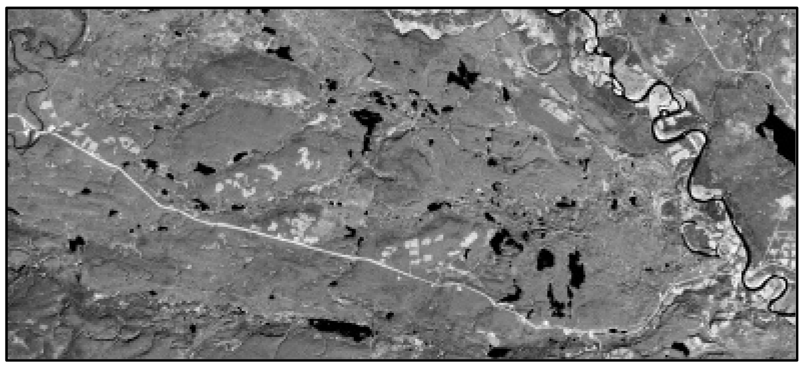
Development of a Threshold Approach for Assessing Industrial Impacts on Woodland Caribou in Yukon

Draft Report, ver. 2.1
November 2002



Prepared for:

Environment Directorate
Northern Affairs Program
345 - 300 Main Street
Whitehorse, Yukon Y1A 2B5

Prepared by:

Robert B. Anderson, M.Sc., P.Biol., R.B.Bio.
Simon J. Dyer, M.Sc., P.Biol.
Shawn R. Francis, M.Sc., P.Biol.
Elizabeth M. Anderson, M.Sc.

APPLIED ECOSYSTEM MANAGEMENT LTD.
100-211 Hawkins Street
Whitehorse, Yukon Y1A 1X3 Canada
Tel (867) 393-3793 Fax (867) 393-2247
Email: whitehorse@aemltd.ca
Web: www.aemltd.ca

SUMMARY

To date, no jurisdiction in Canada has established, implemented and enforced cumulative effects thresholds for industrial activity in woodland caribou range. Instead, guidelines and regulations have been put in place in an attempt to minimize and mitigate the impacts of individual development projects on caribou. Under this system of management, many caribou populations throughout the provinces are either the focus of concern or have been extirpated from former ranges. In some situations, caribou ranges have already been severely impacted and will require a great deal of effort, financial resources, and political will to return habitat effectiveness to an acceptable level. Yukon has a unique opportunity to develop and implement cumulative effects thresholds for caribou range prior to large-scale industrial development over significant areas. This must be initiated now if Yukon wishes to have healthy caribou populations in perpetuity.

The current report is intended to assess potential threshold approaches and recommend a methodology for setting industrial thresholds for woodland caribou range in Yukon. The criteria for recommending a threshold development strategy was that it: 1) be directly relevant to caribou ecology, 2) truly assess cumulative effects of known human influences on caribou, 3) be able to suggest a clear threshold, and 4) be usable and acceptable by a wide range of stakeholders.

Based on a literature review, experience from other jurisdictions, and consideration of the Yukon situation, it was concluded that the most appropriate method for developing cumulative effects thresholds for Yukon caribou range was the habitat effectiveness approach, whether it be based on a full habitat effectiveness model or simply a total zone of influence. This approach addresses the influence of industrial activity on caribou ecology, includes cumulative effects from several disturbance types, can be related to clear thresholds, and generally meets the criteria of being usable and acceptable by a wide range of stakeholders.

Although habitat effectiveness calculations incorporate, in a general sense, the importance of human features in changing mortality rates due to humans and other predators, and the effects of spatial distribution of harvest on caribou habitat effectiveness, there are obvious limitations to this relatively simple threshold approach. Range-specific factors, such as predator density, or distance to human settlements, may influence caribou recruitment and survival differently, despite ranges having similar habitat effectiveness values. Despite these limitations, setting of thresholds represents a risk management exercise for development of industrial activity in caribou range, and is a more defensible management technique than the alternative approaches (project-specific mitigation strategies), which have largely failed in other jurisdictions

Most elements required for the development and implementation of the habitat effectiveness approach within Yukon already exist. The data required to set a threshold for Yukon caribou range are either already in existence, or could be acquired in a timely fashion. The technical expertise and technological resources required to implement thresholds currently exist in Yukon and are fully capable of developing the tools needed to assess proposed projects and undertake long-term range planning. The coordination of these activities among government agencies and existing management structures will be the greatest challenge to implementing a threshold approach for Yukon.

Table of Contents

List of Tables

List of Figures

1. INTRODUCTION

Woodland caribou (*Rangifer tarandus caribou*) are a focus species in the boreal forests of northwest Canada and Alaska. Due to concern over population status and trends, they have been the object of substantial scientific research and monitoring. Caribou, which are often identified as one of the Valued Ecosystem and Cultural Components (VECCs) in environmental impact assessment, are valued for a number of reasons: 1) in the northern reaches of their continental distribution, woodland caribou form an important component of both First Nation's harvest and regulated hunting, 2) caribou are seen as an umbrella species, the protection of which also benefits many other species that occupy caribou habitat, and 3) as animals with large home ranges, woodland caribou may serve the role of a proverbial "canary in the coal mine", with population declines signifying reductions in overall ecosystem health. There is evidence that industrial development associated with oil and gas activity (both exploration and production), forest harvesting, and mining (both exploration and production) negatively impact woodland caribou (see Dyer 1999 and Section 3.1 below for a review). Though southwestern Northwest Territories and northeastern British Columbia are currently experiencing high levels of industrial activity, specifically oil and gas and forest harvesting, the majority of Yukon has experienced relatively low levels. However; with renewed interest in the potential Alaska Highway Pipeline project and forest harvesting in southeast Yukon, industrial activities in southern Yukon are expected to increase in the coming years. As human activity in the caribou ranges increases, cumulative effects of various influencing factors will have increasing impact on populations. Experience from other areas of Canada suggests that a failure to address cumulative effects in the early stages of development leads to threatened and endangered woodland caribou populations (Dzus 2001). The current Yukon situation therefore presents a unique opportunity in Canada: the potential development and implementation of adequate planning and operational guidelines for managing cumulative effects *prior to* large-scale industrial development.

Under the Canadian Environmental Assessment Act, potential cumulative effects of proposed projects and existing disturbances need to be assessed to determine whether an unacceptable change is likely to occur. This assessment of cumulative effects relies on an objective measure of significance for such change – a threshold. A threshold, pertaining to determining the significance of cumulative effects, is defined as the limit to which an important ecological resource can tolerate land-use impacts before experiencing an unacceptable adverse effect (Hegmann et al. 1999) and may be best represented numerically by readily measurable parameters (AXYS 2001a). One criticism of caribou-related cumulative effects assessments (CEAs) performed to date is that there has been no objective threshold by which to measure significance. As such, project proponents have compared the contribution of their project to the total cumulative effect and have based decisions of significance on whether the increase appeared too great. This ignores the potential that a breaking point may have already been reached and negates a true assessment of cumulative effects. It is only with the development of accepted thresholds that valid determination of significance for CEAs will be possible.

In 2001, AXYS Environmental Consulting Ltd. (AXYS) produced a document for the Department of Indian Affairs and Northern Development (DIAND) Environment Directorate and Environment Canada entitled Thresholds for Addressing Cumulative Effects on Terrestrial and Avian Wildlife in the Yukon (AXYS 2001a). The objective of the current report is to further develop the concepts presented by AXYS (2001a) and to make recommendations concerning the development of thresholds for use in assessing cumulative effects in Yukon woodland caribou range. Although AXYS (2001a) discussed the use of thresholds for woodland caribou, moose, grizzly bear, landbirds and waterbirds, the current report will only consider thresholds relating to woodland caribou.

1.1. BACKGROUND

AXYS (2001a) described three broad classes of thresholds: 1) ecological, 2) land and resource use, and 3) social. They defined ecological thresholds as representing the point at which project-related and cumulative impacts may cause caribou to approach a threshold either through influences on habitat availability or population measures. Habitat availability thresholds may incorporate not only absolute quantities of habitat, habitat patch size, connectivity and distribution, but also measures of habitat quality (the forage or "living" value of a particular habitat type) or habitat effectiveness (an animal's willingness and ability to access a particular habitat type or geographic location). Population thresholds reflect the long-term viability of caribou populations as a result of impacts on reproductive success or survival. The land and resource use thresholds defined by AXYS are typically guidelines for restrictions on location, abundance, and operation of various activities (primarily industrial) within a given woodland caribou range. Finally, AXYS (2001a) defined social thresholds as those derived subjectively in the absence of scientific data and traditional knowledge.

