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Response of Wolves to Caribou Migration Patterns and Anthropogenic Disturbance in the Central Canadian Arctic

by

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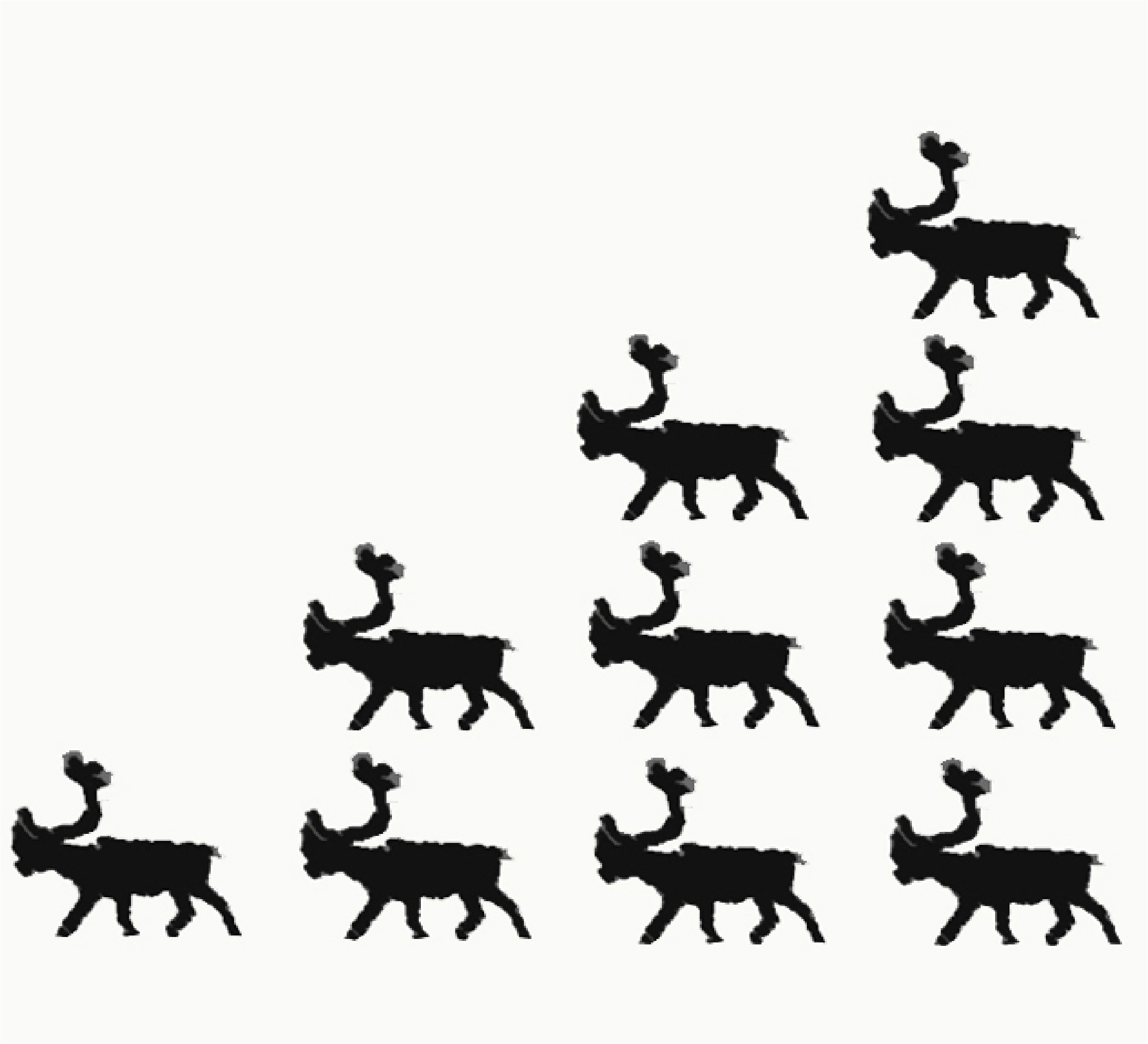

"To follow the caribou is to experience every facet of the northern environment, for the caribou are the central creatures of the North, the pulse of life in the land. They quicken the country not merely by adding animation and excitement themselves, but also by carrying along a host of other creatures: the wolf, the fox, the raven. The empty tundra may appear a drab and barren place, but let one caribou trot onto the skyline of an esker and the land comes alive."

- George Calef

Abstract

Wolves (*Canis lupus*) in the central Canadian Arctic migrate with their main prey, barren-ground caribou (*Rangifer tarandus*). However, most denning wolves select sites closer to tree line than caribou calving-grounds, resulting in separation by several hundred kilometers from the main herds for a period each summer, which can energetically challenge wolves. Despite this, wolves have existed in the region for millennia. However, recent anthropogenic development has brought more activity to the Arctic and may negatively affect the caribou-wolf relationship, impacting the entire system. Location data for wolves and caribou were used to study how caribou migration patterns and anthropogenic development relative to wolf dens influences wolf foraging behavior and reproductive success. Currently, wolf reproductive success appears to be influenced more by caribou migration patterns than development. Wolves made long-distance round trip commutes to caribou when they are scarce nearby. Low intensity experimental disturbance was conducted at tundra wolf home sites to document their response to such intrusion. Age of pups influenced response to disturbance more than development.

Acknowledgements

As with most work conducted above 60^0 North Latitude, this project could not have been completed without the help of many people and organizations. First, thanks to Dean Cluff, North Slave Regional Biologist for the Government of the Northwest Territories (GNWT), Department of Resources, Wildlife, and Economic Development (RWED) for deciding to study the effects of disturbance on wolves in the central Arctic and especially for bringing me on as the student for this project. Dean and the North Slave Region of RWED provided much of the equipment and logistic support necessary for field-camps during summers 2002 and 2003. I especially thank Jill Herbert and Dean Cluff for housing my four assistants and I in Yellowknife at different times during the study. BHP Billiton, Diavik Diamonds, and DeBeers Canada all provided travel to and from field camps as well as logistic support. The Aylmer Lake Lodge helped out with wolf location flights, transport to and from field camps, and logistic support in summer 2002. I received a grant from the Canadian Circumpolar Institute at the University of Alberta, which provided funding for food and travel during summers 2002 and 2003. Anne Gunn, Caribou Biologist for RWED in Yellowknife made caribou location data available and reviewed an early version of chapter two. Dave Mech provided GPS radio collars and much input during our discussions at the Aylmer Lake Lodge in spring and summer 2002. Paul Paquet provided input on the study design and reviewed chapters 2, 3, and 4. Thanks to Lyle Walton who collected some of the reproduction and den site data. Mike Nelson reviewed a draft of Chapter 2. Tracey Smith reviewed earlier drafts of the thesis and provided many hours of discussion about it. The Hik Lab folks, Ryan Danby, Shawn Morrison, Swann, Liesbeth Bakker, Terra Birkigt, Jesse Zgurski, Matt

Mitchell, Maria Didkowsky, Phil DeWitt, and Jackie Weir all helped out at various stages of the work. The Yellowknifes Dene First Nation, Treaty 11 Council, North Slave Metis Alliance, and Lutsel K'e Dene Band supported this work and provided field assistants when requested. Special thanks to my supervisor, David Hik, for bringing me to Edmonton and the University of Alberta, for supporting my decision to work with wolves instead of marmots, for helping with the study design and analysis, for supporting my forays to the south for work, for financial support throughout my program, and for his unending patience.

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Thanks Mom for never giving up on me even when it may have seemed like the best thing to do. If you had...well...

Finally, the land, water, caribou, and wolves of the central Arctic made my 102 days and nights in field camps on the tundra some of the most special times of my life. I look forward to the day I again taste a mixed hand full of cloudberries (*Rubus chamaemorus*), blueberries (*Vaccinium uliginosum*), and cranberries (*V. vitis-idaea*), for when I do, I will know I am back in a special place.

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Chapter 1

The Caribou – Wolf System and Human Disturbance in the Central Canadian Arctic

Introduction

Wolves (*Canis lupus*) in the central Canadian Arctic behave differently than other North American wolves in that they make seasonal migrations of several hundred kilometers each year following their main prey, the barren-ground caribou (*Rangifer tarandus*) (Kuyt 1962, 1972; Parker 1973; Heard and Williams 1992; Walton *et al*. 2001; Musiani 2003). However, most denning wolves do not follow caribou all the way to calving-grounds, instead they select sites further south (Parker 1973; Heard and Williams 1992). Wolves become central-place-foragers (Orians and Pearson 1979) during the denning season, making them less mobile because they need to return food to pups and caregivers at the den (Murie 1944; Harrington *et al.* 1983; Frame *et al*. 2004; Potvin *et al*. 2004). Therefore, most denning wolves are separated from the main caribou herds by several hundred kilometers for part of the summer (Williams 1990; Heard and Williams 1992; Heard *et al*. 1996; Frame *et al*. 2004). This separation can be energetically demanding to wolves as pups are growing quickly, yet the main prey source is scarce near dens (Heard and Williams 1992; Heard *et al*. 1996; Frame *et al*. 2004). Despite these demands, tundra denning wolves have lived in balance with caribou for millennia (Thorpe *et al*. 2001). When predator-prey dynamics get out of balance, the consequences can cascade and influence entire ecosystems (Ripple and Beschta 2003; Hamback *et al*. 2004).

The discovery of diamonds, development of mines, further mineral exploration, and increasing numbers of hunting and fishing lodges in the central Arctic threatens to disrupt this predator-prey balance by impacting caribou behavior (Nelleman and Cameron 1998; Johnson *et al*. 2005). Changes to caribou behavior such as migration timing and routes, could influence predation rates of wolves (Heard and Williams 1992) and reduce wolf reproductive success (Fuller 1989). This further imbalance could lead to undesirable cascading effects (Ripple and Beschta 2003; Hamback *et al*. 2004). As exploration and development activity in the region has increased, so has concern about the effects this activity is having on wildlife populations (Gau and Case 1999; McLoughlin *et al*. 2000; Mulders 2001; Walton *et al*. 2001; Cluff *et al*. 2002; Griffith *et al*. 2002; Gunn *et al*. 2002; Johnson *et a*l. 2005). This thesis is part of a study based on cumulative effects monitoring intended to inform wildlife managers in the central Arctic.

Here I briefly discuss the relationship between wolves and humans in general, and then describe the lack of quantitative data available on disturbance of wolf home sites, touching on issues facing the central Arctic specifically. In subsequent chapters I look at the spatial relationship between wolves, caribou, and anthropogenic development, and test the behavioral response of wolves to a low intensity experimental disturbance at their home sites.

Humans and Wolves

Direct and systematic persecution of wolves accompanied by habitat loss to expanding human populations has been the reason for large-scale range contractions of the species worldwide (Mech 1970, 1995; Boitani 2003; Musiani and Paquet 2004). Human caused mortality remains a primary cause of death in many wolf populations across North America (Mech 1977; Bjorge and Gunson 1989; Fuller 1989; Boyd and Pletscher 1999; Hayes *et al*. 2003). This mortality results from both legal and illegal shootings, snares, traps, and vehicle collisions. In many parts of wolf range, hunting wolves for sport or fur is legal, and sometimes government wildlife agencies kill wolves to reduce predation on wild ungulate game species used for subsistence and sport hunting (Hayes *et al*. 2003). Disturbingly, illegal killing is still a substantial mortality factor in many protected populations (Mech 1977; Fritts and Mech 1981; Fuller 1989; Boyd and Pletscher 1999; U. S. Fish and Wildlife Service *et al*. 2004). Yet despite humans being the major cause of wolf mortality, in the absence of directed population control efforts, recovering wolf populations continue to expand (Fuller *et al*. 1992; Boyd and Pletscher 1999; Hayes *et al*. 2003; U. S. Fish and Wildlife Service *et al*. 2004).

Home Site Disturbance

The effects of human activity on wolves while denning is little studied (Chapman 1977; Thiel *et al*. 1998). As a result, most accounts of wolves responding to human disturbance at dens and rendezvous sites (above ground gathering places at which pups are kept when moved from the natal den) are unreplicated and unstandardized (Chapman 1977; Mech *et al*. 1998; Smith 1998; Thiel *et al*. 1998). While these reports demonstrate that some wolves are tolerant of disturbance near den sites (Mech *et al*. 1998; Theil *et al*. 1998), there are probably many accounts of intolerance that go unnoticed. For instance, a logging operation may move into an area near a pup-rearing site and cause pups to be moved without the intruders even knowing the wolves were there. In such cases, the impact of disturbance is unknown. It is therefore unwise to form conclusions and base management decisions on any number of chance observations.

There has only been one previous experimental study conducted on the response of wolves to disturbance at home sites (Chapman 1977). In this study, wolves were observed at diminishing distances from two wolf home sites in an attempt to infer the minimum distance at which wolves would tolerate this type of intrusion. However, the techniques were different at each site and inadvertent disturbance took place when observers approached home sites to photograph wolves (Chapman 1977). An additional part of that study surveyed the literature, biologists, and others who had reportedly disturbed wolf home sites. From these reports it was concluded that intensity and duration of disturbance were the factors most likely to influence the responses of wolves and that ultimately the seriousness of human disturbance is a human judgment.

