700 caribou calf deaths per year. This direct impact on caribou deserves much greater research attention.

Limited study has been conducted in Alberta to examine causes of neonatal caribou mortality, thus it is unknown if wolves are the primary cause of caribou calf mortality. Results from caribou calf mortality studies in Alaska have found that the cause of death to caribou calves <30 days old is normally 40 - 50% from wolves and 40-50% by bears (Adams et al. 1995). While wolves may be the primary cause for caribou declines in Alberta, further predator research must address the effects of other important predators of caribou calves, such as bears (*Ursus spp.*) (Ballard 1994), coyotes (*Canis latrans*) (Crete and Desrosiers 1995) and lynx (*Lynx canadensis*) (Mahoney et al. 1990). The importance of bear predation on caribou should not be overlooked, and I concur with other researchers in Saskatchewan who have also speculated that black bear predation may play a role in caribou calf survival (Riette and Messier 1998).

During this study, several wolves dispersed as individuals or in small groups (<3 wolves) from their natal territories (Chapter 2), which is consistent with other research (Gese and Mech 1992). These lone wolves, or small groups, may be an important factor when assessing predation risk to caribou. These wolves could represent 10-30% of the wolf population, and would be travelling great distances to establish new territories. If, at a large scale, wolf packs are generally avoiding caribou habitats due to a lack of moose (James 1999), then dispersing wolves may "*select*" these habitats to avoid being killed by pack wolves defending their territories, which is a primary cause of natural wolf mortality (Mech 1994). Conducting research on single or small groups of wolves would be logistically difficult due to a low sample size, difficult in tracking, and high natural mortality of wolves (Mech 1995), but resulting information could lead to important insights into caribou predation risk from wolves.

Researching wolf movements in summer was suggested by James (1999), and I also strongly encourage future research in this direction. The social dynamics of a wolf pack change throughout the year, whereby during winter they hunt as a pack, and in summer they split up and hunt singly or in small groups (Mech 1999). This could have consequences for wolf encounter rates with caribou, especially for caribou calves which are most susceptible to predation in summer.

In summation, only long-term research (> 5 years) will provide meaningful information on wolves (Mech 1995) for caribou managers. This is only the second wolf study to be conducted on caribou ranges in Alberta, and it ran for only two winter field seasons. I also suggest that resource managers consider wolves and their relation to caribou, in the context of the entire system. Single species research, can provide useful information, but it has the potential to be misleading. In west-central Alberta, wolves are intent on hunting moose in certain areas and deer and elk in others; caribou occur as available prey, but in such low numbers that they could not possibly support the present wolf densities (Chapter 2). I hope that future research on wolves and caribou in Alberta is conducted in the context of the system in which they live: a dynamic multi-predator/multi-prey system.

5.4 Literature Cited

Adams, L.G., F.J. Singer and B.W. Dale. 1995. Caribou and calf mortality in Denali National Park, Alaska. Journal of Wildlife Management (59): 584-594.

Ballard, W. 1994. Effects of black bear predation on caribou – A review. Alces 30: 25-35.

Bergerud, A.T. and J. Elliot. 1986. Dynamics of caribou and wolves in northern British Columbia. Canadian Journal of Zoology (64): 1515-1529.

Bergerud, A.T. 1988. Caribou, wolves and man. Trends in Ecology and Evolution (3): 68-72.

Crete, M. and A. Desrosiers. 1995. Range expansion of coyotes, *Canis latrans*, threatens a remnant herd of caribou, Rangifer tarandus, in southeastern Quebec. Canadian Field-Naturalist (109): 227-235

Dzus, E. 2001. Status of woodland caribou (*Rangifer tarandus caribou*) in Alberta. Environment, Fisheries and Wildlife Management Division, and Alberta Conservation Association, Wildlife Status Report Number 30, Edmonton, Alberta. 47 pp.

Farnell, R., N. Barichello, K. Egli and G. Kuzyk. 1996. Population ecology of two woodland caribou herds in southern Yukon. Rangifer Special Issue Number 9: 63-72.

Gese, E.M. and L.D. Mech 1991. Dispersal of wolves (*Canis lupus*) in northeastern Minnesota, 1969-1989. Canadian Journal of Zoology (69): 2946-2955.

Gunson, J.R. 1992. Historical and present management of wolves in Alberta. Wildlife Society Bulletin (20): 330-339.

Hayes, R.D., and A.S. Harestad. 2000. Demography of a recovering wolf population in the Yukon. Canadian Journal of Zoology (78): 36-48.

Hayes, R.D., R.S. Farnell, R.M.P. Ward, J. Carey, M.M. Dehn, G.W. Kuzyk, A.M. Baer, C.L. Gardner and M. O'Donoghue. Experimental reduction of wolves in the Yukon: ungulate responses and management implications. Wildlife Monograph: *in press*

Hummel, M and S. Pettigrew. 1991. Wild hunters: predators in peril. Key Porter Books, Toronto, 244 pp.

James, A.R.C. 1999. Effects of industrial development on the predator-prey relationship between wolves and caribou in northeastern Alberta. Ph.D. Thesis, University of Alberta, Edmonton Alberta. 70 pp.

James, A.R.C. and A.K. Stuart-Smith. 2000. Distribution of caribou and wolves in relation to linear corridors. Journal of Wildlife Management (64): 154-159.

Mahoney, S.P., H. Abbott, L.H. Russell and B.R. Porter. 1990. Woodland caribou calf mortality in insular Newfoundland. 19th International Union of game Biologist Congress, Trondheim, Norway.

Mech, L.D. 1966. The Wolves of Isle Royale. Fauna of National Parks of the U.S., Fauna Series, Number 7, U.S. Government Print Office, Washington, D.C. 210 pp.

Mech, L.D. 1994. Buffer zones of territories of gray wolves as regions of intraspecific strife. Journal of Mammalogy (75): 199-202.

Mech, L.D. 1995. What do we know about wolves and what more do we need to learn? Pages 537-545 *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.

Mech, L.D. 1999. Alpha status, dominance, and division of labor in wolf packs. Canadian Journal of Zoology (77): 1196-1203.

Mech, L.D., L.G. Adams, T.J. Meier, J.W. Burch and B.W. Dale. 1998. The Wolves of Denali. University of Minnesota Press. 225 pp.

Packard, J. M. and L. D. Mech. 1980. Population regulation in wolves. Pages 135-150 *in* M. N. Cohen, R. S. Malpass, and H. G. Klein, editors. Biosocial Mechanisms of Population Regulation. Yale University Press, New Haven, Connecticut.

Rettie, W. J. and F. Messier. 1998. Dynamics of woodland caribou populations at the southern limit of their range in Saskatchewan. Canadian Journal of Zoology (76): 251-259.

Seip, D. R. 1992. Factors limiting woodland caribou populations and their relationships with wolves and moose in southeastern British Columbia. Canadian Journal of Zoology (70): 1494-1503.