While useful concepts, the threshold definitions used above are ambiguous, as some examples could fit into more than one class. For example, maximum disturbance factors and zones of influence were considered ecological thresholds by AXYS (2001a), though they could also be considered land and resource use thresholds. As such, for this report we decided to use slightly different definitions. ***Ecological thresholds***, as we define them, *are thresholds related to the natural ecology of the animal*. ***Industrial thresholds***, similar to the AXYS (2001a) land and resource use thresholds, *are restrictions placed on human activity so as to limit impacts on caribou populations*. ***Social thresholds***, as we define them, *are limits of public acceptability*.

AXYS (2001a) provided a review of the use of thresholds in Yukon. Examination of ecological thresholds revealed that the current primary woodland caribou management tool in Yukon is identification and protection of core winter habitat areas, though no explicit habitat thresholds have been established. Population thresholds have not been specifically identified for Yukon caribou, although herds are being studied and managed on a herd-by-herd basis. Industrial thresholds in Yukon are often stated more as protection or mitigation requirements and land use and access controls (e.g. maximum cutblock width) (AXYS 2001a).

In November 2000, DIAND hosted a workshop to facilitate identification of thresholds for cumulative effects in Yukon and to identify means of implementing such thresholds (AXYS 2001b). It was concluded that the most desirable attributes of thresholds were that they be measurable, practical, and realistic. Generally, land use and activity-based thresholds were considered most feasible to implement, followed by habitat-based thresholds. Examples of such thresholds identified by participants included maximum kilometers of road per unit area, minimum habitat area, maximum linear disturbance densities, seral stage distribution, etc. (AXYS 2001b). A pilot program was agreed upon as the next necessary step to test the application of thresholds in a key area of concern, specifically the Little Rancheria caribou range, near the community of Watson Lake in southeast Yukon.

1.2. DOCUMENT OVERVIEW

The current report is intended to assess potential threshold approaches and recommend a methodology for setting industrial thresholds for woodland caribou range in Yukon. Our criteria for recommending a threshold development strategy was that it: 1) be directly relevant to caribou ecology, 2) truly assess cumulative effects of known human influences on caribou, 3) be able to suggest a clear threshold, and 4) be usable and acceptable by a wide range of stakeholders. To facilitate evaluation of various approaches, Section 2 presents a discussion of caribou ecological processes and thresholds. Section 3.1 contains a review of literature pertaining to the effects of human development on caribou, to facilitate consideration of cumulative effects. Important industrial activities in Yukon and their potential effects are discussed in Section 3.2. In addition to the threshold variables presented by AXYS (2001a, 2001b), we also examined the approaches currently being taken in other jurisdictions to address cumulative effects in woodland caribou range (Section 3.3). Based on our review, we developed a recommended approach for Yukon. In Section 4, we provide recommendations for implementing the selected approaches for setting industrial thresholds for woodland caribou range in Yukon.

2. ECOLOGICAL THRESHOLDS

Two subspecies of caribou exist in Yukon: 1) **barren-ground** (*Rangifer tarandus granti*), which are typically migratory and can exist in herds numbering in the hundreds of thousands (e.g. Porcupine Caribou Herd) and 2) **woodland caribou** (*Rangifer tarandus caribou*), which are more sedentary and are usually found in smaller populations (e.g. Southern Lakes Caribou Herd). **Three ecotypes have been defined for woodland caribou in Canada. Boreal caribou** range from Newfoundland to British Columbia, are generally non-migratory, and inhabit forest habitats throughout the year. Boreal caribou have been listed as Threatened by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC 2002), which means that they are likely to become endangered if limiting factors are not reversed (COSEWIC 2001). Mountain-ecotype caribou exhibit seasonal migrations that often take them from alpine summer habitat to forested wintering habitat. Mountain-ecotype caribou may be differentiated by general geographic range and associated foraging behaviour. **Southern mountain caribou** are found in the relatively high-snowfall areas of central and southern British Columbia. These animals feed primarily on arboreal lichens during winter. Southern mountain caribou have also been listed as Threatened (COSEWIC 2002). **Northern mountain caribou** are found in west-central Alberta (though they were grouped with southern-mountain animals for COSEWIC review), northern British Columbia, and Yukon. These animals feed primarily on terrestrial lichens during winter, but may forage on arboreal lichens under harsh weather conditions. Northern mountain caribou are listed as a species of Special Concern by COSEWIC (2002). This means that they are considered to be particularly sensitive to human activities or natural events (COSEWIC 2001). **The current report deals specifically with setting thresholds for northern mountain woodland caribou range in Yukon**, though studies of barren-ground and other woodland ecotypes may provide useful information as well. Figure 1 shows the distribution of northern mountain woodland caribou range in Yukon – many herds are transboundary with British Columbia and Northwest Territories.

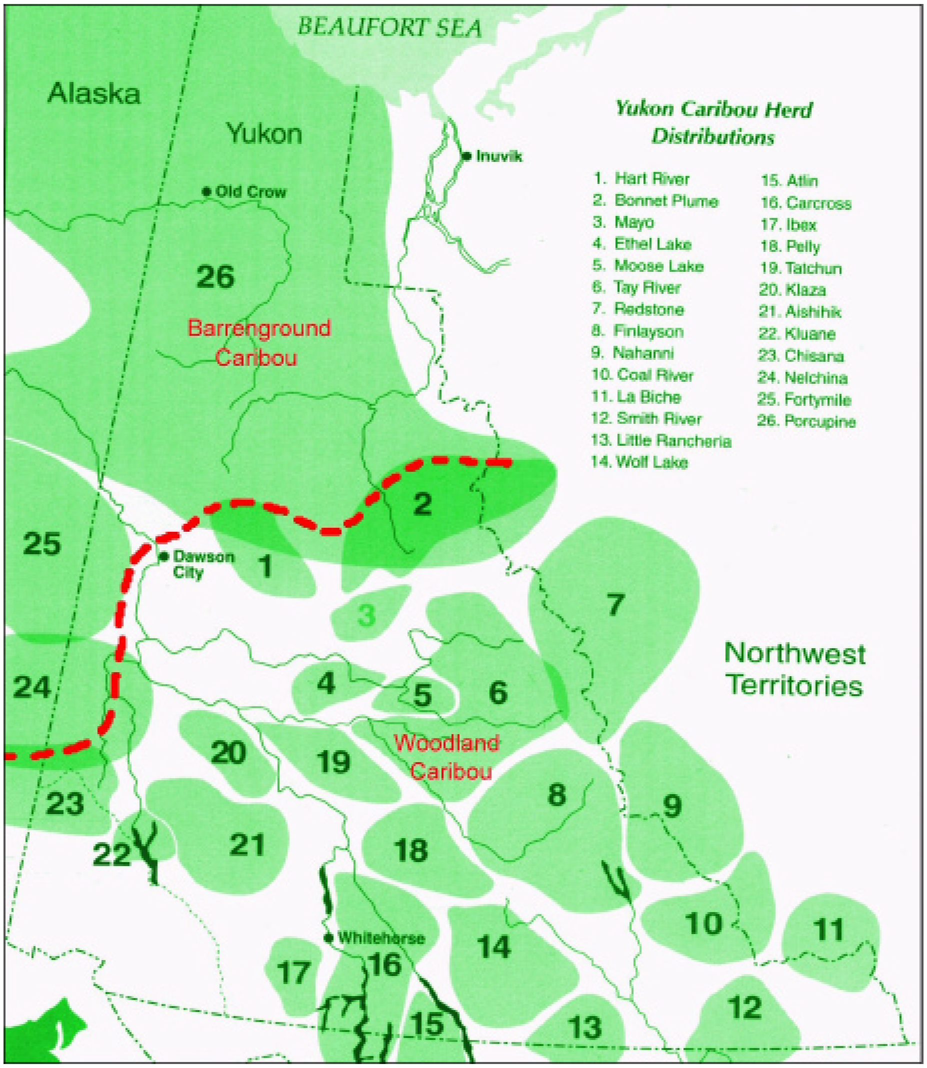


Figure 1. Woodland caribou ranges within Yukon (herds numbered 1-23). Adapted from Yukon Government (1999).