Home Site Disturbance in The Central Arctic

In the central Arctic, human disturbance at wolf home sites is an issue associated with mining activity and mineral exploration, as well as sport hunting, recreational fishing, and wildlife viewing conducted from outfitter camps (Walton *et al*. 2001). Although aboriginal peoples have used the central Arctic as hunting and fishing grounds for centuries (Thorpe *et al*. 2001; Bielawski 2003) the region has seen unprecedented increases in human activity since the early 1990s (Fig. 1-1). Prior to the discovery of diamonds there was little industrial development in the region. Currently there are two diamond mines in operation with four other sites in various stages of development (Fig. 1-1). Exploration for diamonds in the central Arctic is ongoing. In addition, gold and base metal deposits are of interest in the area (Fig. 1-1) but largely remain undeveloped because they are uneconomic at this time.

The Lupin Gold Mine began operation in 1982, and its owners construct a 600 km winter road annually to permit the efficient transfer of fuel and supplies to the mine (Fig.

1-1). The route travels over frozen lakes and portages from Yellowknife, Northwest Territories to the mine at the north end of Contwoyto Lake. This road is now a joint venture between the Lupin Mine and diamond interests in the region. The road is operational from late January to early April each year. Although the road does not operate during the wolf denning season, there may be disturbance associated with maintenance camps that are minimally staffed throughout the year. In addition, there is a current proposal to construct an all-weather road from Yellowknife, Northwest Territories to Bathurst Inlet, Nunavut (Fig. 1-1). This road would provide year-round access to mines and a proposed marine port at Bathurst Inlet (Fig. 1-1), and allow the public vehicular access to the central Arctic. With more people in the region, the possibility of disturbing denning wolves increases.

Study Area and Objectives

The central Arctic is a harsh environment, characterized by long cold winters and short cool summers. The climate is semiarid with average annual precipitation of 30 cm, half of which falls as snow. Winter temperatures are often < -30^0 C and summer averages 10^0 C (Walton *et al*. 2001). Weather patterns that are influenced by Hudson Bay, the Arctic Ocean, and the western cordillera contribute to the harsh climate of the central Arctic (Bryson and Hare 1974).

The northern portion of the study area (Fig. 1-2) is low Arctic tundra becoming forest-tundra transition in the south. The vegetation in the northern portion consists primarily of dwarf shrubs (e.g. *Salix* spp., *Betula glandulosa, Vaccinium uliginosum, V. vitis-idaea, Empetrum nigrum*), heath tundra, and wet graminoid communities (Walton *et* *al*. 2001). The forest-tundra transition zone is defined as that area encompassed by < 0.1% tree cover at the northern boundary and < 0.1% upland tundra cover at the southern extent (Timoney *et al*. 1992). Spruce (*Picea mariana, P. glauca*) are the dominant tree species in this area.

Caribou – Wolf System

The migratory barren-ground caribou (*Rangifer tarandus*) are an integral species on the central Arctic landscape, in that their presence and activities influence ecosystem processes on multiple scales (Heard *et al*. 1996; Thorpe *et al*. 2001; Frame *et al*. 2004). The study area is in the range of the Bathurst caribou herd, which was estimated at 186,000 animals in summer 2003 (Government of the Northwest Territories 2004). As stated above, wolves in the study area follow the seasonal movements of their main prey, migratory barren-ground caribou. Females in the Bathurst herd migrate out of tree line onto the tundra by late April on their way to calving grounds in the north (Gunn *et al.* 2002). Winter range of the Bathurst herd varies between years ranging through the boreal forest, forest-tundra transition zone south of Great Bear Lake to southeast of Great Slave Lake, with some caribou wintering on the tundra (Gunn *et al*. 2002; Thorpe *et al.* 2002).

In winter tundra wolves are not territorial, instead they follow caribou throughout the herd's range (Walton *et al.* 2001; Musiani 2003). However, from May through August while tending dens, the packs' movements are limited by the need to return food to pups, which are born between mid May and early June. Heard and Williams (1992) suggest that because of the timing of caribou movements, wolves maximize access to migrating caribou by selecting den sites that are closer to tree line than to caribou calving grounds. Yet, because of caribou movement patterns, all tundra denning wolves are separated from the main caribou herds by several hundred kilometers at some time during summer (Kuyt 1972; William 1990; Heard and Williams 1992; Heard *et al*. 1996; Walton *et al*. 2001; Frame *et al*. 2004).

Objectives

Motivated by the recent increase of exploration and development related to mineral extraction and tourism, the primary objective of this study was to make research based recommendations for activity near wolf dens and rendezvous sites in the central Arctic. However, the issue of disturbance to wolves is complex (Chapman 1977; Fritts *et al*. 2003), so at the onset of the study, I was faced with the question, "what is meaningful disturbance in the context of wolves?" I believe the effects of human activity to wildlife must be considered at two scales, that of the individual and the population. Because of the inherent difficulty in interpreting and quantifying sub-lethal effects of human activity on wildlife, my study considered the effect of such activity on the reproductive success of wolves at the population scale, as well as the behavioral response of packs and individuals, and how this behavior may influence reproductive success. As reproductive success of wolves is most often related to prey availability (Fuller 1989), and in the central Arctic prey availability is a function of caribou migration patterns relative to wolf dens, I also considered foraging strategies that tundra wolves use to cope with seasonally scarce prey, and how this scarcity may influence reproductive success. Together these three chapters present an increased understanding of the dynamics between wolves, caribou migration patterns, and anthropogenic disturbance in the central Canadian Arctic.

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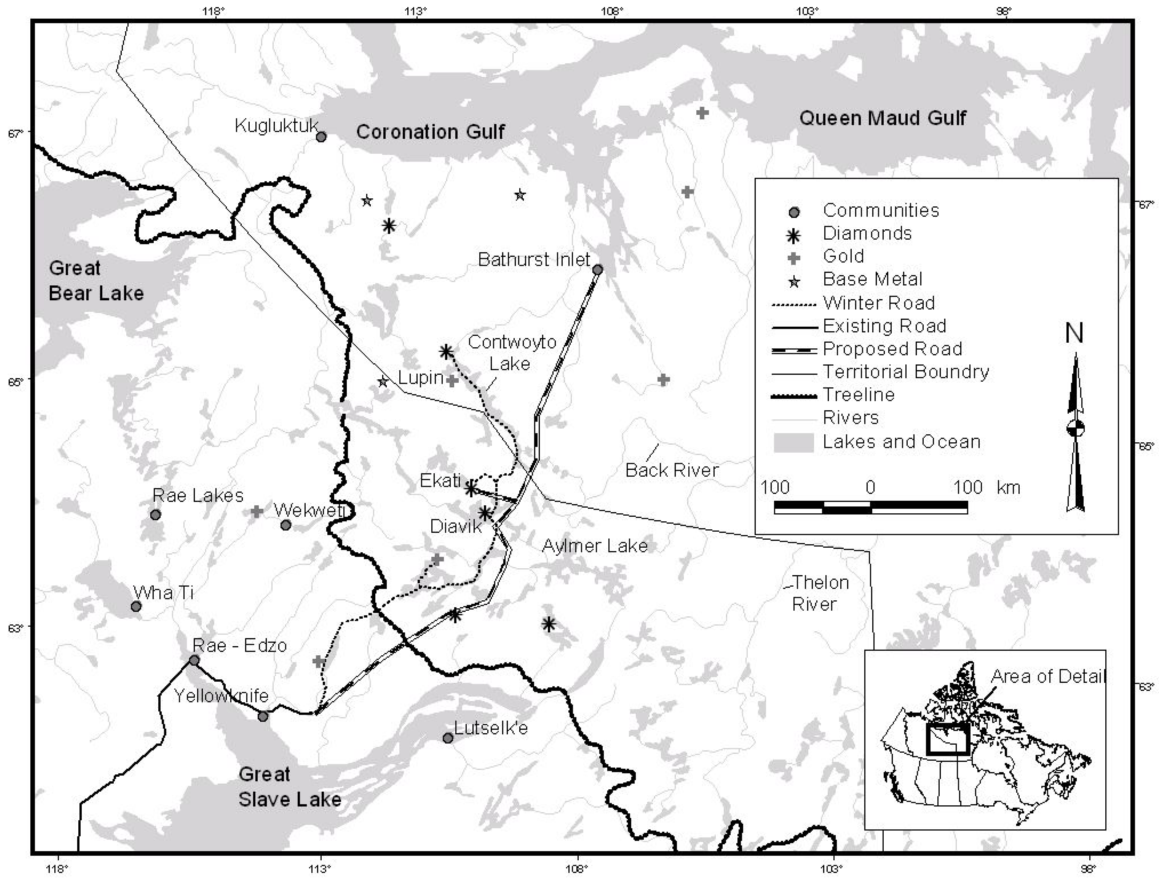

Figure 1-1. Current and proposed industrial development in a portion of the central Canadian Arctic.

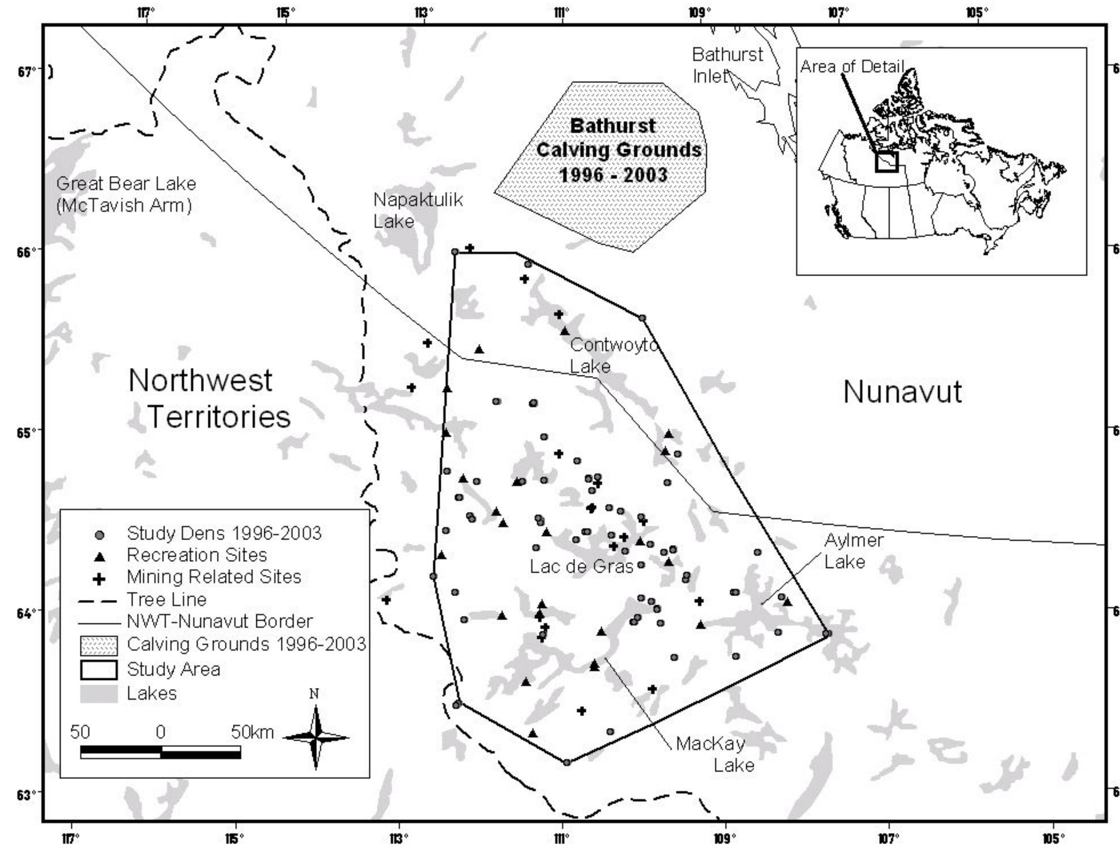

Figure 1-2. Study area for an investigation of the response of wolves to caribou migration and anthropogenic development in the central Canadian Arctic.

Chapter 2

*Long Foraging Movement of a Denning Tundra Wolf**

* A version of this chapter was published in the journal *Arctic* as:

Frame, P. F., Hik, D. S., Cluff, H. D., and Paquet, P. C. 2004. Long foraging movement of a denning tundra wolf. Arctic **57:** 196-203.

Introduction

Wolves (*Canis lupus*) that den on the central barrens of mainland Canada follow the seasonal movements of their main prey, migratory barren-ground caribou (*Rangifer tarandus*)(Kuyt 1962; Kelsall 1968; Walton *et al.* 2001). However, most wolves do not den near caribou calving grounds, but select sites further south, closer to tree line (Heard and Williams 1992). Most caribou migrate beyond primary wolf denning areas by mid June and do not return until mid to late July (Heard *et al.* 1996; Gunn *et al*. 2002). Consequently, caribou density near dens is low for part of summer.

During this period of spatial separation from the main caribou herds, wolves must search for scarce and/or alternate prey near the home-site, travel to where prey are abundant, or use a combination of these strategies.

Walton *et al.* (2001) postulated that tundra wolves travel outside their normal summer ranges in response to low caribou availability rather than as pre-dispersal explorations observed in territorial wolves (Fritts and Mech 1981; Messier 1985). The authors postulated this because most such travel was toward caribou calving grounds. We report details of such a long-distance excursion by a breeding female tundra wolf wearing a GPS radio-collar. We discuss the relationship of the excursion to satellite-collared caribou movements (Gunn *et al*. 2002), supporting the hypothesis that tundra wolves make directional, rapid, long-distance movements in response to seasonal prey availability.

Study Area

Our study took place in the northern boreal forest - low arctic tundra transition zone (63^0 30’ N, 110^0 00’ W; Fig. 2-1; Timoney *et al.* 1992). Permafrost in the area transitions from discontinuous to continuous (Harris 1986). Patches of spruce (*Picea mariana*, *P. glauca*) occur in the southern portion and give way to open tundra to the northeast. Eskers, kames, and other glacial deposits are scattered throughout the study area. Standing water and exposed bedrock are characteristic of the area.