Smith, K.G., E.J. Ficht, D. Hobson, T.C. Sorensen and D. Hervieux. 2000. Winter distribution of woodland caribou in relation to clear-cut logging in west-central Alberta. Canadian Journal of Zoology (78): 1433-1440.

Stuart-Smith, A.K., C.J. Bradshaw, S. Boutin, D.M. Hebert and A.B. Rippin. 1997. Woodland caribou in relation to landscape patterns in northeastern Alberta. Journal of Wildlife Management (61): 622-633.

Szkorupa, T.D. 2002. Multi-scale habitat selection by mountain caribou in west-central Alberta. Masters Thesis, University of Alberta, Edmonton, Alberta, 92 pp.

Appendix 1.

Kuzyk, G.W. 2002. Female and calf moose remain stationary and non-aggressive when approached by wolves in west-central Alberta. Alberta Naturalist (31) 4: 53-54.

Moose (*Alces alces*) calves are preferred prey of wolves (*Canis lupus*) where the two species occur sympatrically (Peterson 1995, Mech et al. 1998, Hayes and Harestad 2000, Kuzyk 2001 *a*). Female moose can successfully protect their calves by remaining behind them when approached by wolves, as wolves usually attack the rump area of the moose first (Mech 1966). Most reported wolf encounters with female moose and their calves suggest that moose will either run, move slowly away, or stand their ground and physically defend themselves against wolves. Moose can improve their protection from wolves by moving from open areas to forests, where the mobility of wolves is hindered by trees and windfalls (Mech 1966, Peterson 1995, Stephenson and Van Ballenberghe 1995). Some moose are wounded by wolves and are preyed upon later (Mech 1966) or escape predation by wolves despite being attacked (Nelson and Mech 1993). I report an observation of a female and calf moose which remained stationary and non-aggressive when approached by wolves in an open forest cutblock and were not attacked.

This observation occurred approximately 65 kilometers east of Grande Cache, Alberta at 54° 17' N 118° 10' W where wolves were being monitored as part of a larger predator-prey study (Edmonds 1988, Smith et al. 2000, Kuzyk 2001 *b*, Kuzyk et al. 2001). At 1759 hrs on 4 March 2000, 11 wolves of the Simonette pack were observed from a Maule 7 airplane moving north along the edge of an open forest cutblock in about 40 centimeters of snow. In the same cutblock, approximately one kilometer away, a female moose was standing directly behind her calf about 100 meters from the cutblock edge, and facing toward the forest.

Three of the wolves led the others by 200 meters, as they ran in the direction of the two moose. These three wolves ran to within 5 to10 meters of the moose where two of the wolves stopped briefly and one female wolf urinated. The wolf which was running slightly ahead of the other two did not stop near the moose, but continued running directly in front of the cow and calf moose then turned sharply running past the moose further into the open cutblock without noticeably slowing its pace. The other two wolves soon followed the snow trail of the lead wolf, and were last seen running about 35 meters behind the lead wolf. During this encounter, the two moose remained stationary and did not act aggressively toward the three wolves.

It was undetermined how the rest of the wolf pack responded to the moose, as efforts were concentrated on following the behavior of the three lead wolves. It was also possible that the aircraft may have been disturbing the wolves, as the three wolves in the lead were still running once they were past the moose. However, the fact that these wolves had elected to run further into the open cutblock and not the more immediate forest, which they would normally do if disturbed by aircraft (Mech et al. 1998), suggests that the aircraft was not the sole reason for the wolves' behavior. It was assumed two of the three wolves in the lead were the breeding pair, due to their position well in front of other pack members and their decisiveness when encountering the moose. The eight wolves following them were likely their offspring, and may have just followed their parents past the moose, as the breeding pair lead most hunting attacks (Mech et al. 1998).

On the following morning of 5 March at 0828 hrs the Simonette wolf pack was located approximately 12 kilometers away from the cow and calf moose encountered the previous day. These wolves were observed moving single file down a cutline for about $1^{1/2}$ kilometers where they encountered a creek and began moving upstream. This presented an opportunity to fly the aircraft at a low level over the wolves to test their response to the aircraft and determine if a pack member with a malfunctioning radiocollar could be identified with this group. When some of the wolves were in a tight group on the creek, the plane was flown about 75 to 100 meters over the wolves on two passes. There was little reaction from the wolves to the airplane, with most wolves either looking at or ignoring the plane, and no wolves running into the forest for cover. This was the seventh flight in four days of radio tracking this wolf pack. Two members of this pack had been captured and radiocollared 38 and 33 days previously at which time the normal response to an approaching aircraft had been to immediately seek forested cover.

This observation indicates that a female moose and her calf can remain stationary and non-aggressive in an area with no forest structure for protection and not be attacked when closely encountered by wolves. The response may vary with individual wolves as moose can kill and injure wolves (Weaver et al. 1992) so it is advantageous for wolves to select the most vulnerable prey (Mech et al. 1998). Moose normally remain in a small area during winter, and wolves may revisit the same moose on several occasions during a winter until circumstances allow them to prey upon the moose (Peterson 1995, Mech et al. 1998). It is therefore possible that the Simonette wolf pack had previously encountered this same female and calf moose and found them to be invulnerable as prey, and the breeding pair consequently paid them little attention. It is also possible that the aircraft had disturbed the wolves' normal hunting behavior; however, when observed from the aircraft, the wolves were running directly towards the moose, suggesting they were still intent on hunting. As well, on the following day - the seventh consecutive flight in four days - the wolves appeared to be habituated to the aircraft concurring with Mech et al. (1998), that wolves can become accustomed to aircraft after a few overflights.

Literature Cited

Edmonds, E.J. 1988. Population status, distribution and movements of woodland caribou in west central Alberta. Canadian Journal of Zoology 66:817-826.

Hayes R.D., and A.S. Harestad. 2000. Wolf functional response and regulation of moose in the Yukon. Canadian Journal of Zoology 78: (1) 60-66.

Kuzyk, G.W. 2001 *a*. Wolf research in west-central Alberta. Progress report for the research subcommittee of the West-Central Alberta Caribou Standing Committee, University of Alberta, Edmonton, Alberta. 21 pages.

Kuzyk, G.W. 2001 *b*. Observation of a large wolf pack on a fragmented landscape in west-central Alberta. Alberta Naturalist 31(2): 26-27.

Kuzyk, G.W., C. Rohner and J. Kneteman. 2001. Grizzly bear defends moose carcass from wolves in west-central Alberta. Alberta Naturalist 30(4): 75-76.

Mech, L.D. 1966. The Wolves of Isle Royale. Fauna of National Parks of the U.S. Government Printing Office: Faunal Series Number 7. 210 pages.

Mech, L.D., L.G. Adams, T.J. Meier, J.W. Burch and B.W. Dale. 1998. The Wolves of Denali. University of Minnesota Press. 225 pages.