2.1. ECOLOGICAL PROCESSES AND LIMITING FACTORS

As the goal of setting industrial thresholds for woodland caribou range is to allow for some level of industrial activity while ensuring caribou conservation, caribou ecology must be taken into consideration. Specifically, thresholds should relate in some way to minimizing human impacts on factors that limit caribou populations. The effects of individual human developments may be subtle, but may influence other limiting factors cumulatively. The main ecological processes that constitute limiting factors for caribou are thought to be: 1) predation, 2) forage availability, 3) snow conditions and 4) insects.

2.1.1. PREDATION

Predation is considered the primary limiting factor for forest-dwelling caribou throughout their distribution (Bergerud et al. 1990; Seip 1992; Stuart-Smith et al. 1997; Rettie and Messier 1998; Schaefer et al. 1999; Dzus 2001; R. Florkiewicz, pers. comm.). Predation is a major source of calf mortality (Bergerud and Ballard 1988; Adams et al. 1995), which can have significant impacts on demography (Dzus 2001). Most calf mortality occurs within the first ten days post birth. Although variables such as extreme weather may periodically affect calf survival, a cow's ability to avoid encounters with predators during this sensitive period has the greatest influence on calf survival. Calving areas typically have a reduced predator encounter probability and thus provide important habitat value for protecting newborn calves from predation (Bergerud and Ballard 1988). Habitat integrity and its relationship to predator avoidance, therefore, is a critical component in maintaining healthy caribou populations.

As predators such as wolves do not show a close numeric response to caribou declines, predation may also be responsible for maintaining declines initiated by other factors (Gasaway et al. 1983). For instance, small declines initiated by weather, human disturbance, and hunting could be magnified through subsequent effects of natural predation. It is, therefore, of utmost importance to ensure that cumulative effects from human activities do not initiate negative population growth rates.

2.1.2. FORAGE AVAILABILITY

Under certain circumstances, caribou herds may become food limited; however, this is generally restricted to populations that have few or no predators (Skogland 1985; 1986; Adamczewski et al. 1988; Ouellet et al. 1997) or those that are able to avoid predation through migration (Crete and Manseau 1996). It is generally believed that forest-dwelling woodland caribou populations are predator limited (Seip 1992; Rettie and Messier 1998; Schaefer et al. 1999) and, therefore, kept at densities far below carrying capacity of the range. Bergerud et al. (1990) suggested caribou first select areas based on predator avoidance then meet their forage requirements within that area. In some situations, competition for food may become important for predator-limited populations as forage availability declines in safer habitats (Ouellet et al. 1997). The need for increased forage intake during summer to compensate for poor winter range (Ouellet et al. 1997) may reduce effectiveness of anti-predator behaviour, thereby increasing predation. It is therefore important to ensure that adequate forage-producing habitat is maintained in areas that caribou select for predator avoidance.

Fire can play an important role in forage availability for woodland caribou. Although fire may reduce winter forage availability within the first 50 years post-fire, fire may also be necessary for maintaining appropriate lichen-growing conditions over the long term (Klein 1982; Thomas et al. 1996a). The fire history of an area may, therefore, influence overall habitat effectiveness.

2.1.3. SNOW CONDITIONS

Extreme winter weather can make forage acquisition difficult due to snow depth (Brown and Theberge 1990) or the presence of ice over vegetation (Reimers 1982). In rare instances weather may even lead to mass starvation events (Reimer 1982). Weather may also affect habitat use at critical times such as calving. Bergerud and Ballard (1988) documented increased predation when caribou were unable to reach calving grounds due to weather. Weather likely seldom acts as a major limiting factor on its own; however, the effects of weather may be magnified when herds are stressed due to other factors (Skogland 1985). Variation in weather conditions may act cumulatively with other factors to influence demography.

2.1.4. INSECTS

Similar to weather, the influence of insects as a primary limiting factor is questionable (Downes et al. 1986; Klein 1992). Insect infestation may influence calf mortality in woodland and barren-ground animals (Kelsall 1968 in Klein 1992) and insects have also been shown to alter caribou behaviour (Downes et al. 1986; Noel et al. 1998), which may have energetic implications. It is unlikely, however, that insect harassment alone could cause major declines in population rate of change. Instead, the influence of insects is likely cumulative with other factors and models have suggested that heavy insect levels may compound the effect of disturbance on caribou populations (Murphy et al. 2000).

2.1.5. HABITAT

Habitat can play an important role in each of the limiting factors mentioned above. Specific habitats may be selected because they provide reduced exposure to predators. Suitable habitat must also provide the opportunity to acquire necessary resources and avoid excessive harassment from insects. A suite of habitat conditions may therefore be required within a given caribou range so that animals are able to compensate for variation in weather throughout the year and among years. As such, preservation of basic habitat effectiveness is essential to caribou conservation.

2.2. CARIBOU TOLERANCE TO INFLUENCES ON LIMITING FACTORS

Wildlife are able to adapt to a certain degree of variability in their environment. For instance, woodland caribou in the boreal forest have persisted under natural rates of fire disturbance, which create a spatial and temporal mosaic of habitats. There is, however, evidence that natural factors may vary to a point at which unacceptable change (from a human perspective) is initiated. Perhaps the most easily identified of these thresholds is related to snow conditions. Several studies have suggested that caribou have difficulty acquiring resources through snow after depths reach approximately 50 to 60 cm (Pruitt 1959; Henshaw 1968; Bergerud 1974a; LaPerriere and Lent 1977; Darby and Pruitt 1984). Brown and Theberge (1990), however, reported that caribou in their study area were able to crater through snow up to 1.2 m deep. The threshold point likely varies with snow conditions, but nonetheless, after this threshold is reached, starvation may become a threat if alternate resources are not available. Energetic thresholds, which incorporate interactions among forage, weather, and insect activity, have also been related to probability of pregnancy in barren-ground caribou (Adamczewski 1987; Russell et al. 1998). The relationship between minimum body condition and pregnancy has been used in models that address the impacts of industrial disturbance on these animals (Murphy et al 2000). The most important set of ecological thresholds for woodland caribou management are those that relate directly to predation and/or population dynamics. As reported by AXYS (2001a), caribou herds in Yukon with 30 or more calves per 100 cows are expected to be stable or increasing; alternatively, ratios below 30 may indicate a declining herd population. This assumes a relatively constant adult mortality rate, but adult mortality thresholds can also be calculated for a range of recruitment scenarios (Dzus 2001). Finally, caribou ranges may have predator abundance thresholds. Caribou populations have declined in areas with wolf densities >10 wolves/1000 km^2 (Bergerud and Ballard 1988). Hayes and Harestad (2000) calculated a theoretical prey biomass to wolf index of 10.6 wolves/1000 km^2 for the Finlayson Region of south-central Yukon. Stable population thresholds based on wolf abundance will vary, however, by caribou population (Bergerud and Elliot 1998).

Because habitat can be related to a series of ecological processes such as forage availability, microhabitat snow conditions, and predation risk, it is reasonable to assume that there may also be a habitat effectiveness threshold. An assessment of southern mountain caribou range in BC lead to the suggestion that caribou were unlikely to use areas with less than 60% of the landscape in high quality habitat (Simpson et al. 1994). This concept of minimum habitat effectiveness may be valuable in setting landuse thresholds as well.

AXYS (2001a; 2001b) suggested that some ecological thresholds such as minimum calves/100 cows may be valuable for addressing cumulative effects. However, the limitation of ecological threshold use, as we define the term, is that by the time violation of an ecological threshold has been detected, existing cumulative effects may already be well beyond an acceptable point and may be very difficult, if not impossible, to reverse. **Hence, ecological thresholds generally cannot be used effectively to determine whether a proposed industrial project will add significantly to cumulative effects. Ecological thresholds have most value as management targets for a given population or as indicators of existing deficiencies in conditions.** Understanding of the relationship between industrial influences and the condition of a range with respect to ecological thresholds may, however, be used to indicate where industrial thresholds should be set. AXYS (2001a) described maximum habitat disturbance and maximum energy expenditure as ecological thresholds. Under our definition, we suggest these should actually be industrial thresholds that may incorporate both natural and human-caused cumulative effects.