The Caribou-Wolf System

The Bathurst caribou herd uses this study area. Most caribou cows have begun migrating by late April, reaching calving grounds by June (Gunn *et al*. 2002; Fig. 2-1). Calving peaks by 15 June (Gunn *et al*. 2002), and calves begin to travel with the herd by one week of age (Kelsall 1968). The movement patterns of bulls are less known but bulls frequent areas near calving grounds by mid-June (Heard *et al.* 1996; Gunn *et al*. 2002). In summer, Bathurst caribou cows generally travel south from calving grounds then parallel the tree line to the northwest. The rut usually takes place at tree line in October (Gunn *et al*. 2002). Winter range of the Bathurst herd varies among years, ranging through the taiga and along tree line from south of Great Bear Lake to southeast of Great Slave Lake. Some caribou spend winter on the tundra (Gunn *et al*. 2002; Thorpe *et al.* 2001).

In winter, wolves that prey on Bathurst caribou do not behave territorially. Instead, they follow the herd throughout their winter range (Walton *et al.* 2001;

Musiani 2003). However, during denning (May-August, parturition late May – mid June), wolf movements are limited by the need to return food to the den. To maximize access to migrating caribou, many wolves select den sites further south, closer to tree line than to caribou calving grounds (Heard and Williams 1992). Because of caribou movement patterns, tundra denning wolves are separated from the main caribou herds by several hundred kilometers at some time during summer (Williams 1990; Fig. 2-1; Table 2-1).

Musk oxen do not occur in the study area (Fournier and Gunn 1998) and there are few moose there (D. Cluff, Gov't NWT, personal observation). Therefore, alternate prey for wolves includes waterfowl, other ground nesting birds, their eggs, rodents, including arctic ground squirrels, and hares (Kuyt 1972; Wiliams 1990; P. Frame, unpublished data). During 56 hours of den observations, we saw no ground squirrels or hares, only birds. It appears that the relative abundance of alternate prey in the study area was low in 2002.

Methods

Wolf Monitoring

Female wolf 388 was captured by helicopter net-gun (Walton *et al.* 2001) near her den on 22 June 2002. She was fitted with a releasable GPS radio-collar (Merrill *et al.* 1998), programmed to acquire locations at 30 minute intervals. The collar was electronically released (e.g., Mech and Gese 1992) on 20 August 2002. From 27 June to 3 July 2002 we observed 388's den with a 60x spotting-scope at a distance of 390 m.

Caribou Monitoring

In spring of 2002, ten female caribou were captured by helicopter net-gun and fitted with satellite radio-collars bringing the total number of collared Bathurst cows to 19. Eight of these spent summer 2002 south of Queen Maud Gulf, well east of normal Bathurst caribou range. Therefore, we used 11 caribou for this analysis. The collars provided one location per day during our study, except for 5 d from 24-28 July. Locations of satellite collars were obtained from Service Argos, Inc. (Landover, Maryland).

Data Analysis

Location data were analyzed by ArcView GIS software (Environmental Systems Research Institute Inc., Redlands, California). We calculated the average distance from the nearest collared caribou to the wolf and the den for each day of the study.

Wolf foraging bouts were calculated from the time 388 exited a buffer of 500 m radius around the den until she re-entered again. We considered her to be traveling when two consecutive locations were spatially separated ($\geq$100 m). Minimum distance traveled was the sum of distances between each location during the excursion.

We compared pre- and post-excursion data using Analysis of Variance (ANOVA; Zar 1999). First we tested for homogeneity of variances with Levene’s test (Brown and Forsythe 1974). No transformations of these data were required.

Results

Wolf Monitoring

Pre-Excursion Period: Wolf 388 was lactating when captured on 22 June. We observed her and two other females nursing a group of 11 pups between 27 June and 3 July. The pack consisted of at least four adults (3 females and 1 male) and 11 pups during our observations. On 30 June, three pups were moved to a location 310 m from the other eight, and cared for by an uncollared female. The male was not seen at the den after the evening of 30 June.

Prior to the excursion, telemetry indicated 18 foraging bouts. The mean distance traveled during bouts before the excursion period was 25.3 km (± 4.5 SE, range 3.1 - 82.5 km). Mean greatest distance from the den on foraging bouts was 7.1 km (± 0.9 SE, range 1.7 - 17.0 km). The average duration of foraging bouts for the period was 20.9 h (± 4.5 SE, range 1 - 71 h).

The average daily distance between the wolf and the nearest collared caribou decreased from 242 km one week before the excursion period (12 July) to 126 km the day it began (Table 2-1).

Excursion Period: On 19 July at 2203 hrs, after spending 14 h at the den, 388 began moving to the northeast and did not return for 336 h (14 d; Fig. 2-2). Whether she traveled alone or with other wolves is unknown. During the excursion, 476 of 672 (71%) possible locations were recorded. The wolf crossed the southeast end of Lac Capot Blanc on a small land bridge, where she paused 4.5 h after traveling for 19.5 h (37.5 km). Following this rest, she traveled for 9 h (26.3 km) onto a peninsula in Reid Lake where she spent 2 h before backtracking and stopping for 8 h just off the peninsula. Her next period of travel lasted 16.5 h (32.7 km), terminating in a pause of 9.5 h just 3.8 km from a concentration of locations at the far end of her excursion, where we presume she encountered caribou. The mean (SE) duration of these three periods of movement and pauses was 15.7 h (2.5) and 7.3 h (1.5), respectively. A total of 72.5 h (3.0 d), were required to travel a minimum of 95 km from the den to this area near caribou (Fig. 2-2). She remained there (35.5 km^2) for 151.5 h (6.3 d), and then moved south to Lake of the Enemy where she stayed (31.9 km^2) for 74 h (3.1 d) before returning to her den. Her greatest distance from the den was 103 km, recorded on 27 July at 0433 hrs, 174.5 h (7.3 d) after the excursion began. She was 8 km from a collared caribou on 23 July (Table 2-1), 4 days after the excursion began.

The return trip began on 2 August at 0403 hrs, 318 h (13.2 d) after leaving the den. She followed a relatively direct path for 18 h back to the den, a distance of 75 km.

The minimum distance traveled during the excursion was 339 km. The estimated overall minimum travel rate was 3.1 km/h, 2.6 km/h away from the den and 4.2 km/h on the return trip.

Post-Excursion Period: Three pups were seen when the collar was recovered on 20 August, but others may have been hiding in vegetation. Telemetry recorded 13 foraging bouts in the period post-excursion. The mean distance traveled during these bouts was 18.3 km (2.7 SE, range 1.2 – 47.7 km). Mean greatest distance from the den post-excursion was 7.1 km (0.7 SE, range 1.1 – 11.0

km). The average duration of foraging bouts for this period was 10.9 h (2.4 SE, range 1 - 33 h).

When 388 reached her den (2 August), the distance to the nearest collared caribou was 54 km. One week after she returned (9 August) the distance was 79 km (Table 2-1).

Pre- and Post-Excursion Comparison

We found no differences in the mean distance of foraging bouts before and after the excursion period (F=1.5, df=1,29, P=0.24). Likewise, the mean greatest distance from the den was similar pre- and post-excursion (F=0.004, df=1,29, P=0.95). However, the mean duration of foraging bouts decreased by 10.0 h after 388's excursion (F=3.1, df=1,29, P=0.09).

Caribou Monitoring

Summer Movements: On 10 July, five of 11 collared caribou were dispersed over a distance of 10 km, 140 km south of calving-grounds (Fig. 2-1). On the same day, three were still on calving-grounds, two were between calving-grounds and the leaders, and one location was missing. One week later (17 July), the leading radioed cows were 100 km farther south (Fig. 2-1). Two were within 5 km of each other in front of the rest, who were more dispersed. All radioed cows had left calving-grounds by this time. On 23 July, the leading radioed caribou had moved 35 km further south, and all of the radioed caribou were more widely dispersed. The two radioed cows closest to the leader were 26 km and 33 km away with 37 km between them. On the next location (29 July), the most southerly caribou were 60 km farther south. All of the caribou were now in areas where they remained for the duration of the study (Fig. 2-2).

A Minimum Convex Polygon (Mohr and Stumpf 1966) around all caribou locations acquired during the study encompassed 85,119 km^2.

Relative to the Den: The distance from the nearest collared caribou to the den decreased from 241 km one week before the excursion to 124 km the day it began. The nearest any collared caribou were to the den was 43 km on 29 and 30 July. During the study four radioed caribou were located $\leq$ 100 km from the den and one of those was $\leq$ 50 km away. Each of these four was closest to the wolf on at least one day during the period reported.

Discussion

Prey Abundance

Caribou are the single most important prey of tundra wolves (Clark 1971; Kuyt 1972; Stephenson and James 1982; Williams 1990). Caribou range over vast areas and throughout part of the summer are scarce or absent in wolf home ranges (Heard *et al.* 1996). The distance between radio-collared caribou and the den the week before the excursion together with more time spent foraging by 388 indicate caribou availability near the den was low. Observations of the pups being left alone for up to 18 h, presumably while adults were searching for food, provides additional support for low caribou availability locally. Mean foraging bout duration decreased by 10.0 h after the excursion when collared caribou were closer to the den, suggesting an increase in caribou availability nearby.

Foraging Excursion

Other workers have reported wolves making long round-trips and referred to them as extraterritorial or predispersal forays (Fritts and Mech 1981; Messier 1985; Ballard *et al.* 1997; Merrill and Mech 2000). These movements are most often made by young (1-3 year old) wolves, in areas where annual territories are maintained and prey are relatively sedentary (Fritts and Mech 1981; Messier 1985). The long excursion of 388 differs in that tundra wolves do not maintain annual territories (Walton *et al.* 2001), and the main prey migrate over vast areas (Gunn *et al*. 2002).

Another difference between 388's excursion and those reported earlier is that she is a mature, breeding female. No study of territorial wolves has reported reproductive adults making extraterritorial movements in summer (Fritts and Mech 1981; Messier 1985; Ballard *et al*. 1997; Merrill and Mech 2000). However, Walton *et al*. (2001) also report that breeding female tundra wolves made excursions.

Direction of Movement

Possible explanations for the relatively direct route 388 took to the caribou include landscape influence and experience. Considering the timing of 388's trip and the locations of caribou, had the wolf moved northwest she may have missed the caribou entirely or the encounter might have been delayed.

A reasonable possibility is that the land directed 388's route. The barrens are crisscrossed with trails worn into the tundra over centuries by hundreds of thousands of caribou and other animals (Kelsall 1968; Thorpe *et al.* 2001). At river crossings, lakes, or narrow peninsulas, trails converge and funnel towards and away from caribou calving grounds and summer range. Wolves use trails for travel (Mech and Boitani 2003; Paquet *et al*. 1996; P. Frame, personal observation). Thus, the landscape may direct an animal's movements and lead it to where cues, such as the odor of caribou on the wind or scent marks of other wolves may lead it to caribou.

Another possibility is that 388 knew where to find caribou in summer. Sexually immature tundra wolves sometimes follow caribou to calving grounds (D. Heard, unpublished data). Possibly, 388 made such journeys in previous years and killed caribou. If this were the case then in times of local prey scarcity she may travel to where she has hunted successfully before. Continued monitoring of tundra wolves may answer questions of how food needs are met in times of low caribou abundance near dens.

Caribou often form large groups while moving south to tree line (Kelsall 1968). After a large aggregation of caribou move through an area their scent can linger for weeks (Thorpe *et al.* 2001). It is conceivable that 388 detected caribou scent on the wind, which blew from the NE 19 – 21 July (Environment Canada 2003), the same time her excursion began. Many factors, such as odor strength and wind direction and strength, make systematic study of scent detection in wolves under field conditions difficult (Harrington and Asa 2003). However, humans are able to smell odors such as forest fires or oil refineries from >100 km away. The olfactory capabilities of dogs, which are similar to wolves, are thought to be 100 to 1 million times that of humans (Harrington and Asa 2003). Therefore, it is reasonable to think that the scent of many caribou traveling together, under the right wind conditions could be detected by wolves from great distances, thus triggering a long foraging bout.

Rate of Travel

Mech (1994) reported the rate of travel of Arctic wolves on barren ground was 8.7 km/h during regular travel and 10.0 km/h when returning to the den, a difference of 1.3 km/h. These rates are based on direct observation and exclude periods when wolves moved slowly or not at all. Our calculated travel rates are assumed to include periods of non-movement or slow movement. However, the pattern we report is similar to that reported by Mech (1994) in that homeward travel was faster than regular travel by 1.6 km/h. The faster rate on return may be explained by the need to return food to the den. Pup survival can increase with the number of adults in a pack available to deliver food to pups (Harrington *et al.* 1983). Therefore, an increased rate of travel on homeward trips could improve a wolf’s reproductive success by getting food to pups quicker.

Fate of 388's Pups

Wolf 388 was caring for pups during den observations. The pups were estimated to be 6 weeks old, and were seen ranging as far as 800 m from the den. They received some regurgitated food from two of the females, but were unattended for long periods. The excursion started 16 d after our observations, and it is improbable the pups could have traveled the distance 388 moved. If the pups died, this would have removed parental responsibility allowing the long movement.

Based on our observations and the locations of radio-collared caribou, prey became scarce in the area of the den as summer progressed. Wolf 388 may have abandoned her pups to seek food for herself. However, she returned to the den after the excursion, where she was seen near pups. In fact, she foraged in a similar pattern after the excursion suggesting she again provided for pups.