Nelson, M.E. and L.D. Mech. 1993. Prey escaping wolves, *Canis lupus*, despite close proximity. Canadian Field-Naturalist 107: (2) 245-246.

Peterson, R.O. 1995. The Wolves of Isle Royale: A Broken Balance. Willow Creek Press, Wisconsin. 190 pages.

Smith, K.G., E.J. Ficht, D. Hobson, T.C. Sorensen and D. Hervieux. 2000. Winter distribution of woodland caribou in relation to clear-cut logging in west-central Alberta. Canadian Journal of Zoology 78:1433-1440.

Stephenson, T.R. and V. Vanballenberghe. 1995. Defense of one twin calf against wolves, *Canis lupus*, by a female moose, *Alces alces*. Canadian Field-Naturalist. 109: (2) 251-253.

Weaver, J.L., C. Arvidson and P Wood. 1992. Two wolves *Canis lupus* killed by a moose *Alces alces* in Jasper National Park, Alberta. Canadian Field-Naturalist 106:126-127.

Appendix 2.

Kuzyk, G.W. 2001. Observation of a large wolf pack on a fragmented landscape in west-central Alberta. Alberta Naturalist (31) 2: 26-27.

Wolf (*Canis lupus*) pack size can vary with prey size (Schmidt and Mech 1997) and human caused mortality (Mech 1995). Wolf pack size is generally less than 7 where white-tailed deer (*Odocoileus virginianus*) are the main prey of wolves with larger packs found where wolves prey predominately on moose (*Alces alces*) (Mech 1991). Wolf packs with over 20 members are usually reported in remote northern areas where there is little wolf harvest (Hayes and Harestad 2000) or in protected areas (Carbyn et al. 1993, Peterson 1995, Mech et al. 1998). The largest recorded wolf pack in Alberta found in the scientific literature, is a pack of 26 wolves in Wood Buffalo National Park (Carbyn et al. 1993 page 150). A review of 5 Alberta wolf studies conducted from 1975-1985 documented a mean wolf pack size of 8.7 wolves/pack (Gunson 1992). There are limited accounts of wolf pack sizes on landscapes currently undergoing increased industrial development (James 1999), as development can increase human access to remote areas and expose wolves to greater human caused mortality from shooting, trapping and road collisions (Mech 1995). The observation reported herein, occurred in west-central Alberta where the landscape is currently undergoing substantial alterations from the resource extraction industries (forestry, oil and gas), and where radiocollared wolves have been effected by human harvest (Kuzyk unpublished data).

On February 11, 2001 at 10:44 am a wolf pack containing a minimum of 18 members, was observed approximately 65 kilometers southwest of Grande Prairie, Alberta at 54° 39' 119° 77'. This wolf pack, known as the Lynx Creek pack, was located by tracking radiocollared wolves from a fixed-wing airplane as part of an ongoing predator-prey study. On the first overflight, 15 members of this pack were seen walking on and near a road in a recently logged cutblock, while additional wolves were observed emerging from the forest to join the rest of the pack. Once all or most of the pack members were in the open cutblock a conservative count of 18 wolves was recorded. The wolves remained in the cutblock for about 5-7 minutes during which time several overflights of the pack were made. Many photographs were taken, but only 14 of the 18 wolves were ever close enough together at one time to be recorded in a single picture. The wolves eventually moved into the forest on the eastern edge of the cutblock. Color phases of the wolves noted during this observation, and later from the pictures, suggest there were 12 black and 6 gray wolves in this pack.

The most probable explanation for this large pack size is that 2 female wolves from this pack produced pups the previous spring, a behavior which has been reported in several other wolf studies (Mech et al. 1998 for review). It is unlikely this was 2 wolf packs amalgamated for the breeding season, as the previous winter there were 13 wolves in this pack, with at least 10 being black, and they occupied the same territory centering on the Lynx Creek/Kakwa River confluence. Also on March 16, 2001, thirty-three days after the initial observation, this pack was again relocated and observed by aircraft a minimum count of 16 wolves recorded. By May 2-3, 2001 this large pack had fragmented, probably due to social stresses near spring denning season (Mech et al. 1998), when 5 pack members (2 males having radiocollars) were found approximately 20 miles outside their territory boundary. It is conceivable that this wolf pack contained more than 18 members in the months preceding the initial observation, as wolf pack size is considered to attain its largest size in December, when winter mortality is at its minimum, and there is little dispersal by pack members (Mech 1986).

Following radiocollared wolves from an aircraft availed the opportunity to locate, follow and count wolves. Nearby studies with radiocollared wolves report largest pack sizes to be 12 wolves in the Simonette River area, near Valleyview, Alberta (Bjorge and Gunson 1989) and 10 wolves in northeast Jasper National Park (Weaver 1994). In west-central Alberta, incidental observations recorded from aircraft of wolf packs with over 20 members are rare (Dave Hervieux, Alberta Natural Resources Service, Grande Prairie, personal communication). Observations of wolf packs recorded from the ground provide valuable information, but it is often difficult to accurately count wolves in these situations where the wolves are usually moving and only single, brief observations are possible.

It is important to document wolf pack size as it can provide an indication of ungulate abundance in the region and of human impacts on the landscape (Mech 1995, Hayes and Harestad 2000). Recent studies suggest that for long-term conservation of wolves in the Canadian Rocky Mountains, a landscape should hold 5 contiguous wolf pack home ranges to allow for adequate wolf dispersal and emigration (Weaver et al. 1996). This observation is therefore important for wolf conservation in Alberta, as it documents that a pack of 18 wolves can persist on a fragmented landscape adjacent to the Rocky Mountains.

Literature Cited

Bjorge, R.R. and J.R. Gunson. 1989. Wolf, *Canis lupus*, population characteristics and prey relationships near the Simonette River, Alberta. Canadian Field Naturalist (103): 327-334.

Carbyn, L.N., S. Oosenbrug, and D. Anions. 1993. Wolves, bison and their dynamics related to the Peace-Athabasca Delta in Canada's Wood Buffalo National Park. Circumpolar Res. Ser. No. 4., Canadian Circumpolar Institute, University of Alberta, Edmonton, 270 pp.

Gunson, J.R. 1992. Historical and present management of wolves in Alberta. Wildlife Society Bulletin (20):330-339.

Hayes R.D. and A.S. Harestad 2000. Demography of a recovering wolf population in the Yukon. Canadian Journal of Zoology 78: (1) 36-48.

James, A.R.C. 1999. Effects of industrial development on the predator-prey relationship between wolves and caribou in northeastern Alberta. Ph.D., University of Alberta, Edmonton Alberta. 70 pp.

Mech, L.D. 1986. Wolf population in the central Superior National Forest, 1967-1985. US Forest Research Paper NC-52.

Mech, L.D. 1991. The Way of the Wolf. Voyageur Press, Stillwater Minn., 120 pp.