3. INDUSTRIAL THRESHOLDS

3.1. HUMAN ACTIVITY AND CARIBOU: A LITERATURE REVIEW

There has been a large reduction in woodland caribou distribution across North America since European settlement (Edmonds 1991). A combination of human settlement, agricultural and industrial expansion and overhunting is thought to have reduced woodland caribou distribution throughout the United States and Canada (Bergerud 1974b).

Much literature exists regarding the influence of human activity on caribou. The majority of these studies have dealt with migratory barren-ground caribou (*Rangifer tarandus granti)* and semi-domesticated reindeer (*Rangifer tarandus tarandus)*. Recent concern about industrial activity in caribou habitat in Alberta has resulted in the development of a number of well funded woodland caribou research initiatives in that province (see Dzus 2001 for a summary of projects), with many results of direct relevance to land-use decisions in Yukon. In assessing the consequences of human activity on caribou, it is possible to draw many contradictory conclusions from the literature. These contradictions may result from extrapolating behavioural observations of individuals to effects on populations and from the use of correlational reasoning rather than rigorous hypothesis testing to explain disturbance phenomena (Bergerud et al. 1984). Nevertheless, human activity has been shown to affect caribou demography through direct increases in mortality, while developments may result in habitat loss, elicit an avoidance response in caribou, act as barriers to movement, and have energetic consequences through harassment and disturbance. Although they are often considered in isolation, the different consequences of human developments on caribou may occur concurrently and act cumulatively on a population. In this review, four major effects are discussed: 1) mortality, 2) habitat loss and avoidance, 3) energetics and 4) barriers to movement.

3.1.1. MORTALITY EFFECTS

Woodland caribou mortalities as a result of human developments are well documented. Human access into previously remote areas can cause significant hunting mortality to caribou populations (Bergerud et al. 1984; Johnson 1985; Harrington 1996; Seip and Cichowski 1996). Caribou mortalities due to vehicle collisions can occur when roads intersect caribou range (Brown and Ross 1994; BC Ministry of Transportation and Highways 1995; Edmonds and Hobson 1995). The A la Peche herd, near Grande Cache, Alberta, has suffered high mortality due to vehicle collisions on Highway 40 (Brown and Hobson 1998), where caribou are attracted to the road surface to lick salt. Increased signage and harassment of caribou was able to reduce mortalities (Brown and Hobson 1998). A similar situation is found in Yukon with the Little Rancheria herd and the Alaska Highway; between 1 and 6 recorded moralities have resulted annually from vehicle collisions for the period 1999-present (J. Adamczewski, pers. comm.).

The effects of human activity on caribou-predator relationships may be equally important to woodland caribou demography (Bergerud 1974b). In order to reduce predation risk, woodland caribou tend to separate themselves spatially from other ungulate prey species (Bergerud and Page 1987; Seip 1992). For mountain caribou this may involve seasonal migrations (Edmonds 1988; Edmonds and Smith 1991), while boreal caribou are distributed sparsely across peatlands (Bradshaw et al. 1995; Stuart-Smith et al. 1997) where other ungulate prey densities are low. Human developments may threaten this approach by altering the abundance or behaviour of predators or prey species. Many studies report wolves, *Canis lupus*, as important predators of caribou (Gasaway et al. 1983; Fuller and Keith 1980; Bergerud 1978), and wolf predation has been implicated as an important factor in caribou declines throughout North America (Bergerud 1974b). Roads (Thurber et al. 1994) and snowmobile trails (Edmonds and Bloomfield 1984) may provide easy travel corridors for wolves. James (1999) demonstrated that wolves travel faster on linear corridors than when traveling in surrounding forest. Spatially explicit predator models predict that this will increase encounter rates between wolves and caribou (McCauley *et al*. 1993). James and Stuart-Smith (2000) demonstrated that wolf locations were closer to linear corridors (primarily seismic lines) than would be expected by chance, and that caribou mortalities caused by wolves were closer to linear features than live caribou locations. This suggests there is a predation risk associated with linear features (James and Stuart-Smith 2000). Increased wolf predation may be related to expansion of moose into caribou habitat (Bergerud 1974b), which provides an alternative prey for wolves and sustains high wolf numbers (Seip 1991). Human habitat modification through forest harvesting may exacerbate the problem by enhancing moose populations (Cumming 1992; Seip 1992).

3.1.2. HABITAT LOSS AND AVOIDANCE EFFECTS

Woodland caribou feed upon lichens found in old coniferous forests and peatlands (Thomas et al. 1996b; Anderson 1999; Dzus et al. 2001). Habitat loss occurs when this forest type is removed. Forest harvesting is thought to have reduced woodland caribou populations in west-central Alberta (Bjorge 1984; Edmonds 1988). Habitat alteration by forestry activities does not constitute permanent habitat loss, unless harvest scheduling does not allow the development of older age classes that support lichens (Dzus 2001).

Direct loss of habitat may also occur when developments such as roads, wellsites and seismic lines are constructed in caribou habitat. In a study in northeastern Alberta, Dyer et al. (2001) reported that approximately 1% of the study area was unforested due to human developments. However, the physical ‘footprint’ associated with human activities may be trivial relative to functional habitat loss or degradation associated with avoidance or displacement (Jalkotzy et al. 1997), especially when considering linear features.

Numerous studies have indicated caribou avoid human developments and activities. Caribou have been shown to avoid tourist resorts (Nelleman et al. 2000), areas frequented by snowmobiles (Simpson 1987), roads (Nelleman et al. 2001; Oberg 2001), oil and gas wellsites (Dyer et al. 2001), seismic lines (James and Stuart-Smith 2000; Dyer et al. 2001), forestry cutblocks (Smith et al. 2000), and power lines (Nelleman et al. 2001).

Nelleman et al. (2000) reported that caribou cows with calves showed reduced use of a zone within 10 km of a major tourist resort. Bulls and yearlings were more tolerant of the resort, but nearly all animals avoided the zone within 5 km of the development. The authors suggested that reduced lichen densities farther from the resort indicated overgrazing caused by avoidance of the development.

Barren-ground caribou have been shown to avoid roads with regular traffic around the Prudhoe Bay complex in Alaska (Smith and Cameron 1983; Dau and Cameron 1986; Murphy and Curatolo 1987), while Mercer et al. (1985) found that centres of caribou activity were “maximum distances” possible from roads in Newfoundland. They attributed this distribution to a combination of hunting and disturbance associated with transportation corridors. Nelleman and Cameron (1998) demonstrated caribou density in the Kuparuk Development Area in Alaska was inversely related to road density. Road densities of greater than 0.6 to 0.9 km/km^2 resulted in declines in caribou density of 86% and virtually excluded cow-calf pairs. The authors cautioned that exclusion from preferred rugged areas could result in increased competition for forage, increased risk of predation and lower productivity. A number of authors also argue that caribou displaced from critical areas, such as late-winter foraging zones, may be susceptible to increased predation (Geist 1978; Whitten et al. 1992).

Experimental log hauling through a caribou wintering area caused caribou to avoid areas near the road (Cumming and Hyler 1996). Caribou in west-central Alberta avoided roads to a maximum distance of 500 m, although when inactive roads were examined separately a 250 m avoidance effect was reported (Oberg 2001). This is similar to the 250 m avoidance effect demonstrated for roads in northeastern Alberta, although these results were conservative and probably a function of low statistical power (Dyer et al. 2001). Studies in Newfoundland and Alaska indicate that traffic levels as low as 15 vehicles per hour cause behavioural changes in caribou (Mercer et al. 1985; Murphy and Curatolo 1987), supporting the argument that even roads with very low human use cause displacement effects.

Dyer et al. (2001) indicated woodland caribou avoid seismic lines throughout the year. Zones of reduced use by caribou ranged from within 250 m of seismic lines during late winter, to within 100 m of seismic lines during other periods. This corroborates work by James and Stuart-Smith (2000), who demonstrated woodland caribou in northeastern Alberta were generally further from linear corridors (primarily seismic lines) than random locations. Oberg (2001) found no avoidance effect associated with seismic lines, which could possibly be attributed to low statistical power, or aspects of mountain caribou life history. Revegetation of old, existing seismic lines could also be responsible for the lack of an observed avoidance effect, since 80% of the seismic lines in the study area were more than 23 years old (Oberg 2001). Dyer et al. (2001) suggested up to 48% of their study area would receive reduced use by caribou. Conservative estimates elsewhere in Alberta indicate that linear developments have reduced habitat effectiveness on between 28% and 70% of boreal and northern mountain caribou ranges (Dzus 2001).