A more likely possibility is that one or both of the other lactating females cared for the pups during 388's absence. The three females at this den were not seen with the pups at the same time. However, two weeks earlier, at a different den, we observed 3 females cooperatively caring for a group of 6 pups. At that den, the three lactating females were observed providing food for each other and trading places while nursing pups. Such a situation at the den of 388 could create conditions where one or more of the lactating females could range far from the den for a period, returning to her parental duties afterwards. However, the pups would have been weaned by eight weeks of age (Packard *et al.* 1992), so nonlactating adults could have cared for them, as often happens in wolf packs (Packard *et al.* 1992; Mech *et al.* 1999).

Cooperative rearing of multiple litters by a pack could create opportunities for long-distance foraging movements by some reproductive wolves during summer periods of local food scarcity. Multiple lactating females at one or more tundra wolf dens per year have been recorded from 1997 to 2003. This reproductive strategy may be an adaptation to temporally and spatially unpredictable food resources. All of these possibilities require further study, but emphasize both the adaptability of wolves living on the barrens, and their dependence on caribou.

Long wolf movements in response to caribou availability has been suggested by other researchers (Kuyt 1972; Walton *et al.* 2001) and traditional ecological knowledge (Thorpe *et al*. 2001). This report demonstrates the rapid and extreme response of wolves to caribou distribution and movements in summer. Increased human activity on the tundra (mining, road building, pipelines, ecotourism) may influence caribou movement patterns and change the interactions between wolves and caribou in the region. Continued monitoring of both species will help assess if the association is being changed adversely by anthropogenic causes.

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Table 2-1. Daily distances from wolf 388 and her den to the nearest radio-collared caribou during a long excursion in summer 2002.

Date (2002)	Mean distance caribou to wolf (km)	Daily Distance from closest caribou to den (km)
12 July	242	241
13 July	210	209
14 July	200	199
15 July	186	180
16 July	163	162
17 July	151	148
18 July	144	137
19 July[a]	126	124
20 July	103	130
21 July	73	130
22 July	40	110
23 July[b]	9	104
29 July[c]	16	43
30 July	32	43
31 July	28	44
1 August	29	46
2 August[d]	54	52

3 August	53	53
4 August	74	74
5 August	75	75
6 August	74	75
7 August	72	75
8 August	76	75
9 August	79	79

[a] Excursion starts

[b] Wolf closest to collared caribou

[c] Previous 5 days caribou locations not available

[d] Excursion ends

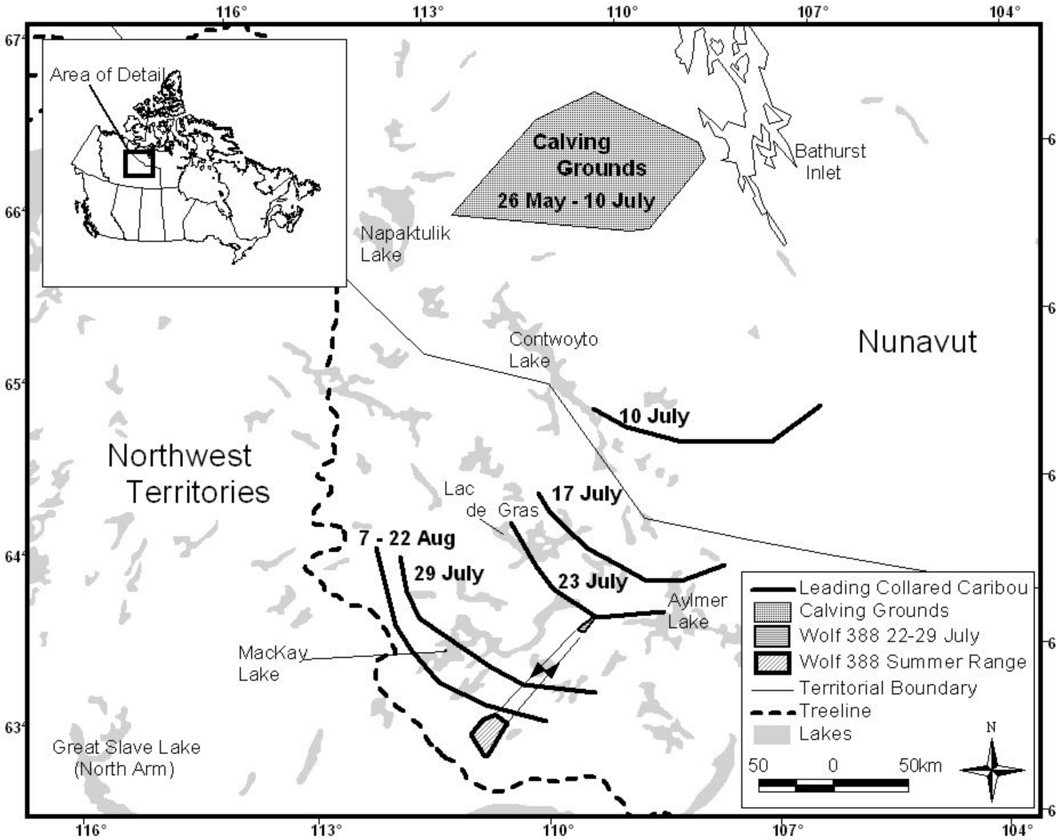

Figure 2-1. Map showing the movements of satellite radio-collared caribou with respect to female wolf 388's summer range and long foraging movement, in summer 2002.

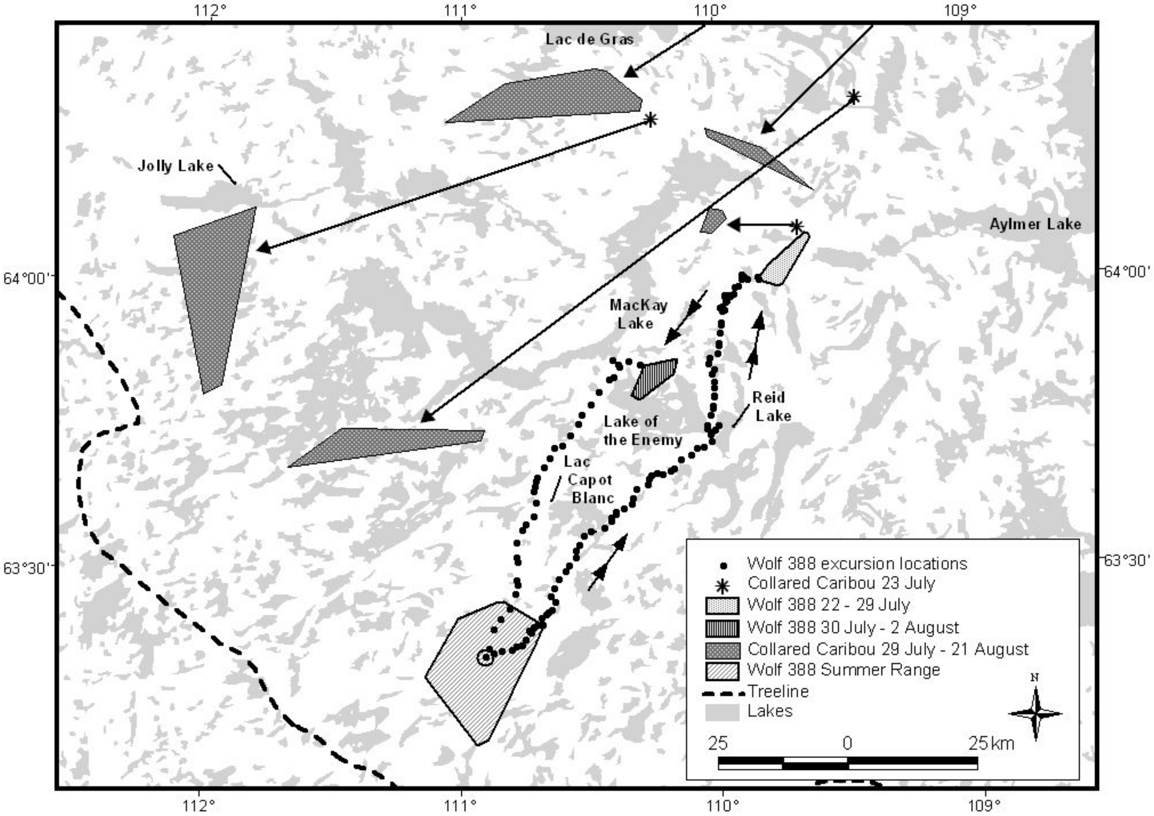

Figure 2-2. Details of a long foraging movement by female wolf 388 between 19 July and 2 August 2002. Also shown are locations and movements of three satellite radio-collared caribou from 23 July to 21 August 2002. On 23 July, the wolf was 8 km from a collared caribou. The furthest point from the den was 103 km recorded 27 July. Arrows indicate direction of travel.

Chapter 3

Effects of Seasonal Caribou Movements and Human Development on Reproductive Success of Tundra Denning Wolves in the Central Canadian Arctic

Introduction

The recent development of a diamond mining industry in the vast tundra region of the central Canadian Arctic has raised concerns about the cumulative effects of industrial development and tourism on wildlife populations there (Gau and Case 1999; McLoughlin *et al*. 2000; Mulders 2001; Walton *et al*. 2001; Cluff *et al*. 2002; Griffith *et al*. 2002; Gunn *et al*. 2002; Johnson *et a*l. 2005). In particular, some evidence suggests that wolves (*Canis lupus*) in this area may be vulnerable to disturbance during the pup-rearing period when pack movements are restricted by the need to return food to dens (Walton *et al*. 2001). While some wolves appear to be tolerant of human activity near dens (Thiel *et al*. 1998), others move pups to secondary sites in response to disturbance (Chapman 1977; Ballard *et al*. 1987). However, undisturbed wolves sometimes move their pups from natal dens to rendezvous sites as early as June (Ballard *et al*. 1987; P. Frame personal observation), demonstrating that this activity is not fatal for pups. Therefore, managers must consider both population effects and behavioral responses of disturbed wolves when making decisions regarding area closures and land use. While Ballard *et al*. (1987) report that no mortality occurred at two dens where human disturbance caused wolves to move pups, the overall reproductive success of wolves in relation to human features on the landscape has not been studied in North America.

Reproductive success of wolves is most often related to prey availability, usually quantified as total ungulate biomass per wolf per pack (Fuller and Keith 1980; Fuller 1989; Fuller *et al*. 2003). For wolves in the central Arctic, prey availability is related to the movement patterns of their main prey, barren-ground caribou (*Rangifer tarandus*) (Heard and Williams 1992; Heard *et al*. 1996; Frame *et al*. 2004), which they follow over hundreds of kilometers between winter and summer ranges (Kuyt 1962; Walton *et al*. 2001; Musiani 2003). Although tundra wolves associate with caribou throughout the year (Walton *et al*. 2001; Musiani 2003), most denning wolves do not follow caribou to tundra calving grounds (Kuyt 1972; Heard *et al*. 1996), but select den sites further south, near the northern limit of trees (Heard and Williams 1992; Cluff *et al*. 2002). Consequently, there is a period during summer when caribou abundance, and thus total ungulate biomass per wolf, is low near dens (Kuyt 1972; Williams 1990; Heard *et al*. 1996; Frame *et al*. 2004). The effect of this period of caribou scarcity on tundra wolf reproduction has not been quantified in detail, however observations indicate pup mortality does occur during this time (Kuyt 1972; Williams 1990).

In most predator-prey systems, including the caribou-wolf system of the central Arctic, prey population size determines their accessibility to predators (Heard *et al*. 1996; Fuller *et al*. 2003). However, in the central Arctic, access to caribou during wolf denning periods is influenced primarily by caribou migration patterns (Heard and Williams 1992; Heard *et al*. 1996; Frame *et al*. 2004). The objectives of this study were (*i*) to determine if human activity is a significant factor in reproduction of tundra wolves, and (*ii*) to determine which of the caribou migration parameters, timing of onset and distance from dens to migration routes, are most important to wolf reproductive success.

Study Area

This study was conducted in the low arctic tundra and forest-tundra transition zone of the central Canadian Arctic (Fig. 3-1). Dens were surveyed throughout a 49,900 km^2 area centered near Lac de Gras (64^0 27'N, 110^0 35'W; Fig. 3-1), where diamond exploration and mining activity has recently expanded. Spruce (*Picea mariana, P. glauca*) occurs in the most southwesterly portion of the study area and gives way to open tundra in the northeast (Timoney *et al.* 1992). Standing water and exposed bedrock are common with eskers, kames, and other glacial deposits scattered across the landscape.

The Caribou-Wolf System

Most females in the Bathurst caribou herd migrate onto the tundra by late April (Gunn *et al.* 2002; Fig.3-1). They reach calving grounds by early June, and parturition usually peaks by 15 June (Gunn *et al.* 2002). Calves begin to travel with the herd by one week of age (Kelsall 1968). The movement patterns of males are less well documented, but they frequent areas near calving grounds by mid-June (Heard *et al.* 1996; Gunn *et al.* 2002). After calving, female Bathurst caribou generally travel south from calving grounds and then move northwest parallel to tree line. The rut usually takes place at tree line in October (Gunn *et al*. 2002). Winter range use of the Bathurst herd varies among years ranging through the boreal forest, forest-tundra transition zone south of Great Bear Lake to southeast of Great Slave Lake, with some caribou wintering on the tundra (Gunn *et al*. 2002; Thorpe *et al*. 2001).