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

Mech, L.D., L.G. Adams, T.J. Meier, J.W. Burch and B.W. Dale. 1998. The Wolves of Denali. University of Minnesota Press. 225 pages.

Peterson, R.O. 1995. The Wolves of Isle Royale: A Broken Balance. Willow Creek Press, Wisconsin. 190 pp.

Schmidt PA and LD Mech. 1997. Wolf pack size and food acquisition. American Naturalist 150 (4): 513-517

Weaver, J.L. 1994. Ecology of wolf predation amidst high ungulate diversity in Jasper National Park, Alberta. Ph. D. Dissertation. University of Montana.

Weaver, J.L., P.C. Paquet and L.F. Ruggiero. 1996. Resilience and conservation of large carnivores in the Rocky Mountains. Conservation Biology (10): 964-976.

Appendix 3.

Kuzyk, G.W., C. Rohner and J. Kneteman. 2001. Grizzly bear defends moose carcass from wolves in west-central Alberta. Alberta Naturalist (30) 4: 75-76.

Wolves (*Canis lupus*) prey on moose (*Alces alces*) throughout the year (Mech et al. 1998), while grizzly bears (*Ursus arctos*) prey primarily on moose calves <10 days old (Larsen et al. 1989), and occasionally adult moose (Bortje et al. 1988). Wolf predation rates on moose may increase when grizzlies usurp moose carcasses from wolves (Boertje et al. 1988) as grizzlies usually dominate moose carcasses over wolves (Murie 1944, Peterson et al. 1984). In Alaska, Mech et al. (1998) observed a grizzly bear killing a cow moose with a wolf pack nearby, where the wolves scavenged pieces of the hair and meat left from the bears' struggle, but vacated the area once the bear had killed the moose and began feeding. Also in Alaska, Peterson et al. (1984) reported 5 incidences in spring of wolves and grizzlies sighted in close proximity to the same moose carcasses, where the grizzlies were dominant over the carcass. These researchers also visited over 100 moose carcasses in late spring, some of which were wolf-killed, and noted many had grizzly bear sign present. Servheen and Knight (1993) concluded from a literature review and survey of scientists that there was little evidence of sympatric gray wolf and grizzly bear populations having significant demographic effects on each other. Reports of grizzly bear-wolf interactions in Alberta (Hornbeck and Horejsi 1986) are not well documented.

This observation occurred about 50 kilometers north of Grande Cache, Alberta where radiocollared wolves were being monitored as part of a predator-prey study. A flight was made using a B-206 helicopter with the objective of flying over wolves instrumented with GPS (Global Positioning System) radiocollars and remotely releasing collars. On

April 20, 2000 at approximately 1030hrs Wolf # 5, the breeding male of the Cutbank Wolf Pack (wearing a remotely releasable GPS collar) was located north of the Cutbank River near a frozen creek with surficial overflow at 54°19' 119°13'. A lone dark colored grizzly bear was noticed adjacent to the creek standing on or near a moose carcass. While pursuing the wolf, the helicopter flew within 100 meters of the bear, during which time the bear did not flee from the disturbance, but remained next to the carcass. The bear was also noticed chasing ravens away from the carcass. Within a few minutes, the pursuit of the wolf was abandoned due to technical difficulties with the radiocollar. Two other members of the Cutbank wolf pack were instrumented with standard VHF (very high frequency) radiocollars, and during the time near the grizzly bear, only adult male # 7 was heard, but not the breeding female #10.

Approximately four hours later we returned to the same location, and found the grizzly bear still on the moose carcass and wolf #5 being within 200 meters of the bear. The wolf was again pursued for a short time, and moved in an easterly direction away from the bear. A final flight was made within 75 meters of the bear to possibly identify the age and sex of the moose from the air. The moose carcass was on a frozen creek which is a common place for wolves to kill ungulates (Mech et al. 1998), but the cause of the moose mortality was not determined, and we did not want to further disturb the bear. During this time there was little response from the bear, as it would not leave the carcass and stared intently at the helicopter.

On both occasions when we approached the area with a helicopter the wolf was within 100 meters from the grizzly defending the moose carcass. Although wolves and bears occasionally kill each other (Carbyn 1975, Ballard 1980, 1982, Hayes and Baer 1992, Mech et al. 1998)(see also review by Servheen and Knight 1993), wolves usually defer to grizzlies when in competition for a moose carcass as was noted in this observation. It is noteworthy that the grizzly bear would not move from the moose carcass even in the close proximity of a helicopter, as it has been suggested that humans presence maybe the only time a grizzly bear may abandon a moose carcass, and that being dependent on the individual bear (Hornbeck and Horejsi 1986).

Literature Cited

Ballard, W.B. 1980. Brown Bear kills Gray Wolf. Canadian Field-Naturalist.94 (1) :91.

Ballard, W.B. 1982. Gray Wolf-Brown Bear relationships in the Nelchina basin of south-central Alaska. Pp. 71-80. *In* Wolves of the world: perspectives of behaviour, ecology and conservation. Edited by F.H. Harrington and P.C. Paquet. Noyes Publications, Park Ridge, New Jersey, 474 pp.

Boertje, R.D., W.C. Gasaway, D.V. Grangaard, and D.G. Kellyhouse. 1988. Predation on moose and caribou by radio-collared grizzly bears in east central Alaska. Canadian Journal of Zoology 66: 2492-2499.

Carbyn, L.N. 1975. Wolf predation and behavioral interactions with elk and other ungulates in an area of high prey diversity. Ph. D. Thesis, University of Toronto, 234 pages.

Hayes, R.D. and A. Baer.1992. Brown bear, *Ursus arctos*, preying upon gray wolf, *Canis-lupus*, pups at a wolf den. Canadian Field-Naturalist.106 (3): 381-382

Hornbeck, G.E. and B.L. Horejsi. 1986. Grizzly Bear *Ursus arctos*, usurps wolf *Canis lupus* kill. Canadian Field-Naturalist.100 (2): 259-260.