Habitat loss and disturbance may cause displacement in caribou. Clear-cutting in Ontario and Newfoundland resulted in displacement of woodland caribou from cut areas (Darby and Duquette 1986; Chubbs et al. 1992). In Alberta, mountain caribou were found on average 540 m farther from cut clocks than random locations (Smith et al. 2000). Newly harvested cut blocks had a greater influence on caribou distribution; caribou locations were on average 1.2 km farther from these blocks than random locations. Changes in woodland caribou distribution through this avoidance behaviour is likely to concentrate caribou in space and time, making them more vulnerable to predation (Dzus 2001). Ouellet et al. (1996) also suggested that human disturbance may cause animals to move from areas of low predation risk to higher predation risk.

It has also been argued that linear developments may enhance caribou habitat (Cronin et al. 1994). Incidental sightings of caribou tracks along pipeline right-of-ways indicated that they were used as a spring and summer forage source, and as a movement corridor in winter (Eccles et al. 1985; Eccles and Duncan 1986). A 'dust shadow' effect (Cronin et al. 1994) has been observed in oilfield development areas in Alaska, whereby dust alongside roads causes earlier snowmelt and green-up of vegetation. Caribou feeding in these areas may enhance nutritional intake before calving (Lawhead and Cameron 1988).

Despite concerns, demographic effects have not been rigorously demonstrated as a result of avoidance and displacement (Smith and Cameron 1983; Mercer et al. 1985; Dau and Cameron 1986; Murphy and Curatolo 1987). Migratory herds in Alaska have increased in size despite rapid petroleum development in parts of their traditional range (Cronin et al. 1998), emphasizing the importance of confounding factors such as range condition to caribou demographics. Although population-level responses due to avoidance effects have not been conclusively demonstrated (Bergerud et al. 1984; Cronin et al. 1997), preliminary analysis in Alberta indicates that there may be a 'breaking point' in habitat effectiveness beyond which caribou populations go into decline (BCC 2001).

3.1.3. ENERGETIC EFFECTS

Thirty years of research into the energetic consequences of human disturbance on caribou has resulted in a very large quantity of information that attempts to address the potential impact of disturbance and harassment on caribou. Disturbance from a variety of human activities has been examined, including aircraft (Calef et al. 1976; Miller and Gunn 1979; Valkenberg and Davis 1985; Harrington and Veitch 1991; Harrington and Veitch 1992), roads and vehicles (Roby 1978; Horejsi 1981; Mercer et al. 1985; Dau and Cameron 1986), snowmobiles (Tyler 1991) and simulated petroleum development (Bradshaw et al. 1998).

Studies that attempt to identify the energetic costs of disturbance assume that any harassment costs are additive to the energy budget of caribou, and that caribou are unable to compensate for increased energy costs associated with disturbance by increasing forage intake. Although ungulates recovering from nutritional stress may display higher levels of forage consumption (Robbins et al. 1981), this assumption appears to be well-founded, since winter weight loss in northern ungulates is well documented (Renecker and Hudson 1993).

Winter weight loss of 10-15% of autumn weight has been recorded in caribou (Steen 1968; Dauphiné 1976); even reindeer fed lichens *ad libitum* lose weight during winter (Holleman et al. 1979). It appears that the dual constraints of rumination time (Robbins 1983) and poor forage quality (Arnold 1985) may prevent compensatory feeding. Bergerud (1975), studying Newfoundland woodland caribou for five years, described winter weight loss of 8-26% in overwintering animals. The 26% weight loss occurred during a winter of extreme snow accumulation, and females produced the smallest calves that year. Jabobsen and Skjenneberg (1975) reported that winter weight loss of 20% in reindeer was not uncommon. Weight loss above 'normal' values could cause embryonic absorption (Zhigunov 1961) or premature birth, although such problems are thought to be uncommon (Cameron et al. 1993).

It has been hypothesized that caribou are most vulnerable to disturbance during winter (Bradshaw et al. 1997). Many of the physiological and behavioural adaptations to winter displayed by woodland caribou may intensify the potential threat of industrial disturbance. Caribou arrest all growth during the winter months, reducing their metabolic rate by up to 30% (Segal 1962; McEwan 1968; McEwan and Whitehead 1970; Dauphiné 1976). Woodland caribou movement rates also decline during late winter (Schneider et al. 1999), possibly since increasing snow cover makes movement more energetically costly (Fancy and White 1987). Woodland caribou are well adapted to locomotion in snow and have large splayed hooves that confer low foot loading values (defined as body weight divided by total foot area contacting the snow) (Kelsall and Telfer 1971). Among ungulates, only the musk deer (*Moschus moschiferus*) has a lower foot loading than the caribou. Despite this adaptation, energetic costs of locomotion for caribou walking in uncrusted snow increase exponentially with increased snow depth (Fancy and White 1987).

Calorific costs of pregnancy also increase exponentially during gestation in ungulates, and reach their highest levels immediately prior to parturition (Robbins 1983). Adamczewski et al. (1993)

found that gestation costs represented 12-14% of energetic maintenance costs by late winter. Winter also often represents the period of peak industrial activity in caribou habitat in northern regions, thus caribou are likely to experience more potentially disturbing encounters at this time. Animals that have evolved as prey of other animals exhibit predator-avoidance behaviours to prevent being preyed upon (Shalter 1984). Thus, novel objects perceived as predators, such as vehicular traffic, aircraft, roads and oilfield infrastructure may elicit disturbance responses in caribou. This may have consequences to caribou demographics if harassment is severe enough to affect caribou body condition. Energetic demands associated with human disturbance may be additive, thus winter harassment could reduce an individual's ability to grow and reproduce next spring (Geist 1971a).

Caribou generally exhibit signs of anxiety and fear when encountering fast-moving vehicles (Horejsi 1981). Horejsi (1981) described the behaviour of barren-ground caribou encountering a pick-up truck as a 'limited flight response'. He found female caribou responded to an approaching vehicle by fleeing for a mean of 73 seconds. Bergerud (1974c) reported mean flight distances of 81 m and 165 m for females without calves and females with calves, respectively, responding to the presence of a man on foot. Miller and Gunn (1979) reported the locomotory response of Peary caribou subjected to helicopter overflights rarely exceeded 500m. A combination of vehicle traffic and physical barriers elicited increased energy expenditures in caribou (Murphy and Curatolo 1987), while in contrast, Fancy (1983) found caribou near two active drilling sites had similar movement rates and activity budgets to caribou at controlled sites. Low-level jet overflights have been shown to cause disturbance responses in woodland caribou (Harrington and Veitch 1991). Long-term studies on the same population showed it failed to grow between 1972 and 1987, despite a complete hunting ban (Harrington and Veitch 1992), while a neighbouring control population not subjected to overflights more than doubled in size during the same period.

Caribou close to oilfield disturbances in Alaska spent less time lying and increased locomotion relative to control individuals (Murphy and Curatolo 1987). The authors reported that caribou moved faster and spent more time running near a road with moderate traffic (15 vehicles per hour) than at control sites with little traffic (less than one vehicle per hour), although no differences in activity budgets were evident when insect harassment by mosquitoes was high. Murphy and Curatolo (1987) argued that increased activity as a result of disturbance could contribute to energetic stress, but cautioned these energetic costs may be small since calving caribou distance themselves from these reactive zones.

Cow/calf pairs have been shown to respond to lower levels of disturbance than bulls and calfless cows (Calef et al. 1976; Kuck et al. 1985; Murphy and Curatolo 1987). Bergerud et al. (1984) argue that the difference in response by bulls and cows with calves is ultimately due to the differing parental investments associated with a polygynous breeding system. Because of these differences, females should be more likely to select predator-free habitats than males, and be more sensitive to anthropogenic disturbances. Calf locomotion costs may be higher than those of adult caribou (Luick and White 1980), and increased movement rates caused by disturbance may be detrimental to calf growth (Kuck et al. 1985).