During winter, wolves preying on Bathurst caribou do not maintain territories. Instead, they follow the caribou throughout the herd's range (Walton *et al.* 2001; Musiani 2003). However, from May through August (denning period) their movements are limited by the need to return food to dens for pups, which are usually born between mid May and early June. Heard and Williams (1992) suggested that the timing of caribou migration results in wolves maximizing access to migrating caribou by selecting den sites that are closer to tree line than to caribou calving grounds. Furthermore, because of caribou movement patterns, all denning tundra wolves are separated from the main caribou herds by several hundred kilometers at some time each summer (Williams 1990; Frame *et al.* 2004).

A few muskoxen (*Ovibos moschatus*) occur in the north and eastern portions of the study area (Fournier and Gunn 1998) and may supplement the diet of some wolf packs. Occasionally moose are seen in the southern extent of the study area, but their densities are low (D. Cluff, unpublished data). Other alternate prey includes waterfowl and other ground nesting birds, eggs, rodents, and hares (Kuyt 1972; Williams 1990; P. Frame, unpublished data).

Methods

Locating Dens

Fixed wing aircraft were used to locate active wolf dens in late May – early June 1996 – 2003. Dens were initially found from a database of historic wolf dens maintained by the Government of the Northwest Territories (GNWT) or by investigating reports provided by other researchers (Cluff *et al*. 2002). From June 1997 to 2003 (excluding 2000), 90 individual wolves were captured by helicopter net-gunning. After being captured, wolves were immobilized and fitted with radio-collars (Walton *et al*. 2001). Fixed wing aircraft were then used to relocate radio-collared wolves at dens in spring. Known den sites were also surveyed for activity each year.

Dens were considered active if wolves were observed there during the spring survey flight. Reproduction was often confirmed 1-2 weeks later during capture efforts or through ground-based den observations.

Pup Counts

Pups were counted in August or September either by flying over known den sites or relocating radio-collared adults with fixed wing aircraft and counting the accompanying pups. Aerial counts were supplemented with ground observations when possible. The lack of trees on the barrens allowed for reliable ground and aerial counts of pups by experienced observers.

Caribou Monitoring

Caribou location data were collected via satellite radio telemetry (Fancy *et al*. 1989) from April 1996 through December 2003 as part of ongoing GNWT research and monitoring of the Bathurst herd (Gunn *et al*. 2002). Female caribou were captured via helicopter net-gunning (Gunn *et al.* 2002). During calving and post calving (early to late June), satellite collars recorded one location per day (Gunn *et al*. 2002). The rest of the year one location was taken every five days (Gunn *et al*. 2002), except for July and August 2003 when one location was taken per day. Locations of satellite-collared caribou were obtained by Service Argos Inc. (Landover, Maryland, U.S.A.).

Regression Variables: The date range that caribou began migrating both north and south and the distance of migration routes from dens were assumed to influence caribou availability to wolves and subsequently, late summer pup numbers. Migration variables from caribou location data were calculated using ArcView Geographic Information System (GIS) software (Environmental Systems Research Institute Inc., Redlands, California, U.S.A.).

We calculated the mean (SE) Julian date of migration onset for all satellite-collared caribou both seasons of each year during the study (Table 3-1.) The beginning of the northern migration in spring was defined when caribou were $\geq$ 50 km from tree line and consecutive locations indicated directed movement. Southern migration was considered to begin when consecutive locations showed uninterrupted directed movement away from calving grounds.

To estimate caribou migration routes for both northern and southern travel, consecutive locations of individual radio-collared caribou were connected with a straight line. We then measured the distance from each wolf den to the closest point along each caribou migration line. We calculated the mean (SE) distance to caribou migration lines for each den and used this measure as the distance to migration route variable (Table 3-1).

Anthropogenic Landscape Features

Human activity in the study area was related to mineral exploration and extraction, ecotourism, fishing, and hunting. We used relevant portions of a GIS data layer of human activity sites in the study area originally compiled by Johnson *et al.* (2005). The location and year of mining and exploration activity were compiled from Federal and Territorial government records. Outfitting camp locations were taken from the GNWT Parks and Recreation Operator database. GNWT personnel provided coordinates of winter road camps (Johnson *et al*. 2005).

To decrease the probability of finding no effect of development when one does exist we generated disturbance indices (primary, secondary, and maximum) that ranked anthropogenic features at three levels of intensity. To calculate these indices, each human feature was assigned a numeric value based on its assumed impact to wolves. In the primary index, fishing and hunting lodges, off-season winter road maintenance camps, and the Misery pit haul road were all given a score of five because the true impact to wolves is unknown, but likely similar to each other, and considerably less than mining activity. Mining exploration sites vary in intensity, with the most advanced having infrastructure similar to functional mines but with less activity. Consequently these sites were given a score of eight. Active mines were given a score of 10 because the infrastructure footprint is considerable, there are various degrees of truck and other heavy equipment traffic, a steady flow of incoming aircraft, and an average of five rock blasts per week in mine pits.

For our secondary disturbance index, the effect of mining activity was considered to be a magnitude greater (exploration camps 80, active mines 100) than recreation sites (including winter road camps and the Misery Pit haul road), which retained a score of five. For our maximum index, we considered all sites equal and assigned each a relatively high value of 100.

Each den was buffered with a simulated circular summer range of 1130 km^2 (19 km diameter), which was equal to the average summer range of female tundra wolves (Walton *et al*. 2001). The values of all human features within the simulated wolf home ranges were summed, and distance was incorporated into the disturbance index by multiplying the summed score by the inverse of the distance (km) from the den to the nearest disturbance, thus generating a final disturbance index for each den given the three sets of disturbance values.

Data Analysis

To determine which variable most influenced late summer pup numbers we used a cross-sectional time-series regression (Stata Corporation, College Station, Texas, U.S.A.). Independent variables used in the regression included (*i*) distance from each den to the mean estimated caribou migration route for both northern and southern migrations, (*ii*) mean start date of northern and southern migration, and (*iii*) each of the three disturbance indices for each den. Each den's annual pup count was treated as an individual observation and then grouped by year. The cross-sectional time-series analysis adjusts the degrees of freedom to account for some dens being observed in multiple years and therefore not being strictly independent samples (Stata 2003). Because this analysis has implications for environmental impact assessment, *P*-values of ≤ 0.1 were considered to be significant in our statistical model (Steidl *et al*. 1997).

Results

Wolf Dens

The mean number of dens surveyed per year (1996 – 2003) was 10 (range 7–14; Table 3-1). During the study, 80 observations were made at 40 dens (mean 2 observations/den, range 1 – 7).

Pup Counts

The mean date pups were counted each year was 19 August (Julian 231; range 2 August - 5 September, Julian 214 – 248). The mean number of pups/den (SE) ranged from 0.6 (0.37) in 2001 to 4.1 (0.92) in 2002 (Table 3-1). Overall, the mean number of pups/den was 2.7 (0.31, range 0 – 15).

Caribou Migration

The mean number of female caribou monitored each year was 11 (range 7 – 16; Table 3-1). The overall mean date of northern migration onset (1996 – 2003) was 3 May (Julian 124; range 21 April – 13 May, Julian 112 – 134; Table 3-1). The annual mean date of southern migration onset was 30 June (Julian 182; range 21 June – 12 July; Julian 171 – 194; Table 3-1). The mean annual northern migration routes of collared caribou averaged 86 km (range 53 – 119) from monitored wolf dens (Table 3-1). For southern migration, the mean annual routes of collared caribou were 64 km from monitored wolf dens (range 29 – 110; Table 3-1).

Anthropogenic Landscape Features

The number of active mine pits in the study area went from zero in 1996 to four in 2003 (Table 3-2). The mean annual development scores for study dens ranged from 0.46 to 1.70, 1.25 to 10.02, and 6.67 to 24.97 for the primary, secondary, and maximum disturbance indices respectively (Table 3-2).

Analysis

The results for all three disturbance indices were similar (R^2=0.21; Table 3-2) so we will discuss only the primary index hereafter. Both the mean distance from dens to northern (Z= -1.76, P= 0.079) and southern (Z= -3.03, P= 0.002) caribou migration routes were related to the number of pups/den in late summer (Table 3-3). The development score of dens did not significantly influence reproduction (Z= 0.30, P= 0.764; Table 3-3).

Discussion

Statistical Model

The relatively low R^2 of the model (Table 3-3) could be explained by the absence of information about factors that affect pup numbers other than caribou movements and human disturbance. Factors such as disease, age and experience of the parents, predation, or climate may influence reproduction as well. Thus, our analysis only differentiates the role of caribou movements from human disturbance on wolf reproductive success and not the ultimate influences of tundra wolf productivity. Ongoing investigations into the prevalence of disease in this wolf population (D. Cluff, GNWT, unpublished data) will further fill gaps in our understanding of other factors that influence reproductive success in the central barrens of mainland Canada.

Distance of Migration Routes from Dens

It is possible that the spatial separation of denning wolves from their main prey for part of summer influences reproductive success (Kuyt 1972; Heard and Williams 1992; Heard *et a*l. 1996). Heard and Calef (1986) and Heard *et al*. (1996) hypothesized that density dependent caribou herd expansion would make them available to denning wolves earlier in summer and thus improve pup survival which, barring other influences, may contribute to a numeric response in wolves. The results of this analysis indicate that the distance from wolf dens to caribou migration routes influences pup numbers more than the timing of caribou movements. However, density dependent range expansion could be the mechanism behind distribution of caribou migration routes (Messier *et al*. 1988). With increasing herd size, caribou expand their range, presumably to access adequate food resources (Messier *et al*. 1988). Such range expansion would bring more caribou closer to more dens, thus, on average, caribou availability to wolves and ultimately pup numbers should increase (Fuller 1989). Conversely, when caribou populations decrease, their range contracts (Messier *et al*. 1988) and thus, on average, migration routes will be farther from wolf dens and pup numbers will decrease.

Messier *et al*. (1988) believed caribou of the George River herd were unavailable to wolves during the 4 – 5 months pups are not mobile enough to travel with the pack. However, denning wolves in the Bathurst caribou range do travel long distances to encounter caribou during this sedentary period (Walton *et al*. 2001; Frame *et al*. 2004). Our analysis indicates an inverse relationship between the distance wolves must travel to caribou and the number of pups/den in late summer. This may be because the closer caribou migration routes are to a den, the less time and energy adult wolves have to spend securing food for pups. Shorter amounts of time between feedings would increase net energy intake for pups, which should better their chance of surviving to late summer. Further, adult wolves often feed regurgitated prey to pups. The less energy adults use traveling to and from caribou, the more food they will be able to transfer to pups upon return to the den.

Our analysis also indicated that the distance to southern migration routes has a greater influence on pup numbers than does distance to northern migration routes. This could be due to the food requirements of growing pups being proportional to body size and growth rate (Heard and Williams 1992). Growth rate is greatest when pups are 8 - 14 weeks old (Pulliainen 1965; Kuyt 1972), which generally corresponds with caribou southern migration. Therefore, greater distances to southern migrating caribou would limit nutrient availability during a critical period in pup development and have a more significant effect on pup numbers than would distances to northern migration routes, a time when growth rates are less. However, our results do indicate that distance to northern migration routes is an important determinant of pup numbers. It is conceivable that potential nutrient limitation, resulting from long time periods required for adults to commute greater distances to caribou migrating north, may be reflected in low pup numbers in late summer, albeit to a lesser degree.

Onset of Migration

Interestingly, the timing of migration onset has no significant influence on late summer pup numbers (Table 3-3). Each year, timing of caribou migration and travel routes vary (Kelsall1968; Kuyt 1972; Gunn *et al.* 2002; Table 3-1). In theory, caribou migration could begin one week earlier than in previous years, yet their route of travel could take them farther from most wolf dens than in the past. Thus, caribou availability to wolves would be low, resulting in low pup numbers regardless of whether migration began early. Conversely, in previous years when caribou began migrating one week later, they could have traveled such that the mean distance to wolf dens was close, thus both availability to wolves and pup numbers would be average.

Anthropogenic Landscape Features

The results of this study indicate that development in the study area is not yet having a negative impact on late summer pup numbers. Throughout North America, wolf populations reproduce successfully in areas with more human development (i.e., roads, railways, etc.) than is currently present in the central barrens (Fuller 1989; Mech 1989; Thurber *et al*. 1994; Thiel *et al*. 1998; Hebblewhite *et al*. 2002; U. S. Fish and Wildlife Service *et al*. 2004). Although human caused mortality can influence wolf numbers in these areas, local populations do persist when adjacent unexploited core populations exist (Fuller 1989; Mech 1989; Boyd and Pletscher 1999). Fuller and Keith (1980) found that development did not negatively affect wolves in an area undergoing intensive oil development in NE Alberta, and wolves still occur in that region (James and Stuart-Smith 2000). However, it is possible for development to increase in an area, such that wolves are excluded (Thiel 1985; Jensen *et al*. 1986; Mech *et al*. 1988; Hebblewhite *et al*. 2002). This in turn could create unbalanced predator-prey systems and influence ecosystem processes (Ripple and Beschta 2003; Hamback *et al*. 2004).

At present the central Arctic remains inaccessible by road except in winter and then lack of services along the route limits public use. There are approximately 61 km of privately maintained all season road in the study area (Johnson *et al*. 2005). Thiel (1985), Jensen *et al*. (1986), and Mech *et al*. (1988) found that wolf populations declined in areas with average road densities greater than 0.6 km/km^2. In our study area road density during the denning period was 0.001 km/km^2. Additionally, the only year-round residences in the study area are associated with mining operations. Any activity on the land takes place within tens of kilometers of mines, decreasing as distance from the main site increases. Thus, while some individual dens may be influenced by mining, exploration, or recreation activity, our results indicate the majority are not.