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

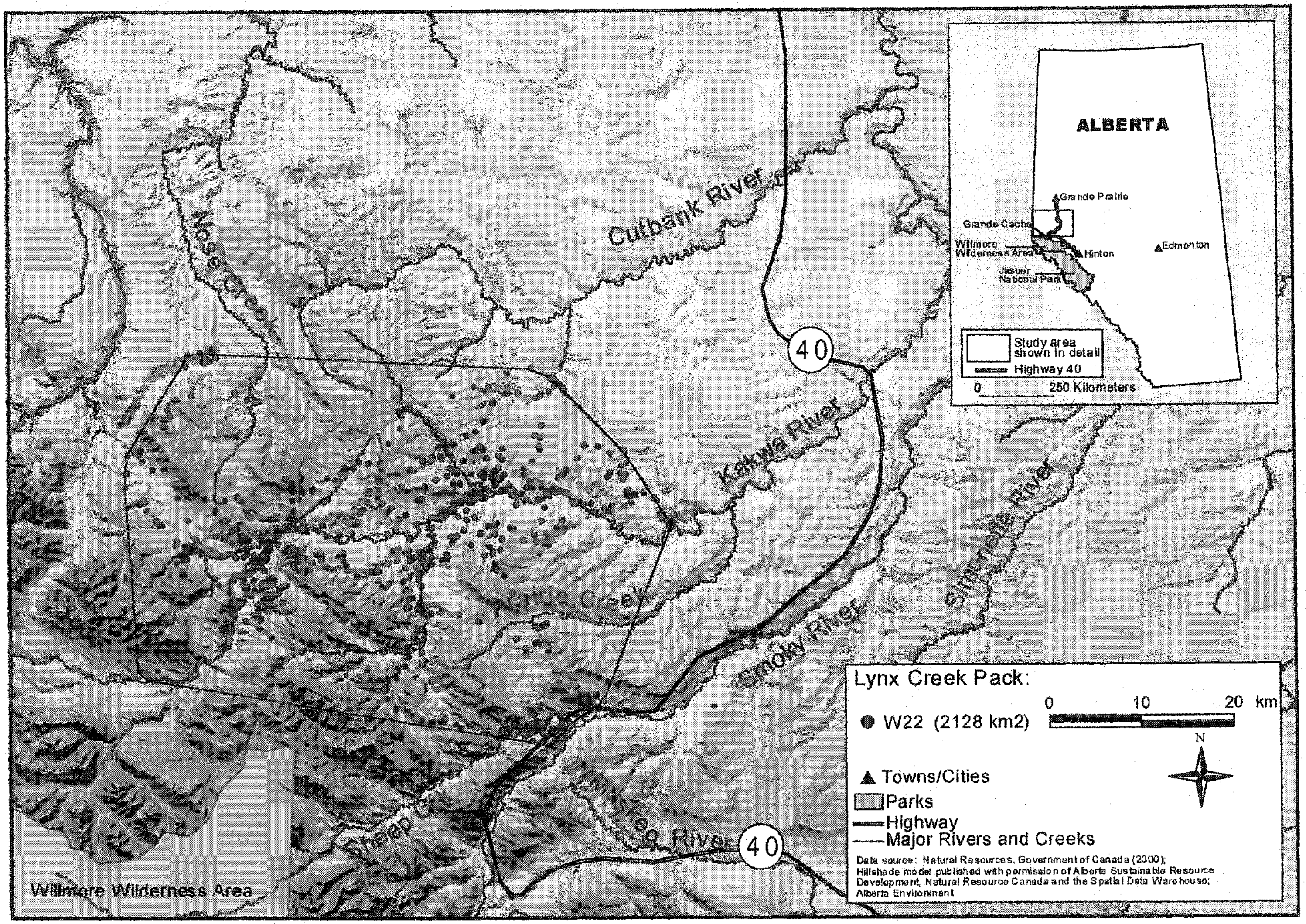
Mech, L.D., L.G. Adams, T.J. Meier, J.W. Burch and B.W. Dale. 1998. The Wolves of Denali. University of Minnesota Press. 225 pages.

Murie, A. 1944. The Wolves of Mount McKinley. U. S. National Park Service, Fauna Series 5. Washington, DC, USA.

Peterson, R.O., J. D. Woolington, and T. N. Bailey. 1984. Wolves of the Kenai Peninsula, Alaska. Wildlife Monographs 88.

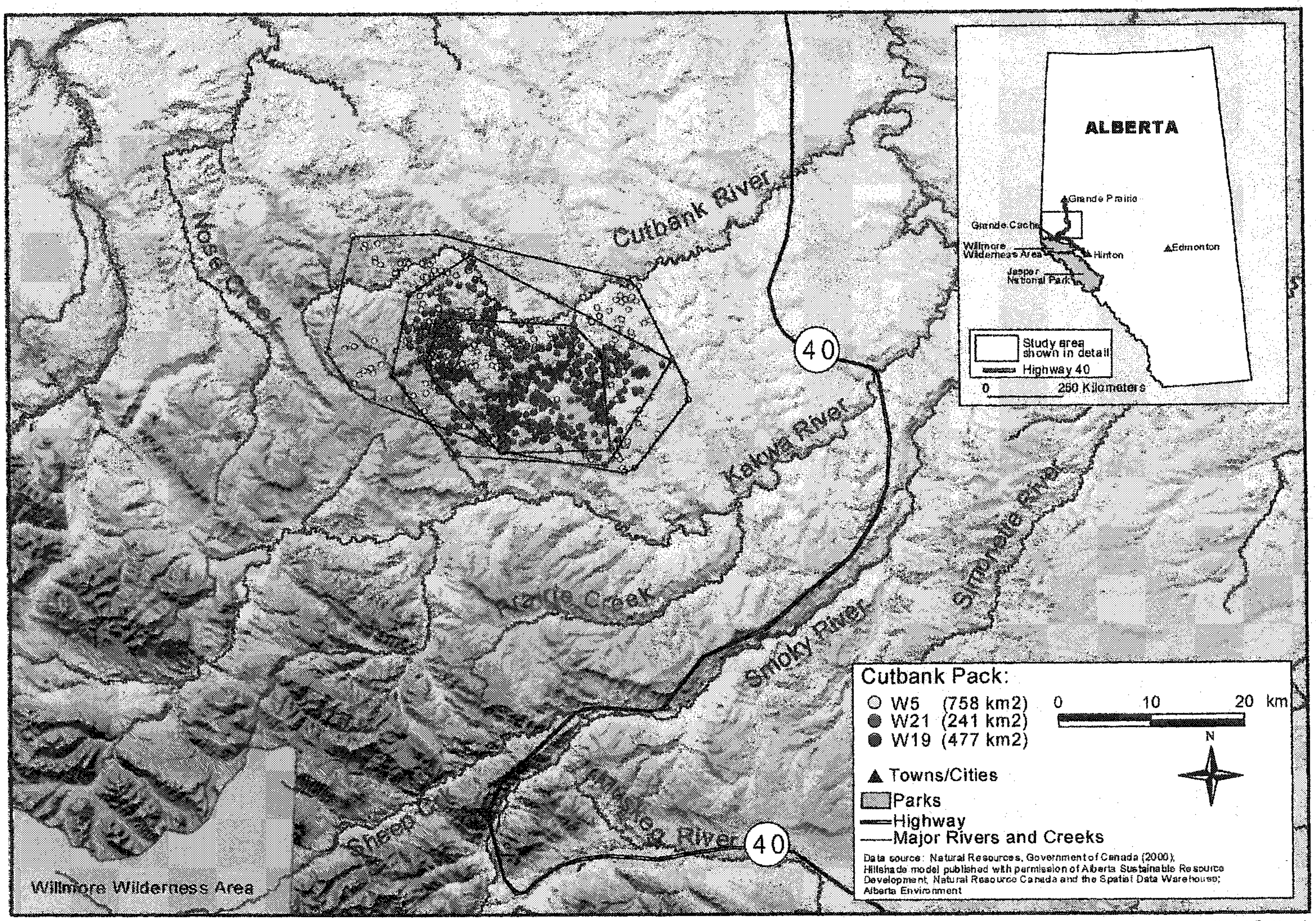
Servheen C. and R.R. Knight 1993. Possible Effects of a Restored Gray Wolf Population on Grizzly Bears in the Greater Yellowstone Area. In Ecological Issues on Reintroducing Wolves Into Yellowstone National Park. Editor Robert S. Cook. Scientific Monograph NPS/NRYELL/NRSM-93/22. United States Department of the Interior, National Park Service 1993.