Bradshaw et al. (1998) attempted a manipulative approach to analyze the effect of simulated industrial activity on woodland caribou behaviour. His simple model estimated the energetic consequences of woodland caribou encountering simulated seismic activity. He suggested an exposure rate threshold of 0.0375 industrial encounters/km^2/winter could be used to reduce disturbance, and hence weight loss of woodland caribou (Bradshaw 1994; Bradshaw et al. 1998). Other authors have suggested that the long-term impacts associated with avoidance behaviour may be a more serious threat than energetic costs and physiological stress (Dyer 1999; Nelleman et al. 2000).

Cronin et al. (1994), in a review of the effects of oil field development on caribou, argue that caribou should readily habituate to the visual presence of sedentary oil field structures, with their associated sounds and odours, and this assertion is supported to a limited extent by other studies in Alaska (Roby 1978; Curatalo and Murphy 1986; Murphy 1988). Motion, however, appears to be a major elicitor of alarm reactions and flight in caribou (Roby 1978), and evidence of habituation is extremely fragmentary. Higher levels of aircraft overflights (Valkenburg and Davis 1985); vehicular traffic (Roby 1978) and snowmobile harassment (Tyler 1991) all caused weaker alarm responses in caribou and reindeer than in populations that had been subjected to lower levels of harassment. Direct approaches by moving objects elicit a greater response in caribou than right-angled or tangential motion (Horejsi 1981; Tyler 1991). In conclusion, it appears that caribou are likely to habituate very slowly and incompletely to vehicular traffic, since vehicles represent potential predators and are highly unpredictable in time and space (Cronin et al. 1994).

Although the responses of individual caribou to human developments are well documented, it has been difficult to establish a relationship between human harassment and decreased reproduction in ungulates. Experimental harassment of red deer (*Cervus elaphus*) in New Zealand resulted in slower growth and declines in reproduction (Batcheler 1968), while female mule deer (*Odocoileus hemionus*) harassed with an All-Terrain Vehicle (ATV) displayed lower reproduction than a control group not subjected to harassment (Yarmoloy et al. 1988).

There is a direct relationship between pregnancy rate and autumn body condition (Dauphiné 1976; Reimers 1983; Allaye-Chan 1991; Cameron et al. 1993) and substantial evidence suggests caribou calf survival is dependent on maternal nutrient uptake and body condition during late pregnancy (Dauphiné 1976; Adamczewski et al. 1987; Cameron et al. 1993). Numerous studies indicate birth weights of caribou calves are correlated with female forage intake (Varo and Varo 1971; Bergerud 1975; Espmark 1980; Rognmo et al. 1983; Skogland 1984; Eloranta and Nieminen 1986). This is an important consideration, since small calves have lower survival rates than larger calves (Haukioja and Salovaara 1978; Rognmo et al. 1983).

The distinction between conceiving a fetus and early calf survival may be obscured by carryover effects between seasons (Cameron and Ver Hoef 1994). Winter malnutrition may affect the ability of caribou to gain mass in summer, while malnutrition in summer may exacerbate overwinter weight loss. If female caribou are repeatedly unable to compensate for the metabolic costs of gestation and lactation, there may be a cumulative deterioration of body condition that results in a breeding pause (Dauphiné 1976; Reimers 1983; Cameron 1994). Periodic infertility is thought to be common in many ungulates (Clutton-Brock et al. 1982; Bowyer 1991; Rachlow and Bowyer 1991), and may have significant adaptive value. A mechanism that prevents ovulation when maternal reserves are low prevents wasted reproductive effort and increases the likelihood of a successful neonate the following year (Cameron 1994).

3.1.4. BARRIER EFFECTS

Most studies addressing potential barriers to caribou movements concern short-term responses of migratory barren-ground caribou to human structures. Many descriptive studies have attempted to assess the effects of human developments as barriers to caribou movements. Anthropogenic features that may act as barriers to caribou movements include logging slash piles, berms, pipelines, roads, fences and pipelines (Bloomfield 1979; van Zwoll 1983; Klein 1971; Miller et al. 1971; Roby 1978; Johnson and Todd 1977; Klein 1980; Whitten and Cameron 1983; Bergerud et al. 1984). A typical study of this type reported how only 26% of a group of barren-ground caribou crossed an elevated pipeline despite 36 attempts (Smith and Cameron 1985). The assertion that roads and railways have caused abandonment of traditional migration routes by reindeer in Eurasia has been challenged by Bergerud et al. (1984), who argue that range reductions due to population declines are responsible for these observations.

Controlled experiments that rigorously test hypotheses are less common. Curatolo and Murphy (1986) reported that caribou in Alaska crossed roads and pipelines as frequently as control sites without these developments. Presence of the Trans-Alaska Pipeline did not appear to affect the traditional migration of the Nelchina caribou herd (Carruthers and Jakimchuk 1987). However, where a pipeline paralleled a road with traffic, crossing frequencies were significantly less than expected (Curatolo and Murphy 1986). The authors suggested that roads and pipelines act in a synergistic fashion. Dyer (1999) used a GIS approach and modeled a ‘control’ road network to compare to actual road crossing events. He demonstrated that caribou crossed roads up to six times less than expected. He described this as a ‘semi-permeable’ barrier effect (Dyer 1999). In the same study, Dyer (1999) concluded that seismic lines were not barriers to caribou movements.

3.1.5. CONCLUSIONS

To be of significance to wildlife managers, behavioural responses to disturbance must have demonstrable demographic consequences (Shank 1979). However, demographic responses to disturbance are rarely reported. Many authors tend to generalize about demographic effects based on dubious cause-and-effect reasoning which may confound our understanding of caribou behaviour and demography (Bergerud et al. 1984).

Despite the controversy, there is ample evidence that human activities cause behavioural changes in caribou, and it seems reasonable to assume that under certain circumstances, human-induced disturbances may adversely affect caribou populations. Numerous factors may contribute to the degree of response to human activities displayed by caribou, including the type of disturbance, the frequency of disturbance (Roby 1978; Valkenberg & Davis 1985; Tyler 1991), the physical condition (Skogland & Grovan 1988), sex (Horejsi 1981) and reproductive condition (Maier et al. 1998) of the disturbed animal, and effects of vegetation and topography (Lyon 1979). Disagreements about the relative importance of human activities to caribou behaviour and demography appear to stem from these differences.

Consequences of these disturbances to caribou populations are still unclear. Undoubtedly, woodland caribou have declined in the face of human encroachment throughout their southern ranges (Bergerud 1974b) and arguing over mutually exclusive hypotheses about the causes of these declines may be oversimplistic (Bloomfield 1979). Rigorous hypothesis testing to determine disturbance responses may be scientifically desirable, but there are also major logistical and ethical constraints to research of this type. Geist (1971b) argued “Would one wish to compile hard, fast and irrefutable data by testing how far 100 caribou females have to be run in April before they all abort, collapse or die of emphysema?”

The GLOBIO report (UNEP 2001) describes how a simple, science-based communication tool can map the likely impacts of human developments on wildlife species. As a synthesis of several thousand studies, the GLOBIO report showed that the probability of human impacts on ecosystem function and biodiversity can generally be related to the distance to human infrastructure. The next hurdle for management of woodland caribou populations in Yukon will be to similarly move beyond individual studies and develop a framework for caribou conservation at a landscape or regional level. The development of land use thresholds will be essential if this process is to succeed.

3.2. INDUSTRIAL ACTIVITY IN YUKON

The purpose of this section two-fold: 1) to provide an overview and historical context of major industrial activity in Yukon and 2) to provide a description of potential impacts resulting from each activity. Four major sectors, mining (hardrock), oil and gas, forestry, and transportation/construction, are discussed in terms of their history and current status in Yukon. The potential impacts of each sector on woodland caribou are also discussed. A brief summary of other potential activities is also included.

3.2.1. MINING SECTOR

3.2.1.1. Overview

For the past century, mining has been the largest non-renewable industry in Yukon. Two major types of mining activities occur within the territory: 1) hardrock, both open pit and below ground, and 2) placer. Hardrock mining activities occur throughout Yukon with major concentrations of activity associated with specific geologic settings such as the highly mineralized Tintina Trench of central Yukon or the Whitehorse Copper belt within the City of Whitehorse. Hardrock mining may occur at almost any location on the landscape, from forested valley bottoms to non-vegetated alpine areas. In contrast, placer mining is generally limited to specific geographic areas within the territory, with the highest concentration of placer activities occurring in the Dawson and Carmacks regions, areas that remained largely unglaciated during the end of the Pleistocene Epoch. Placer activities are generally constrained to creek beds and related fluvial landforms. For the purposes of characterizing potential woodland caribou impacts, our discussion of mining is limited to hardrock mining.