While anthropogenic development is not currently having a direct impact on wolf productivity in the study area, it is possible there will be indirect affects. Johnson *et al*. (2005) used a resource selection model (Manly *et al*. 2002) to infer population viability of large mammals in a region that contains our study area at its center. They found caribou avoid areas of disturbance in the post-calving period (late June through August). Nellemann and Cameron (1998) found that female-calf pairs displayed sensitivity to surface development. If females with calves are more sensitive to disturbance (Nellemann and Cameron 1998) resulting in avoidance of development areas (Johnson *et al*. 2005), then as the central Arctic is further developed, migration routes may change such that the distance wolves have to commute to and from herds becomes great enough to impact pup numbers. While the role of wolf predation in limiting caribou populations has often been debated (Bergerud 1980, 1983; Messier *et al*. 1988), this unresolved debate implies the importance of the wolf as a predator on caribou in the Arctic. Therefore, decreased productivity in wolves could affect their population size (Fuller 1989), which would change caribou predation rates, and the entire central Arctic ecosystem could be negatively affected (Terborgh 2001; Ripple and Beschta 2003; Hamback *et al*. 2004).

Continued Monitoring of Wolves, Caribou, and Development

Exploration and development is continuing in the central Arctic of Northwest Territories and Nunavut. While current levels of development are not yet having a measurable effect on late summer pup numbers, the threshold where wolves will begin to respond numerically is unknown. The potential for indirect effects of disturbance on wolf reproductive success exists, such that changes to caribou movement patterns could reduce the availability of prey for wolves during the critical summer months. Therefore, we suggest continued monitoring of wolf reproduction, caribou movements, and human development so land use practices can be monitored and assessed in the long-term. Furthermore, it is possible that the decline of the Bathurst caribou herd (Government of the Northwest Territories 2004) in consort with measurable avoidance by caribou of surface development (Johnson *et al*. 2005) could reduce prey availability and adversely affect wolf numbers.

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Table 3-1. Summary of annual caribou migration parameters used in an analysis of factors influencing late summer pup numbers at wolf home sites in the central Arctic of mainland Canada (mean values (SE)).

Year	# Dens	Mean Pups/Den (SE)	# Caribou	Mean Julian Date of Migration Onset		Mean Distance (km) Dens to Migration	
				Northern (SE)	Southern (SE)	Northern (SE)	Southern (SE)
1996	7	3.4 (0.69)	7	117 (3.64)	171 (1.41)	53 (3.32)	42 (5.46)
1997	8	4.0 (0.76)	7	121 (4.61)	178 (0.46)	54 (8.89)	29 (3.70)
1998	11	3.1 (0.73)	7	112 (3.56)	173 (1.34)	82 (11.54)	53 (4.22)
1999	7	3.0 (0.98)	14	129 (0.97)	179 (1.37)	90 (21.10)	58 (8.90)
2000	12	3.8 (1.19)	13	121 (1.41)	184 (1.91)	103 (7.95)	61 (8.11)
2001	14	0.6 (0.37)	13	129 (0.76)	194 (1.35)	91 (8.27)	110 (3.19)
2002	10	4.1 (0.92)	16	134 (0.93)	185 (2.08)	75 (5.77)	65 (10.19)
2003	11	1.3 (0.49)	12	131 (1.97)	179 (1.66)	119 (14.24)	60 (9.70)
Mean	10	2.7 (0.31)	11	124 (0.80)	182 (0.72)	86 (4.25)	64 (3.56)

Table 3-2. The number of human landscape features from 1996 to 2003 in three categories and three development indices (Primary, Secondary, and Maximum) occurring in a 49,900 km^2 area of the central Arctic of mainland Canada. For the primary index, recreation sites were scored 5, exploration camps 8, and active mines 10. For the secondary index, recreation sites again were scored 5, exploration 80, and active mines 100. For the maximum index all disturbance was scored 100. Indices were generated by summing all scores in a simulated circular tundra wolf summer range (Walton *et al*. 2001, 1100 km^2, 19 km radius) around each den and multiplying by the inverse of the distance (km) to the nearest disturbance.

Year	Recreation*	Exploration Camps	Active Mines	Primary Index Mean (SE)	Secondary Index Mean (SE)	Maximum Index Mean (SE)
1996	26	12	0	0.57(0.15)	1.25(0.76)	9.61(3.05)
1997	26	12	0	0.46(0.21)	3.38(2.18)	6.67(2.76)
1998	26	12	1	0.76(0.38)	5.21(3.87)	11.05(4.58)
1999	26	17	1	0.91(0.59)	6.48(6.14)	13.00(6.73)
2000	26	16	1	0.75(0.37)	4.21(3.35)	11.50(4.42)
2001	27	15	2	1.03(0.41)	7.09(3.66)	14.22(4.95)
2002	27	15	3	1.31(0.68)	9.05(5.10)	18.29(9.43)
2003	27	14	4	1.70(0.70)	10.02(6.56)	24.97(8.23)

*Hunting and fishing lodges, off-season winter road maintenance camps, Misery pit haul road

Table 3-3. Results of cross-sectional time-series regression model evaluating the influence of caribou movement parameters and human development on late summer wolf pup numbers. Eighty samples of 40 dens in an area of 49,900 km^2 were considered for the period 1996-2003.

	Primary Index		Secondary Index		Maximum Index	
Variable	Coefficient(+-SE)	P>z	Coefficient(+-SE)	P>z	Coefficient(+-SE)	P>z
Distance to Southern Migration Routes	-0.035 (0.012)	0.002	-0.036 (0.012)	0.002	-0.035 (0.012)	0.003
Distance to Northern Migration Routes	-0.013 (0.008)	0.079	-0.013 (0.008)	0.083	-0.013 (0.008)	0.077
Date of Southern Migration Onset	0.025 (0.065)	0.707	0.025 (0.065)	0.704	0.025 (0.065)	0.708
Date of Northern Migration Onset	-0.013 (0.050)	0.800	-0.013 (0.050)	0.798	-0.012 (0.050)	0.803
Development Index	0.057 (0.190)	0.764	0.008 (0.211)	0.711	0.004 (0.015)	0.791
Constant	3.213 (9.960)	0.747	3.168 (9.923)	0.750	3.200 (9.975)	0.748
Model Fit, R^2	0.21		0.21		0.21	

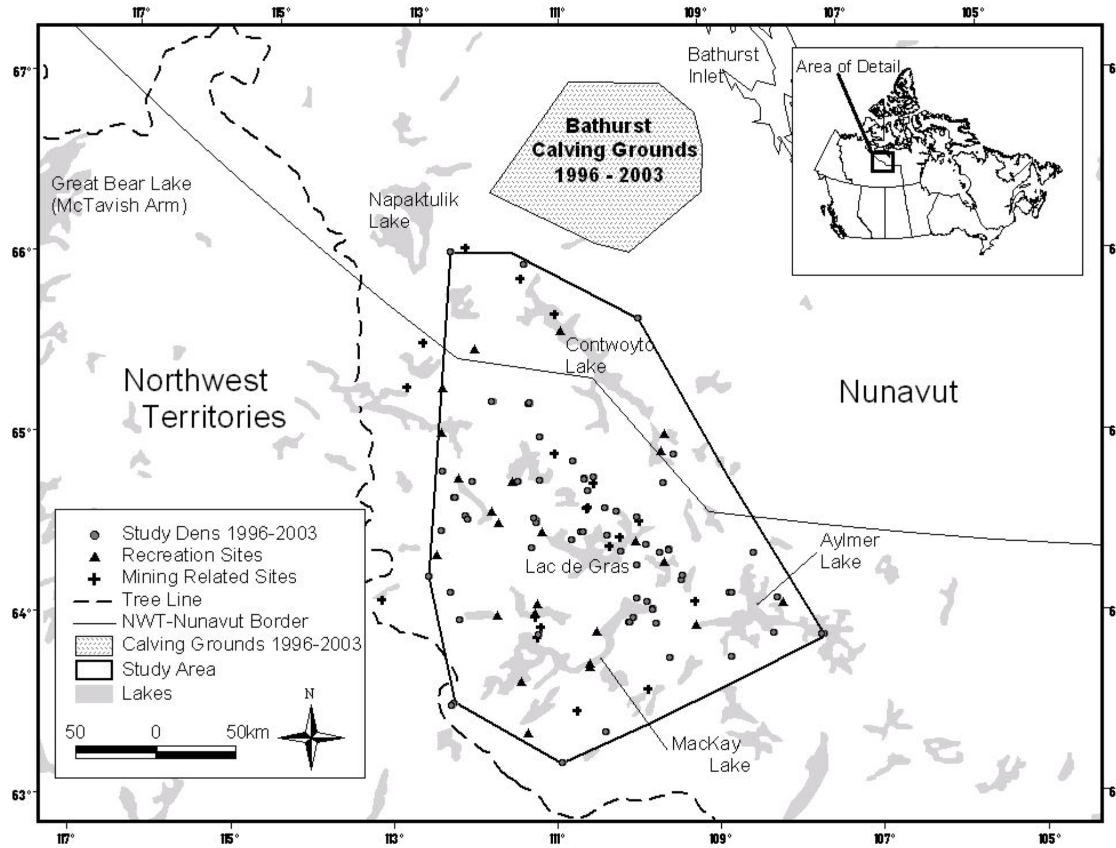

Figure 3-1. Map of wolf dens, caribou calving grounds and human development relevant to a study of wolf reproductive success in the central Canadian Arctic.

Chapter 4

Response of Wolves to Experimental Disturbance at Den and Rendezvous Sites in the Central Canadian Arctic

Introduction

Minimizing the occurrence and impacts of human disturbance at wolf (*Canis lupus*) dens and rendezvous sites (home sites) is an ongoing issue for land managers throughout North America (Chapman 1977; Golder Associates 1997; Anonymous 2000; Paquet and Darimont 2002; Smith *et al*. 2004). Some authors have indicated that the seriousness of human disturbance to wolves is ultimately a human judgment and some people may consider any modification of wolf behavior due to human activity undesirable (Chapman 1977; Paquet and Darimont 2002). Others report wolves as being a resilient species (Weaver *et al.* 1996; Thiel *et al*. 1998) and consider impacts to populations to be more important than behavior changes of individual wolves.

Interestingly, these two views are closely related. Presumably, alterations to wolf behavior resulting from home site disturbance could impact pup survival by reducing resource availability (Fuller 1989) via changes in hunting patterns of adult wolves (Paquet and Darimont 2002). Alternatively, pups may be moved to secondary or alternate den sites, which could be sub-optimal, resulting in reduced pup survival. Furthermore, direct mortality may result from a home site move (Smith 1998).

Some wolves will move pups in response to disturbance (Chapman 1977; Ballard *et al*. 1987, Smith 1998), and others tolerate human activity near home sites (Chapman 1977; Thiel *et al*. 1998). The factors that influence whether pups are moved in response to disturbance are not well studied, although intensity and duration of the disturbance (Chapman 1977) as well as the "disturbance history" or amount of ambient background disturbance that individual wolves are exposed to, are involved (Chapman 1977; Paquet and Darimont 2002). To date, there has only been one study that used an experimental approach to investigate wolf home site disturbance, however only two dens were included in that study (Chapman1977).

The recent development of a diamond mining industry in the vast tundra region of the central Canadian Arctic has raised concerns about the cumulative effects of industrial development and tourism on wildlife populations there (Gau and Case 1999; McLoughlin *et al*. 2000; Mulders 2001; Walton *et al*. 2001; Cluff *et al*. 2002; Griffith *et al*. 2002; Gunn *et al*. 2002; Johnson *et a*l. 2005). Along with the proposed removal of wolves from the Endangered Species List in the United States (U. S. Fish and Wildlife Service 2004) and increasing contact with humans throughout North America (Paquet and Darimont 2002; Fritts *et al*. 2003) knowledge of how wolves respond to human disturbance at or near home sites is of increasing importance. In this study we applied a standardized low intensity experimental disturbance treatment at 12 wolf home sites in a portion of the central Canadian Arctic that is being developed for diamond extraction, sport hunting and recreational fishing. Our objectives were to determine if (*i*) home sites along a gradient of background disturbance would be moved in response to our disturbance treatment, (*ii*) home site disturbance influences reproductive success, by comparing late summer pup numbers at disturbed and undisturbed home sites, (*iii*) disturbed sites were re-used the following year, and finally, (*iv*) to make management recommendations based on our results.

Study Area

This study was conducted in the low arctic tundra and forest-tundra transition zone of the central Canadian Arctic (Fig. 4-1). Disturbed dens occurred in a 24,400 km^2

area near Lac de Gras, Northwest Territories, Canada (64^{0}27’N, 110^{0}35’W) where diamond exploration and mining activity have recently expanded. Spruce (*Picea mariana, P. glauca*) grows in the southwestern portion of the study area and becomes open tundra in the northeast (Timoney *et al.* 1992). Standing water and exposed bedrock are common with eskers, kames, and other glacial deposits scattered across the landscape. During the wolf denning period this area is only accessible by aircraft.

The Caribou-Wolf System

Wolves in our study area follow the seasonal movements of their main prey, the migratory barren-ground caribou (Kuyt 1972; Walton *et al.* 2001; Mussiani 2003). The study area is located in the range of the Bathurst caribou herd. Most females in this herd migrate out of tree line onto the tundra by late April (Gunn *et al.* 2002). They reach calving grounds by early June, and most have given birth by 15 June (Gunn *et al.* 2002). Calves begin to travel with the herd by one week of age (Kelsall 1968). The movement patterns of males are less documented, but they frequent areas near calving grounds by mid-June (Heard *et al.* 1996; Gunn *et al.* 2002). After calving, female Bathurst caribou generally travel south from calving grounds and then move northwest parallel to tree line. The rut usually takes place at tree line in October (Gunn *et al*. 2002). Winter range of the Bathurst herd varies between years ranging through the boreal forest, forest-tundra transition zone south of Great Bear Lake to southeast of Great Slave Lake, with some caribou wintering on the tundra (Gunn *et al*. 2002; Thorpe *et al*. 2002).