Appendix 2-1. Territory of the Lynx Creek wolf pack in winter of 2001 in west-central Alberta.



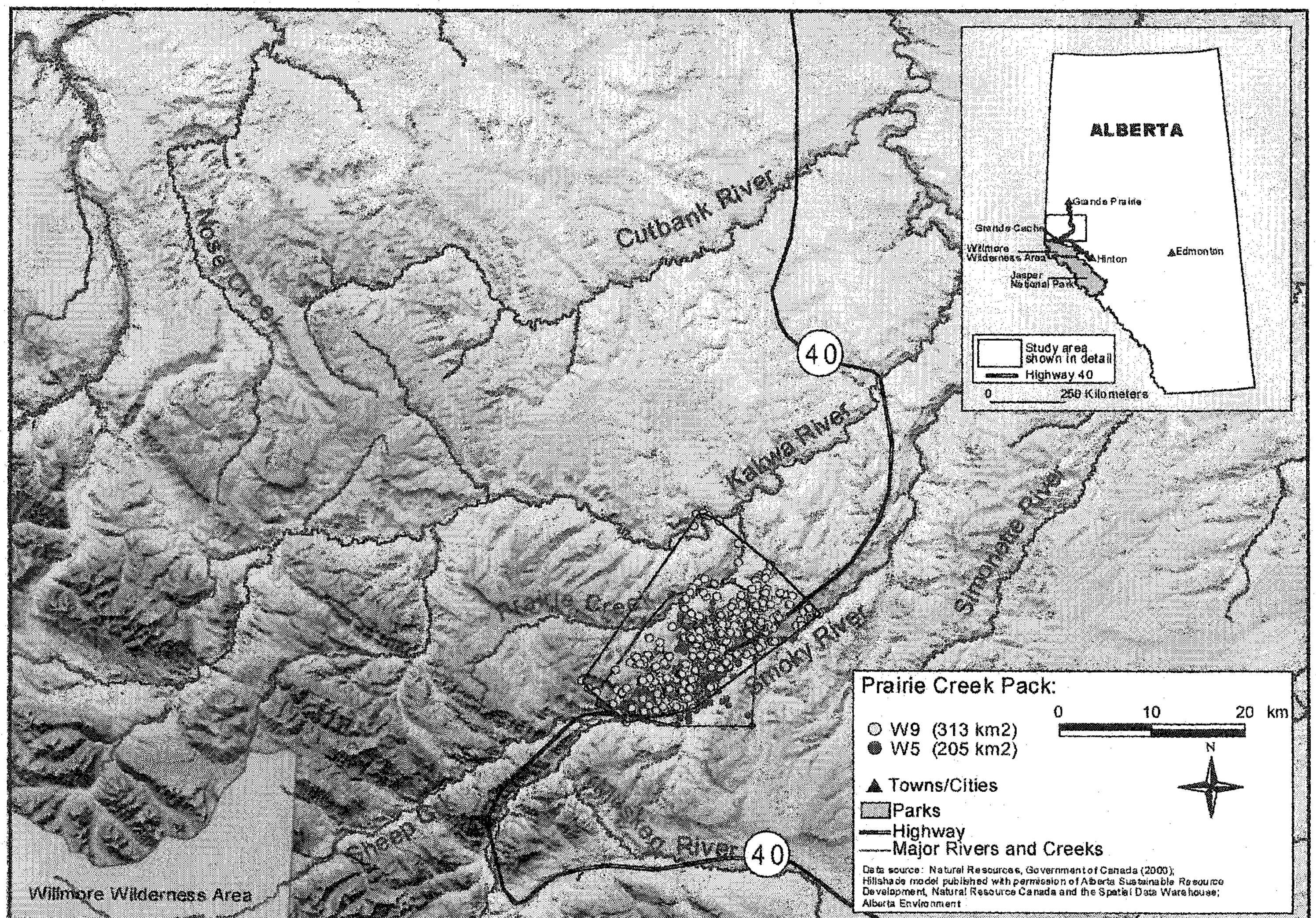
Map compiled by: S. Shirkoff and G. Kuzyk

Appendix 2-2. Territory of the Cutbank wolf pack during winters of 2000 and 2001 in west-central Alberta.



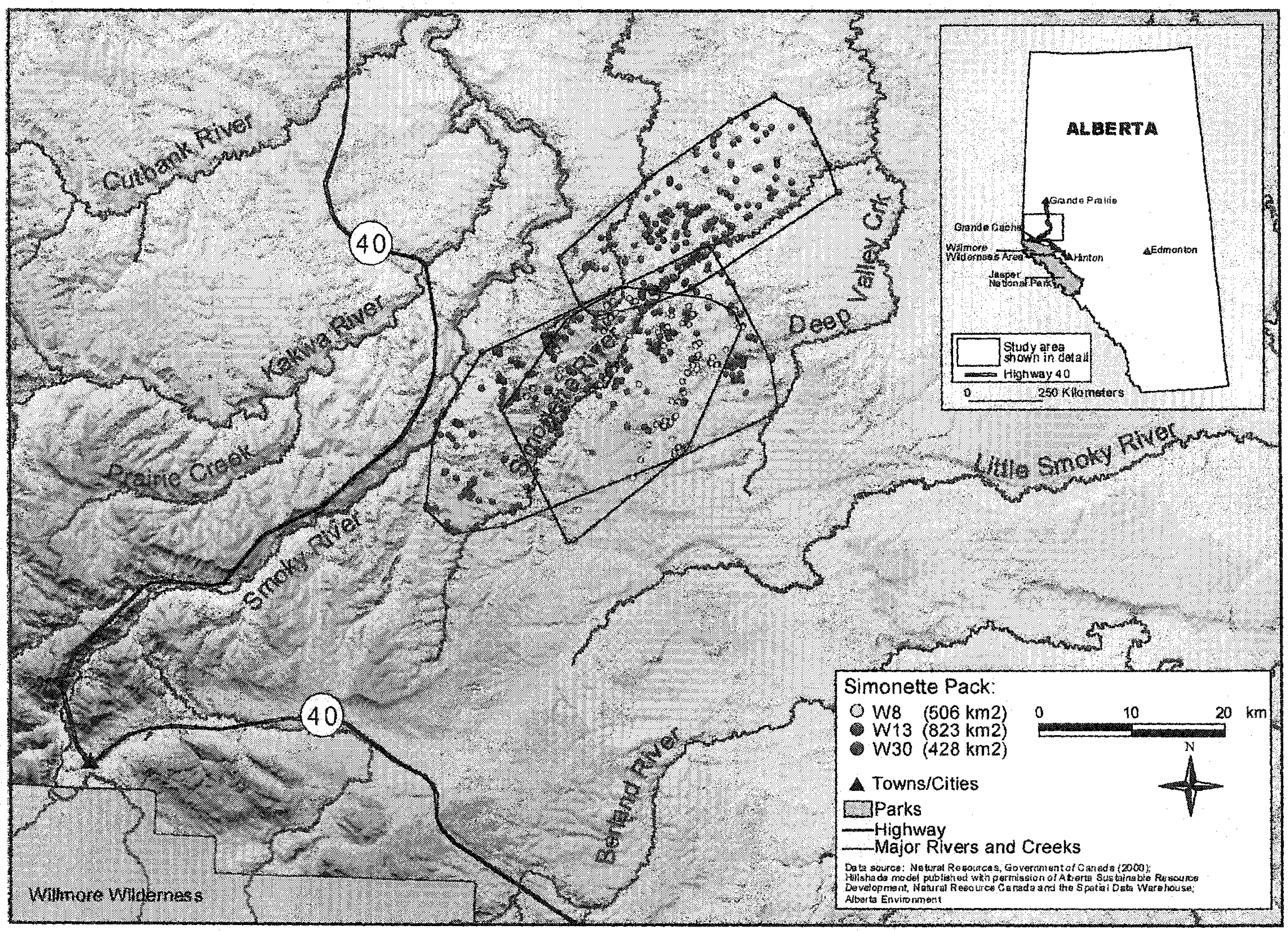
Map compiled by: S. Shirkoff and G. Kuzyk