Three main sources of legislation are used to regulate land-related aspects of mineral exploration: 1) Yukon Quartz Mining Act, which allows staking of quartz claims and the development of and production on minesites; 2) Yukon Quartz Mining Land Use Regulations, which regulate exploration and mine reclamation; and 3) Territorial Lands Act, which regulates the construction and maintenance of access roads for any purpose, not just mining. All three regulatory acts and documents are currently regulated by federal agencies. As of November, 1998 approximately 16,000 km^2, or 3.3 percent of Yukon, was occupied by mining claims in good standing, with the majority of these being quartz (hardrock) mineral claims (Yukon Department of Renewable Resources 1999). It is anticipated that less than one percent of territorial mineral claims would ever become an operating mine. As of February, 2002 only one hardrock mine was active in Yukon, Elsa, and the Tungsten mine on the Yukon – NWT border, with access provided through southeast Yukon on the Nahanni Range Road. Both of these mines were existing sites that were re-opened due to favorable market conditions. Major abandoned or decommissioned hardrock mines are located in the following mining areas: Finlayson – Faro, Kudz Ze Kayah; Watson Lake – Sa Dena Hes; Whitehorse – Whitehorse Copper; Carmacks – Minto, Mt. Nansen, Carmacks Copper; Keno – Keno Hill, Dublin Gulch; and Dawson – Brewery Creek. Most abandoned or decommissioned minesites and current exploration targets within Yukon occur within woodland caribou ranges.

3.1.2.2. Potential Impacts

For the purposes of a discussion on cumulative environmental effects assessment and management, hardrock mining involves three major phases: 1) exploration, 2) active mineral extraction and associated activities and 3) decommissioning. Quantifying potential environmental effects associated with the exploration phase of mineral development is generally more difficult than quantifying potential effects associated with defined minesites and haul roads. The active mining phase of mineral development involves the intensive development and working of a relatively small, well-defined area and the hauling of ore and supply vehicles along designated access roads. Understanding the decommissioning phase of a mine and associated road access and the rate of recovery from minesite disturbances is a critical component of cumulative environmental effects assessment and management as some mine-related footprints may be persistent landscape features.

3.2.1.2.1. Mineral Exploration

Mineral exploration ranges from small, sporadic programs to large, intensive, multi-year efforts. Mineral exploration may be vehicle based and therefore dependent on existing access, or rely almost exclusively on helicopter support in remote regions. Preliminary hardrock mineral exploration generally consists of helicopter based sampling and mapping programs. Advanced exploration programs include localized trenching and drilling activities with one or multiple field camps. Depending on the size and duration of a mineral exploration program, some will develop fixed-wing aircraft runways to allow for more efficient delivery of crews and supplies. The amount of industrial footprint created by mining exploration programs ranges from almost undetectable levels for preliminary exploration to several hundreds of meters for camps and airstrips, and potentially large areas of soil/rock disturbance created through trenching and sampling. A zone of influence probably exists around most mining camps and exploration properties, where woodland caribou are temporarily displaced from the immediate surroundings.

3.2.1.2.2. Minesite and Access Road Development, and Ore Hauling

Following the establishment of an active minesite, an all season, fixed-link haul road must be constructed to the area. Due to the high cost of road construction, the historical pattern of mine development in Yukon has resulted in most major mines to be located near existing access. The modern exception to this example would be the Tungsten mine on the NWT – Yukon border in the Nahanni area, where an approximate 200 km haul road was constructed off the Robert Campbell Highway specifically for the mine. Like most primary resource extraction industries, existing access generally promotes mineral development. Depending on the type of mine, below ground or open pit, the areal extent of minesite footprint varies dramatically. Some below ground mines create limited amounts of surface footprint while open pit mines can create very large surface disturbances, as both mine tailings and the pit itself are cumulative. A major contribution to almost all minesite industrial footprints is discarded rock tailings. An extensive network of exploration roads and trails, trenches and survey lines surround many minesites, increasing the total footprint around most mines considerably. A much larger zone of influence may be expected from operational minesites than from mineral exploration programs.

Access roads are a major industrial footprint associated with minesite development and they may have a large zone of influence. Depending on the type of mine (all season versus seasonal production), multiple daily trips of large ore trucks will generally travel the road. For the majority of historical mines, ore concentrate has been hauled great distances for final processing, as in the case of Faro where ore was hauled from the minesite to the port of Skagway. At peak production, more than 50 ore trucks per day were traveling nearly 900 km along the Robert Campbell Highway, Klondike Highway and Alaska Highway to the port of Skagway, Alaska. These large haul distances serve to spread potential environmental effects (i.e. increased risk of mortality from vehicle collisions) over a much larger distance beyond the minesite and haul road. Vehicle traffic utilizing mine access roads and off-road vehicles originating from access roads is an important environmental effect associated with access road development. Some Yukon mines have managed access through the use of control gates, with an apparent high level of success. However, for minesites that utilize public access roads, this option is generally not possible.

3.2.1.2.3. Mine Decommissioning (Closure, Access Management and Minesite Rehabilitation)

While mine decommissioning, road deactivation and minesite rehabilitation are often not considered in the assessment of cumulative environmental effects, consideration of these minesite "closure" phases may be as important as the initial assessment and mitigation activities. The residence time of mine footprint (i.e. rate of vegetation recovery to pre-disturbance state) and the extent and success of access road decommissioning are two very important factors that should be considered in the assessment and management of regional cumulative effects. The establishment of a relatively permanent road network in previously un-roaded areas allows access for recreation, hunting and in many cases, further mining or associated industrial development. While the effective decommissioning of roads is a commonly cited goal of mine closure plans, historically this has rarely occurred. Potential reasons include: 1) refusal of public to stop utilizing road infrastructure, 2) reluctance or inability of territorial regulatory agencies to enforce road deactivation (i.e. off-road vehicles can travel almost anywhere), 3) non-permanent mine closures due to economic conditions (i.e. most mines in Yukon have never been formally decommissioned, they have ceased operations due to poor economic conditions with the intent to re-open during higher mineral prices), 4) necessity for road access to remain in place for environmental remediation and treatment of mine waste water and tailing pond dams, and 5) new industrial developments or private residences have been constructed off of the main access road. Several research projects have investigated the rate and success of minesite revegetation at various locations throughout Yukon (e.g. Mougeot 1996, Mougeot and Withers 2001) but our state of knowledge about the residence time of mine footprints should still be considered limited.

3.2.2. OIL AND GAS SECTOR

3.2.2.1. Overview

While the Canol pipeline and associated Whitehorse oil refinery was a historically important event in Yukon's World War II history, and a pulse of oil and gas exploration occurred from the late 1960s-early 1980s, the "modern" oil and gas sector is a relatively new industry to Yukon. Oil and gas rights were transferred from the Federal to the Yukon Territorial Government in 1998. The Yukon Oil and Gas Act is the guiding regulatory document for oil and gas activity in the territory. Operational guidance is currently provided by the Geoscience Operational Guidelines, and the Yukon Oil and Gas Branch has also recently developed Draft Oil and Gas Geoscience Exploration Regulations (March 23, 2001). In addition, the federally-regulated Territorial Lands Act plays a major role in the approval and regulation of any road development that would be associated with oil and gas activity. Since 1998 the Oil and Gas Branch of Yukon

Energy, Mines and Resources has issued three calls for oil and gas bids (exploration rights); all have been located in North Yukon outside of woodland caribou ranges. Two calls for bids were completed in the Eagle Plains Region with Devon Canada Corporation, formerly Anderson Exploration Ltd., gaining exploration rights to both dispositions. The most recent call for bids concluded in January 31, 2002 for the Peel Plateau, with Hunt Oil Company of Canada Ltd. being the successful bidder. Northern Cross (Yukon) Ltd. has interests in several Significant Discovery Licences within Eagle Plains immediately adjacent to the Devon Canada Corporation parcels. In Yukon, oil and gas dispositions provide the company with complete sub-surface rights beneath a specified parcel of land, thereby preventing multiple companies from performing exploration programs on the same parcel simultaneously. This is an important distinction from the oil and gas regimes of neighbouring jurisdictions such as Alberta and British Columbia.