In winter, study wolves do not maintain territories; instead they follow caribou throughout the herd's range (Walton *et al.* 2001; Musiani 2003). However, from May through August while tending dens, a pack's movements are limited by the need to return food to pups, which are born between mid May and early June. Heard and Williams (1992) suggest that because of the timing of caribou movements, wolves maximize access to migrating caribou by selecting den sites that are further south, closer to tree line than to caribou calving grounds. Yet, because of caribou movement patterns, all tundra denning wolves are separated from the main caribou herds by several hundred kilometers at some time during summer (Williams 1990; Frame *et al.* 2004).

A few musk oxen (*Ovibos moschatus*) occur in the north and eastern portions of the study area (Fournier and Gunn 1998) and may supplement the diet of some wolf packs. Occasionally moose (*Alces alces*) are seen in the southern extent of the study area, but their densities are low (D. Cluff, GNWT, personal observation). Additional alternate prey includes waterfowl and other ground nesting birds, eggs, rodents, and hares (Kuyt 1972; Williams 1990; P. Frame, unpublished data).

Methods

Locating Home Sites

Dens were initially located from a database of historic wolf dens maintained by the Government of the Northwest Territories (GNWT) or by investigating reports provided by other researchers (Cluff *et al*. 2002). From June 1997 to 2003 (excluding 2000), 90 individual wolves were captured by helicopter net-gunning, chemically immobilized, and fitted with radio-collars as part of ongoing research in this population (Walton *et al*. 2001; Cluff *et al*. 2002; Frame *et al*. 2004). In spring (late May – early June), we used fixed wing aircraft to relocate radio-collared wolves and to survey known den sites for activity. Dens were considered active if wolves were observed there during the survey flight.

Disturbance Treatment

Active home sites were observed from concealed observation points with 60x spotting scopes for a period prior to each disturbance. The disturbance treatment was replicated on three consecutive days and consisted of an observer walking to the site and remaining there for 5-8 minutes. While at the home site, the intruder described reactions of wolves into an audio recorder noting time of first response, time of each vocalization, and the time the treatment ended, as well as details of response behavior. Location of the intruder when wolves first responded and the den entrance or estimated home site center were recorded with a Global Positioning System (GPS) receiver. The intruder’s retreat followed the same track as their approach. A second observer remained at the observation point and recorded the wolves’ response through a Nikon field imaging system (Nikon Canada, Mississauga, Ontario, Canada) attached to a 60x spotting scope and digital video-recorder. The two observers were in contact by radio during the disturbance treatment.

Reproductive Success

Pups were counted in late summer 2002 and 2003 by flying over known dens sites or relocating radio-collared adults with fixed wing aircraft and counting the accompanying pups. Aerial counts were supplemented with ground observations when possible. The lack of trees on the tundra allowed for reliable ground and aerial counts of pups by experienced observers. We estimated the age of pups by comparing photos and video of study animals with images of known age pups taken at one-week intervals (Wildlife Science Center, Forest Lake, Minnesota).

Background Disturbance Index

Human activity in the study area was related to mineral exploration and extraction, ecotourism, fishing, and hunting. Johnson *et al.* (2005) compiled a GIS data layer of human activity sites in the study area, which was used for a population viability analysis of large mammals in the region. We used relevant portions of this same data layer for consistency among studies. The locations of mining and exploration activity were compiled from Federal and Territorial government records. Outfitting camp locations were taken from the GNWT Parks and Recreation Operator database. GNWT personnel provided coordinates of winter road camps (Johnson *et al*. 2005). We generated a disturbance index for each den in the study area by assigning each human feature type a numeric value based on its assumed impact to wolves (see Chapter 3). Fishing and hunting lodges, off-season winter road maintenance camps, and the Misery Pit haul road were all given a score of five because their true impact to wolves is unknown, but likely similar to each other, and considerably less than mining activity.

Mining exploration sites vary in intensity, with the most advanced having infrastructure similar to functional mines, but with less activity. Consequently these sites were given a score of eight. Active mines were given a score of 10 because the infrastructure footprint is considerable, there are various degrees of truck and other heavy equipment traffic, a stream of incoming aircraft, and about five rock blasts per week in mine pits.

Each den was buffered with a simulated circular summer home range of 1130 km^2 (19 km diameter), which is equal to the average of female tundra wolves (Walton *et al*. 2001). The values of all human features within the simulated wolf home ranges were summed, and distance was incorporated into the disturbance index by multiplying the summed score by the inverse of the distance (km) from the den to the nearest disturbance, thus generating a final disturbance index for each den.

To quantify the intensity of wolves' response to the disturbance treatment, we added the number of adult wolves present at the site to the duration of responsive vocalizations (in minutes) then divided this by the total time of the disturbance (in minutes). In this way, each disturbance treatment was assigned a wolf response intensity value.

Analysis

We used a Mann-Whitney *U* test (SPSS Inc., Chicago, Illinois, U.S.A.) to determine if our disturbance influenced reproductive success. The Pythagorean theorem was used on Universal Transverse Mercator coordinates to calculate the distance between the intruder and the den when wolves first responded (response distance). We compared differences in response distances and intensity for subsequent disturbances using

Kruskal-Wallis tests. Linear regression was used to test for relationships between response distance and intensity relative to a dens' background disturbance index, as well as response intensity relative to the age of pups. We compared the frequency of re-use for experimentally disturbed dens with undisturbed dens using a Chi-square test.

Logistic regression models were used to test for relationships between the age of pups and background disturbance index with whether a home site was relocated in response to our disturbance.

Results

Disturbance Treatment

We disturbed 12 individual home sites over summers 2002 (n= 6) and 2003 (n= 6). Adults moved pups in response to our disturbance at three sites each year (50%). When these sites were abandoned, it was done so after the second disturbance, however two of five pups may have been moved after the first disturbance at one den. Five of six disturbed sites where pups were $\geq$ 5 wks old were moved (Table 4-1). One home site with 11, 6 wk old pups was not moved. However, one of three sites where pups were 4 wks old was moved. The mean distance from field camps to home sites was 2.12 km (0.40 SE; range 0.78 – 4.70) and did not influence whether a site was moved in response to our experimental disturbance (U= 14.00; P= 0.59). The mean distance of our observation points from home sites was 683 m (108 SE; range 300 – 1600), which did not influence if sites were moved (U= 18.00; P= 1.00). We observed home sites for 388.5 h (n= 12; mean 32.37; 4.12 SE; range 8.36 – 58.26).

The most common response of wolves to the disturbance treatment was to bark and howl at the intruder, occurring during 24 of 26 (92%) disturbances. The two instances that wolves did not vocalize happened at the same den. On three occasions (11%), the wolves' initial response was to move towards the intruder. During the remaining 21 instances of vocalization, wolves moved away first. Wolves left the immediate area during the disturbance 42 % (n=11) of the time. For the 15 times wolves remained in the area, they checked on pups 11 times (73%) immediately after the disturbance ended. Adults were not present during the second and third treatments at the site with 11 pups, so they were not included in the analysis. However, adults were observed with these pups periodically during our observations. Home sites were just as likely to be re-used the following year whether or not they were disturbed (n= 24; X^2= 0.667; df= 1; P= 0.41).

The response distance for subsequent disturbance replicates was similar (X^2= 1.31; P= 0.52); therefore we calculated the mean response distance for each home site for use in our regression analysis. Likewise, the response intensity between replicates was similar (X^2= 0.52; P= 0.77) so again, we used the mean at each home site for our regression analysis.

Reproductive Success

Pups at disturbed home sites ranged in age from 2 to 12 wks (Table 4-1). Because the overall mean number of pups/pack was higher in 2002 than it was in 2003 (U= 14.00; P= 0.006; Table 4-2), we analyzed each year separately. In 2002, the mean number of pups at experimentally disturbed home sites was similar to that of undisturbed sites (U=

8.50; *P*= 0.91; Table 4-2). While there were fewer pups/pack overall in 2003, as in 2002, the mean at disturbed and undisturbed sites was similar (*U*= 7.50; *P*= 0.18).

Background Disturbance Index

The number of active mine pits in our study area increased from three in 2002 to four in 2003. With the opening of the fourth mine pit, exploration sites correspondingly decreased from four in 2002 to three in 2003. Other sites in our disturbance index (n= 20) included outfitters camps, off-season winter road maintenance camps, and the 29 km Misery Pit haul road. The mean disturbance score at treated dens (n= 12; 0.56, 0.25 SE; range 0.00 – 2.14) was similar (*U*= 46.00; *P*= 0.14) to that at untreated dens (n= 12; 2.12, ± 0.77; range 0 – 7.5).

Regression Analysis

Our regression of response distance for dens against the corresponding background disturbance index suggests no significant relationship (R^2= 0.10; *F*= 1.125; *P*= 0.31). Similarly, there was no relationship between wolf response intensity and age of pups (R^2= 0.01; *F*= 0.100; *P*= 0.76). However, there appears to be negative relationship (R^2= 0.32; *F*= 4.721; *P*= 0.06) between response intensity and background disturbance. The logistic regression using age of pups to predict if sites were moved or not, provided a better fit (R^2= 0.645; *P*= 0.09) than the one that used the background disturbance index (R^2= 0.092; *P*=0.378).

Discussion

Disturbance Treatment

All 12 disturbed packs tolerated our intrusion into their home site the first time. Those that moved did so after the second disturbance, similar to what Chapman (1977) documented in his review of reports of wolf home site disturbance. At several sites we watched adults attempt to lead young pups (3 - 4 wks old) away from their dens between subsequent disturbances, but the pups would get distracted by each other and start to play, or become apprehensive and return to the den. It has been reported that adults will carry pups as old as 5 wks (Packard 2003). We observed a mother wolf carry a 4 wk old pup about 5 m from one den hole to another, however we saw another mother wolf struggle and fail to lift a 3 wk old pup. These observations indicate there is variation among mother wolves and some may not be able to physically move pups once they are more than a few weeks old. At one site we observed two 12 wk old pups being led away from a home site in response to our disturbance. It took 1.5 h to travel 1.25 km after which the wolves went out of sight. Along the way the pups were playing and sometimes would stop to rest. They appeared oblivious to the sense of urgency implied by the adults' attempts to keep them moving, however they did continue to follow. While the decision to move pups is probably that of the mother, the behavior of the pups may also influence if a home site is abandoned or not.

Our logistic regression suggests that the age of pups is an important factor affecting if a disturbed site is moved or not. This is most likely because pups become more mobile and develop better muscle control, as they get older (Packard 2003). At four of the six disturbed sites that moved, pups had already traveled to rendezvous sites up to 8 km from their natal den, which further supports our results that age of pups is the best predictor of whether or not a site is moved in response to low intensity disturbance. Our results indicate that pups ≤ 3 wks are not moved, those between 4 – 6 wks may or may not be moved, and that pups > 6 wks old are always moved in response to low intensity disturbance.

The amount of background disturbance wolves were exposed to did not influence whether home sites were moved. This is contrary to other reports and suggestions that wolves habituate to human activity near home sites (Thiel *et al*. 1998; Paquet and Darimont 2002). One possible explanation for this could be the remoteness of our study area. While the amount of human activity taking place in this portion of the North has increased in the past decade, it is still quite low compared to other regions of wolf range where healthy populations exist (e.g. Fuller 1989; Mech 1989; Thurber *et al*. 1994; Thiel *et al*. 1998; Hebblewhite *et al*. 2002; U. S. Fish and Wildlife Service *et al*. 2004). Because of this, our study dens with the highest background disturbance index scores may not be exposed to human activity at a frequency that would result in habituation to this activity near home sites. However, the response intensity of wolves to our disturbance slightly decreased as the background disturbance in a pack’s summer range increased, suggesting some level of habituation, but the relationship is weak. However, if habituation is occurring in the study area, our results suggest it is not influencing whether a home site is moved in response to low intensity disturbance.

Reproductive Success

In North America, prey availability is the factor that most influences the reproductive success of wolves (Fuller 1989; Fuller *et al*. 2003). For wolves that den in the central Arctic, prey available to a pack is determined by the migration patterns of caribou herds (Heard and Williams 1992; Heard *et al*. 1996; Frame *et al*. 2004). In summer of 2003 the mean distance from study dens to caribou migration routes was greater than it was in 2002 (P. Frame, unpublished data) and probably explains the difference in mean pup numbers for these two years. Within a year, the low intensity disturbance treatment did not have a negative effect on late summer pup numbers. For our intrusion into wolf home sites to negatively impact reproductive success it would have to provoke a behavioral change in the whole pack such that food being provided to pups was reduced causing malnutrition and culminating in mortality. This could occur if adults either spent more time away from the den because of the disturbance and therefore returned less food to the pups, or if they spent more time at the den guarding pups which would prohibit them from hunting. Our observations of wolf 388 and others (Frame *et al*. 2004; D. Cluff, unpubl. data) demonstrate that foraging patterns (as indicated by home site attendance) were similar before and after our disturbance, therefore we assume this to be the case in general.

Another possible way for disturbance to impact reproductive success is if pups were moved and died while traveling to the new home site (Smith 1998). While this may have happened in individual packs that we disturbed, our results suggest no negative impact on pup numbers resulting from the disturbance. Furthermore, our late summer pup counts at disturbed dens were consistent with counts made earlier while we were at home sites to disturb them, suggesting no such mortality occurred.