Appendix 2-3. Territory of the Prairie Creek wolf pack during winters of 2000 and 2001 in west-central Alberta.



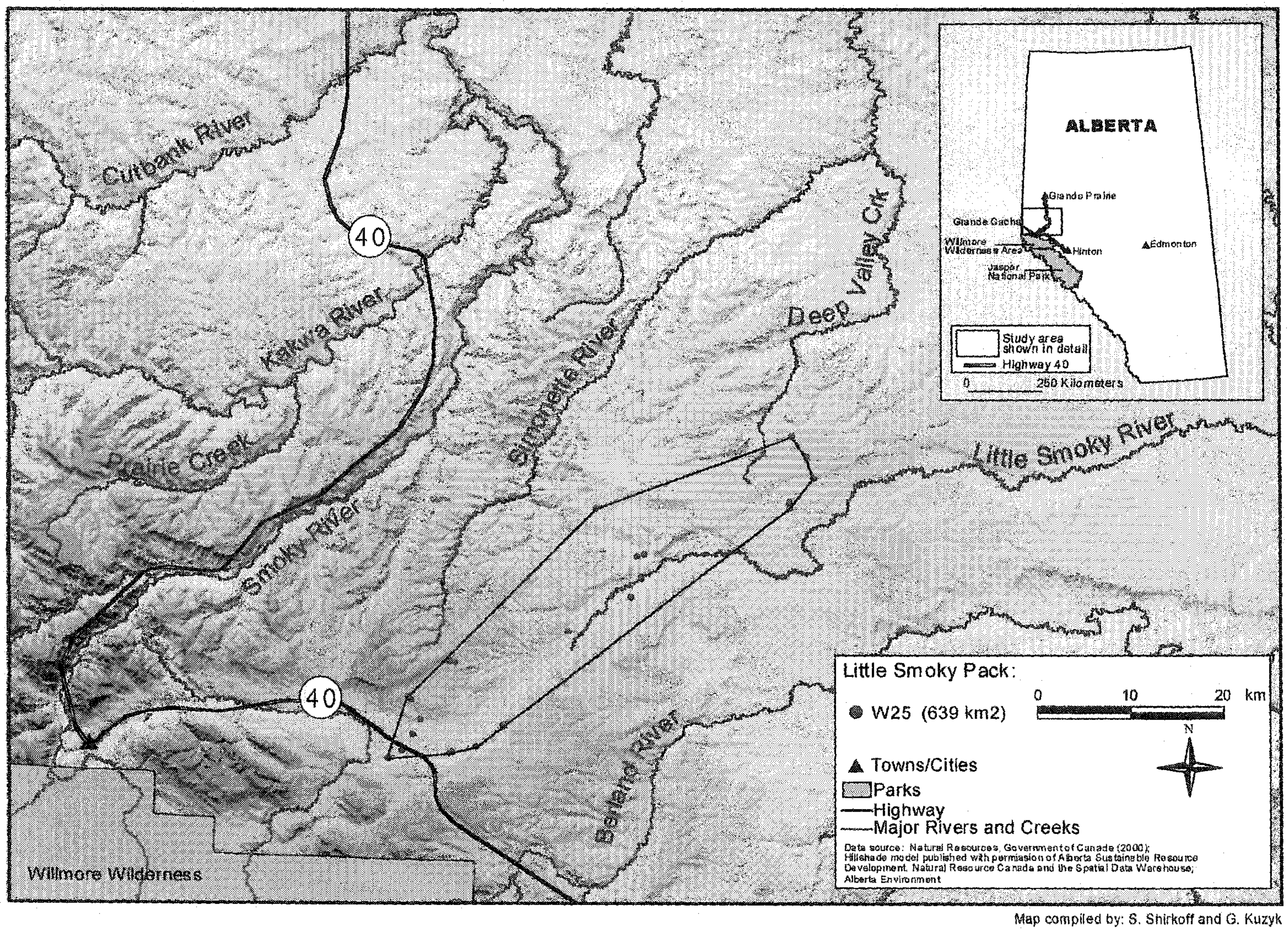
Map compiled by: S. Shirkoff and G. Kuzyk

Appendix 2-4. Territory of the Simonette wolf pack during winters of 2000 and 2001 in west-central Alberta.

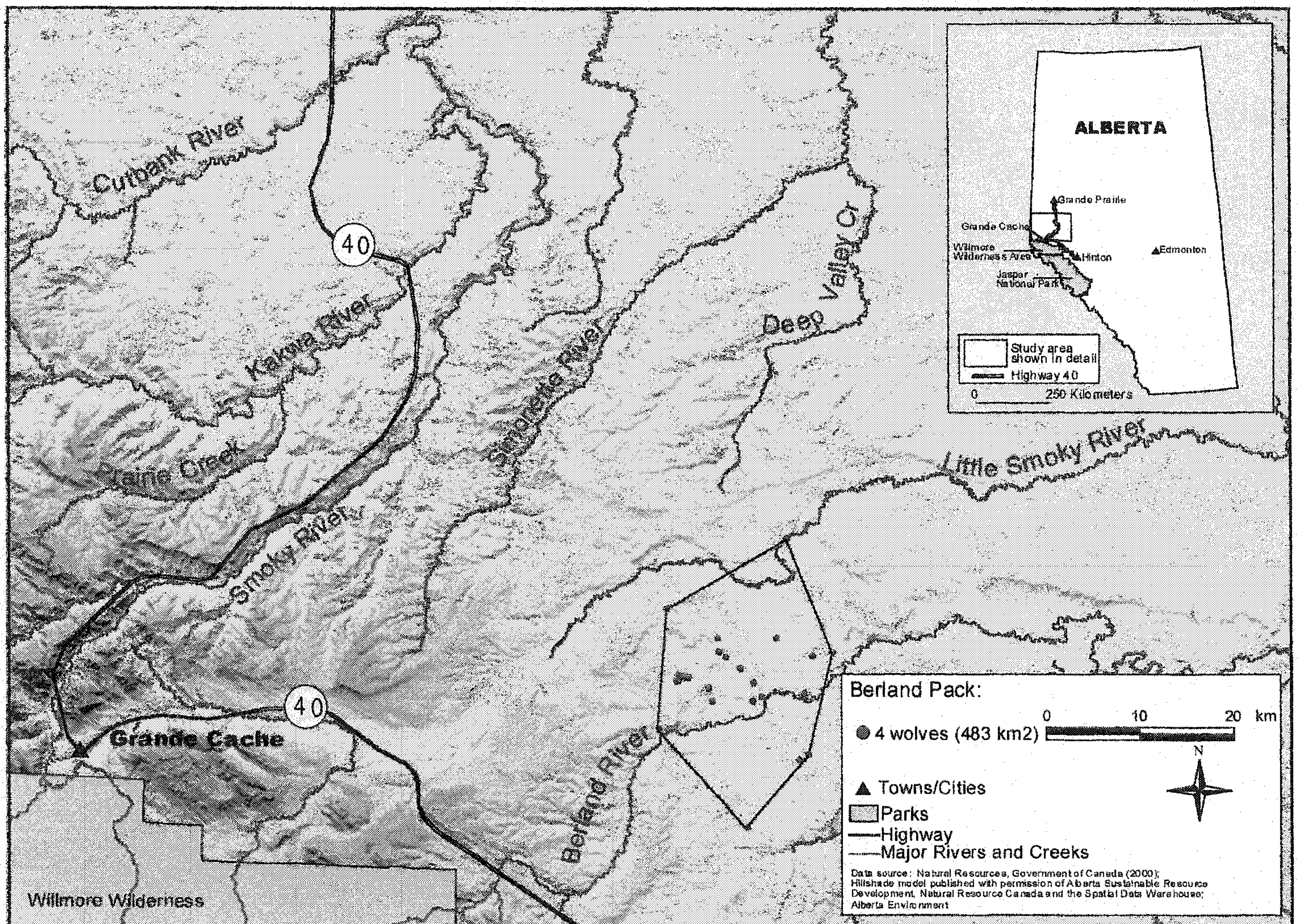


Map compiled by: S. Shirkoff and G. Kuzyk

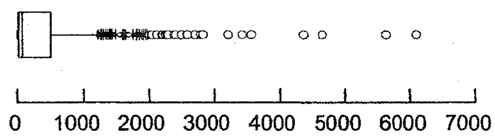
Appendix 2-5. Territory of the Little Smoky wolf pack during winter of 2001 in west-central Alberta.



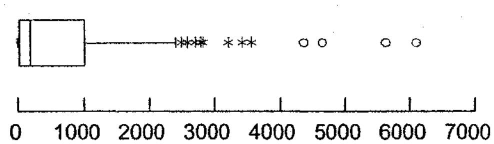
Appendix 2-6. Territory of the Berland wolf pack during winters of 2000 and 2001 in west-central Alberta.



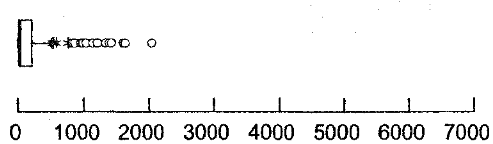
Map compiled by: S. Shirkoff and G. Kuzyk



Combined wolf travel distance (m/hr).



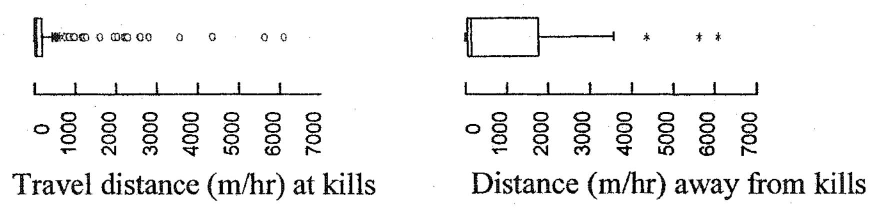
Wolf travel distance (m/hr) away from killsites



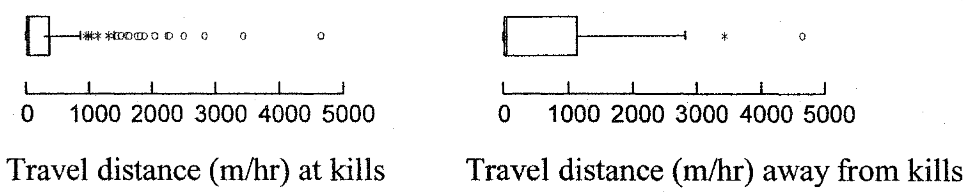
Wolf travel distance (m/hr) at killsites

Appendix 3-1. Wolf travel distance (m/hr) in relation to ungulate killsites determined by GPS location data from three wolves, in separate packs, in west-central Alberta from March 2-15, 2000.

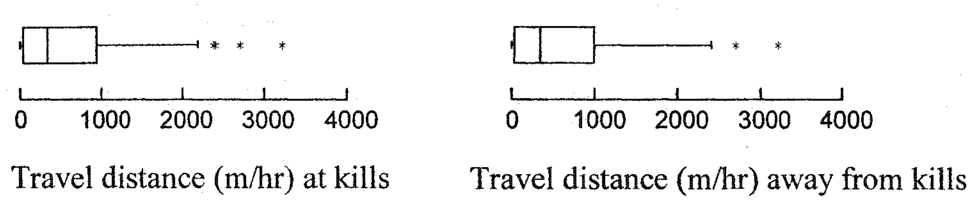
Cutbank Wolf Pack



Simonette Wolf Pack



Prairie Creek Wolf Pack



Appendix 3-2. Wolf travel distance (m/hr) in relation to ungulate killsites as determined by GPS location data from three wolves, in separate packs, in west-central Alberta from March 2-15, 2000.