Home Site Re-use

While the reasons wolves select home sites are not well studied (Ciucci and Mech 1992; Heard and Williams 1992), our results demonstrate that disturbed home sites were re-used just as often as undisturbed sites, suggesting that factors other than disturbance are more influential in predicting home site reuse. Tradition has been suggested as one reason wolves re-use home sites in multiple years (Murie 1944; Ballard and Dau 1983; Ciucci and Mech 1992). For instance, during seven years that we monitored dens in the study area, the Thonokeid Lake site was used consecutively from 1997 to 2001. During this time both breeders were radio-collared. In 2002, after using the same den for five years, the breeding female used a new den 14.5 km from the previous site. In 2003 the collared female had died and the breeding male’s new mate selected a den 9.5 km from the one used in 2002, and 6 km from the pack’s original den. During 2002 and 2003 the original den was inactive.

In the central Arctic, wolves are migratory and not territorial in winter, traveling on average between 265 and 510 km between winter range and den sites (Walton *et al*. 2001). At present, the degree of territoriality of these wolves in summer is unknown. However, the re-use of natal dens over consecutive years by the same breeding pair suggests some level of territoriality, such that newly formed breeding pairs do not occupy den sites of established packs. If this is the case, the re-use of traditional den sites the year after exposure to low intensity disturbance, is not surprising. Alternatively, a pack may choose a new site for unknown reasons, as demonstrated by the Thonokeid Lake wolves.

Summary and Management Recommendations

The frequency with which wolves moved from disturbed home sites increased with pup age. An important consideration then is at what age, and why, are pups most vulnerable. Theoretically, if human activity began near a wolf home site when the pups were > 6 wks old, they would likely be moved to a new site away from the disturbance. However, if pups were < 6 weeks old they may not be physically able to follow adults away from the disturbance and, if the activity were intense enough to keep adults away from the site for an extended period, the result could be pup mortality. While mortality may result as pups are being moved from a disturbed site (Smith 1998), pups are often moved without provocation after they reach 6 wks of age (Table 4-1). Therefore, we suggest that pups are more vulnerable to disturbance early in the denning period because of their immobility and the reluctance of adults to move them. Managers responsible for area closures around wolf home sites should consider the age of pups while placing restrictions on land use. Such restrictions should be strict early in the denning period, when pups are more vulnerable, but could be relaxed as the season progresses and pups get older.

It is of interest that our disturbance did not influence reproductive success or re-use of disturbed dens. It is possible that the intensity of our disturbance treatment was similar to that encountered naturally by wolves through interactions with other carnivore species, such as grizzly bears (*Ursus arctos*), in our study area (Frame 2003). Ballard *et* *al*. (2003) report that 14% of 108 documented interactions between wolves and grizzly bears took place near wolf home sites. If our disturbance was similar in intensity to these interactions, it is not surprising that there were no negative impacts to wolf reproductive success or re-use of sites, as wolves would have adapted resilience to such activity. However, our disturbance treatment was low in intensity (e.g., no loud noises, only one intruder) and short in duration. Perhaps a disturbance event of higher intensity that lasted longer would have negative effects on wolf reproductive success and site re-use, as reported elsewhere (Chapman 1977; Smith 1998).

With continued increases in mineral exploration, mining activity, recreational fishing, sport hunting, and a proposed all-weather road from Yellowknife, Northwest Territories to Bathurst Inlet, Nunavut, the likelihood of more intense disturbances near wolf home sites in the central Arctic will only increase. In a region where healthy wildlife populations are important to traditional lifestyles of Indigenous peoples (Thorpe *et al*. 2001), cumulative effects to wildlife must be considered during the planning phase of new development. Measures should be taken to limit human activity on the landscape during the portion of the year when wildlife is most vulnerable. In the case of wolves in the central Arctic, this would be the early denning period extending from mid May to early July. In addition to wolves, barren-ground caribou would benefit from limited human activity in the region during this period, which coincides with the calving season. The dates of early denning seasons will vary throughout wolf range, an important consideration when implementing our recommendations.

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Table 4-1. Number and age of pups and if they were moved or not in response to experimental disturbance at tundra wolf home sites in the central Canadian Arctic.

			Type of Home Site	
Site Name	No. Pups	Age of Pups (wks)	Den= D; Rendezvous= R	Moved (Y/N)
Haywood	Unknown	2	D	N
MacKay	7	2	D	N
Box Lake	6	3	D	N
West Afridi	5	4	D	N
Thonokeid	3	4	D	N
Lockhart	5	4	D	Y
SW LdG	3	5	D	Y
Hilltop	11	6	D	N
N Thon R	1	7	R	Y
Yamba	3	8	R	Y
W Aylmer	9	10	R	Y
S Aylmer	2	12	R	Y

Table 4-2. Mean number of pups per den in late summer at experimentally disturbed and undisturbed tundra wolf home sites in the central Canadian Arctic.

	Disturbed Sites	Undisturbed Sites	All Sites
Year	Mean Pups/Den (n*, SE)	Mean Pups/Den (n, SE)	Mean Pups/Den (n, SE)
2002	4.7 (3, 1.57)	4.5 (6, 0.99)	4.6 (9, 0.90)
2003	2.0 (5, 0.63)	0.7 (6, 0.67)	1.3 (11, 0.49)

* We were unable to obtain late summer pup counts at all disturbed sites because all packs did not contain radio-collared individuals thus we were unable to locate them after they moved from natal dens.

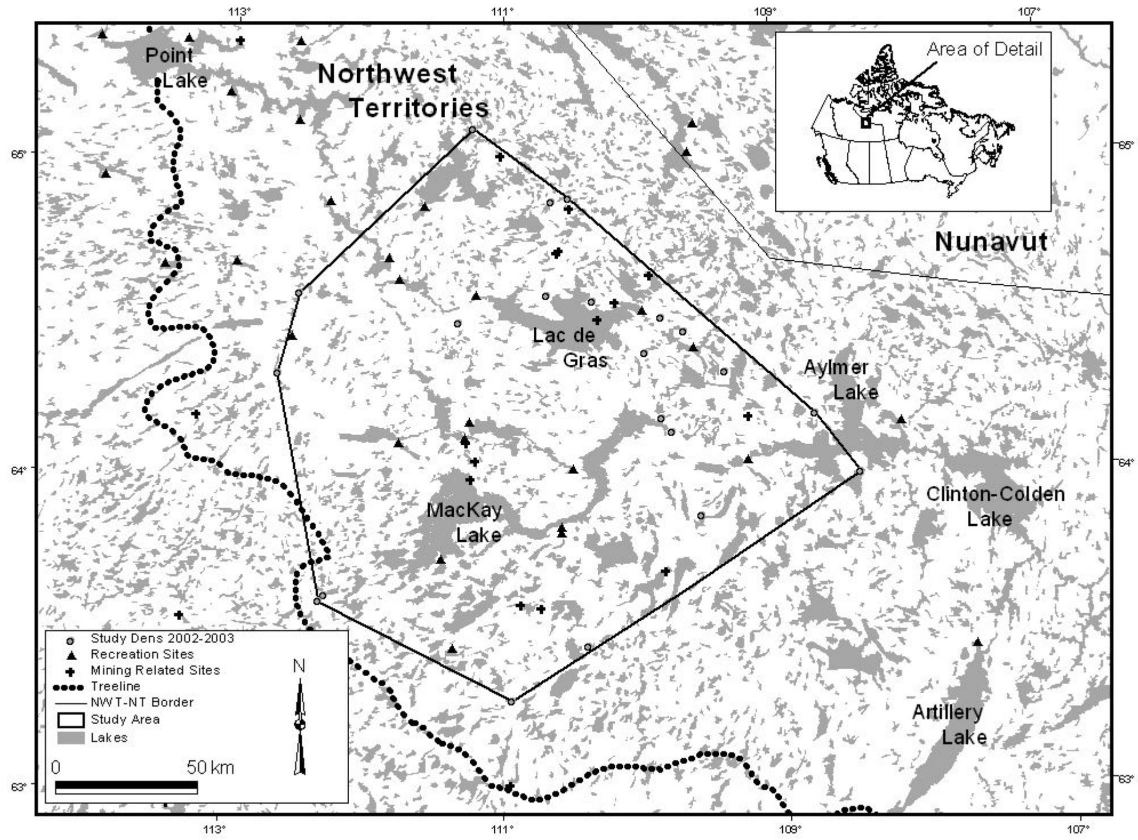

Figure 4-1. Map of the study area, wolf home sites, and human disturbance features considered in a study of the effects of experimental disturbance on wolf behavior and reproduction, in the central Canadian Arctic, summers 2002 – 2003.

Chapter 5

Summary and General Conclusions

The impact of disturbance and development on denning wolves (*Canis lupus*) is a management challenge throughout wolf range (Chapman 1977; Mech 1995; Mech *et al*. 1998; Smith 1998; Walton *et al*. 2001; Paquet and Darimont 2002). Prior to the current study nearly all conclusions about the effects of human activity on denning wolves were based on chance observations and the subjective analysis of the potential impacts (Chapman 1977; Theil *et al.* 1998; Fritts *et al*. 2003). Although some wolves are tolerant of disturbance near dens and rendezvous sites (Chapman 1977; Mech *et al*. 1998; Theil *et al*. 1998), others are not (Chapman 1977; Smith 1998; Chapter 4). It is likely that the frequency of intolerant responses is under reported therefore earlier conclusions about the impacts of disturbance to wolves could have been incorrect.

What constitutes an “impact” when considering disturbance to denning wolves? Pups may be moved from one site to another in response to disturbance, but this happens naturally during the summer anyway (Fritts and Mech 1981; Ballard *et al*. 1987; Chapter 4). Perhaps being forced to move will result in the death of pups that may otherwise have survived (Smith 1998). However, pup mortality also happens naturally through malnutrition because of low prey availability (Williams 1990; Chapter 3). So clearly, determining the “impact” of home site disturbance to wolves is complex (Fritts *et al*. 2003). Therefore, in this thesis I looked at the impacts of home site disturbance and industrial and tourism development on the reproductive success of wolves because it is a quantifiable measure with population level consequences (Fuller 1989). I was also able to look at how wolves are responding to background disturbance in their summer ranges and how this may influence wolf behavior and ultimately reproductive success.

It is important to note that in the only other experimental investigation of wolf home site disturbance, Chapman (1977) concluded that "the seriousness of human disturbance, is ultimately a human judgment and, as such, any alteration of the normal activities of wolves in summer may be judged by some to be undesirable." This statement presents an ethical component to home site disturbance that I did not touch on in the current study, but that deserves consideration for future research and in the development of management plans regarding wolves.

Earlier in this study I found that, although the amount of anthropogenic disturbance near wolf home sites in the central Arctic is increasing, it is not yet impacting wolf reproductive success (Chapter 3). Instead, prey availability, as expressed in distance from wolf home sites to caribou migration routes was more important (Chapter 3). Wolves appear to have adapted to seasonal caribou migration patterns, such that as prey availability near home sites decreases, wolves make long commutes to caribou herds and back (Chapter 2). Questions still remain regarding this behavior (e.g., frequency and prevalence of commutes, alternate prey availability), but ongoing research indicates most, if not all, breeding male tundra wolves make these foraging trips (D. Cluff, unpublished data).

While the impact of disease in this population is not known, wolf reproductive success appears to be most influenced by the distance from dens to caribou migration routes (Chapter 3). As such, the potential exists for anthropogenic development to indirectly influence wolves by causing changes in caribou movement patterns (Nelleman and Cameron 1998; Johnson *et al*. 2005). It is conceivable that climate change will influence caribou population size which could in turn influence wolf numbers (Mech

2000). Wolves are considered a keystone predator in other ecosystems, such that their absence allows ungulate herbivore populations to increase to unnatural levels, which impacts the vegetation upon which these grazers depend (Ripple and Beschta 2003). There is no reason to think that the central Arctic would respond differently to a reduction in wolf numbers. Therefore, human activities that impact wolf populations should concern wildlife and land use managers in the region because of the importance of this system in providing subsistence for First Nations communities in the area (Thorpe *et al*. 2001; Bielawski 2003).

The potential for human disturbance at wolf dens and rendezvous sites to impact wolf reproductive success is also a concern (Walton *et al.* 2001; Cluff *et al.* 2002; Chapter 4). The results of my disturbance experiment suggests that, although reproductive success at disturbed home sites was similar to that of undisturbed sites, wolf pups are most vulnerable and deserve more protection during their first six weeks of life. There may be some habituation of wolves to human activity in the study area, however it did not influence if pups were moved in response to experimental disturbance (Chapter 4). The age of pups at the time of disturbance did influence if they were moved or not. This finding led to the management recommendation that in places where wolf home sites are protected, the protection is more important when pups are young (< 6 weeks) and less mobile. However, as pups age, the restrictions on human activity can be relaxed. Although this work has answered some questions, there are others yet to be addressed, such as the frequency of pup mortality during moves in response to disturbance (Smith 1998) and if secondary sites are less suitable such that pup survival in affected.

As anthropogenic development in the central Arctic continues to increase, managers will be challenged to maintain the balance between critical ecosystem components such as wolves and caribou (Cluff *et al*. 2002; Chapter 3), and caribou and the plants they feed on (Griffith *et al*. 2002). For not only is ecosystem function in itself important, but there are several communities of First Nations people that rely on caribou herds for their subsistence (Thorpe *et al*. 2001; Bielawski 2003). For this reason alone, the Canadian public should be aware of the changes taking place in the central Arctic related to anthropogenic development, and the potential impacts of these changes.

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