Unlike mineral deposits that may occur throughout Yukon, sedimentary basins with hydrocarbon potential only underlie specific areas of the territory (Yukon Territorial Government 2000). In North Yukon, north of the Mackenzie Mountains, major sedimentary basins include Eagle Plain, Peel Plateau, Kandik, Old Crow, Bonnet Plume and North Coast. A portion of the Bonnet Plume basin is used as winter range by the Bonnet Plume woodland caribou herd; the Hart River woodland caribou herd utilises a portion of Eagle Plain for winter habitat. All other North Yukon sedimentary basins are within barren ground caribou winter ranges. South Yukon sedimentary basins include the Whitehorse Trough and Liard Plateau; both are within woodland caribou ranges. The Whitehorse Trough is largely unexplored. The Liard Plateau of extreme southeast Yukon is situated on the margin of the Western Canadian Sedimentary Basin and contains the only producing gas wells in the territory at the Kotaneelee Field operated by Devon Canada Corporation. This field and associated infrastructure have been operational since the 1980s. Most seismic exploration work in the La Biche River area occurred in the early 1970s. Approximately 60 km of 2-D seismic was collected to the east of the Kotaneelee gas plant during the winter of 2000. Levels of oil and gas exploration and production in the neighbouring jurisdictions of NWT and British Columbia have increased dramatically since 1996, with most activity centered around the communities of Ft. Liard and Ft. Nelson. A preliminary analysis of the Yukon Oil and Gas Branch / National Energy Board seismic line database indicates that approximately 680 kms of seismic lines were cut in southeast Yukon between the late 1960s and early 1980s. However, a visual analysis using Landsat imagery reveals that approximately 1/3 of the total seismic line features are missing from this database, increasing the total seismic footprint to approximately 900 kms.

While the Eagle Plains and Peel Plateau are not within woodland caribou ranges, it is relevant to acknowledge historical and anticipated oil and gas activity in the region. To date, Devon Canada Corporation has completed one winter seismic program (winter 2000/2001). Current and future oil and gas exploration activity in the Eagle Plains and Peel Plateau Regions of North Yukon are occurring in an area that experienced substantial levels of seismic exploration during the 1960s through to the early 1980s. Preliminary analysis of the Yukon Oil and Gas Branch / National Energy Board seismic line database indicates that more than 6200 km of 5-8m seismic lines were cut between the 1960s and early-1980s (preliminary analysis completed for Eagle Plains, Peel Plateau and the Whitefish Wetlands portion of Old Crow Basin Ecoregions). The majority of these seismic lines are still readily visible on the landscape. Approximately 40 wellsites and associated road and airfield infrastructure were also developed during the 1960s-80s period of frontier exploration.

3.2.2.2. Potential Impacts

For the purposes of evaluating potential environmental impacts on woodland caribou, oil and gas activity can be separated into three major phases: 1) exploration, 2) construction and production and 3) abandonment and reclamation. With the exception of the Kotaneelee Gas Plant on the NWT – Yukon border of southeast Yukon, all near-term oil and gas activity will likely be involved in the exploration phase of the oil and gas sector. The possibility of a large diameter natural gas pipeline being constructed along the Alaska Highway also appears to be a probable scenario within the coming years. For this discussion, pipeline-related activities would be considered in the construction and production phases.

3.2.2.2.1. Oil and Gas Exploration

Similar to mineral exploration programs, oil and gas exploration occurs with a range of intensities depending on the duration of the program, the geographic extent and the methods employed. Oil and gas exploration is generally conducted using some form of seismic exploration. In areas with existing access, seismic exploration programs may be carried out primarily with vehicle support. The use of helicopter support to access remote locations or for completing exploration projects in sensitive wildlife areas has become common practice. Work camps of various levels may be necessary depending on the duration of a program and the location of existing communities. Seismic exploration can be collected through 2-D and 3-D methods, with 3-D requiring a more dense grid of seismic lines, but offering a much higher level of resolution of underlying geologic structures. Seismic line width and Line-of-Site (LOS) has received much attention in western Canadian exploration programs during the recent past, and the generally accepted practices of obtaining seismic data have changed substantially in the past 10 years. Historical seismic lines in Yukon, similar to most other jurisdictions, were constructed by a bulldozer of similar piece of heavy equipment clearing 5-8m wide linear corridors through forested areas. In addition to the seismic disturbances, road access of some level was generally established. The majority of seismic programs are now conducted using seismic line widths less than 5m, with many approaching 3m or less. Hand falling and limbing of trees and the use of small machinery decreases the need for large seismic line widths. In sensitive areas, the use of helicopter portable drills and geophones has also become common practice. All of these techniques have become known as “Low Impact Seismic”, or LIS. However, the potential impact of one LIS method versus another on woodland caribou and associated wildlife species is not currently known, nor has it been documented whether LIS techniques result in lower wildlife impacts. The two most recent seismic exploration programs in Yukon (Eagle Plains, North Yukon - Devon Canada Corporation 2000/2001 seismic program; La Biche River, Southeast Yukon – Chevron Canada 2000 seismic program) employed LIS techniques.

The final stage of exploration is the drilling of one or multiple test wells, which involves the development of road access to allow transport of a drilling rig. If a major economic reserve is found through the exploratory drilling program, infrastructure is required to either transport the oil or gas to a processing facility, store the product, or process the hydrocarbon on site. All of these activities initiate the next phase of oil and gas development, construction and production.

3.2.2.2.2. Construction of Oil and Gas Infrastructure, and Production

The only current producing oil and gas field in Yukon is the Devon Canada Corporation Kotaneelee Field in the La Biche River area of southeast Yukon. Given the state of Yukon’s developing oil and gas industry, the construction and production phases of the oil and gas sector outside of southeast Yukon will not likely occur in the immediate future. However, a major exception to this situation could be the construction of a large diameter natural gas pipeline along the Alaska Highway Corridor in coming years. Construction activities associated with conventional (i.e. not oil sands) oil and gas infrastructure can be grouped into two major types: 1) access, wellsites and associated facilities, 2) pipelines and associated facilities.

- **Development of Access, Wellsites and Associated Facilities.** The level of access that may be associated with any given oil and gas development is highly variable. Most "frontier" oil and gas fields require the development of primary road access prior to the initiation of significant activities. In these situations, main line roads may become nodes of activity for further development or potentially new industrial or recreational activities. In the case of Yukon's only operating gas field, access provided by the Kotaneelee Field in southeast Yukon allowed access for forestry activities surrounding the facility in the mid-1990s, with continued activities expected. The development of oil and gas fields in roaded areas may result in a very small additional road footprint. Similar to most road construction, the requirement for local aggregate resources may necessitate gravel pit development, further contributing to access footprint. A variety of access management strategies can be employed from simple locked gates to the use of seasonal (i.e. ice roads) or temporary (i.e. geotextiles) roads. Access management should be a major consideration in the development of any oil and gas reserves.

  Depending on the nature and engineering of the oil or gas field, the development of wellsites and associated infrastructure may begin with a potentially large construction phase on multiple hectares, or consist of single gas wells scattered over a landscape, with individual wells sites occupying approximately 1ha. Many new oil and gas projects attempt to concentrate wellsite facilities into one larger area, which may create a clearing of several hectares. Work camps, possible runways, heavy equipment and high levels of human activity are generally associated with the construction phase. While this approach results in a single large footprint, the amount of road, power and eventually pipeline infrastructure that is required can be reduced significantly, resulting in an overall decreased industrial footprint from concentrated facilities. Again depending on the nature and engineering of the oil or gas field, compressor and/or scrubber stations and flare stacks may also be associated with wellsites, potentially resulting in additional noise, air and visual quality impacts. After a wellsite is established, maintenance must be performed on an ongoing basis. Due to the additive effect of all activities, wellsites and associated infrastructure are considered to have a potentially large zone of influence (ZOI).

- **Pipelines and Associated Facilities.** Pipelines are required to collect hydrocarbons from dispersed wellsites, transport them to a central preliminary processing facility, and then transport them to a refinery or similar final producing facility. Pipelines represent the interface between the upstream and downstream sectors of the oil and gas industry. Pipelines create long, non-forested linear corridors with potentially long LOS. A pipeline right-of-way (ROW) may range in size from 5m to >100m, depending on the pipe diameter and number of pipelines sharing the same corridor. Cumulatively, multiple, wide pipeline ROWs adjacent to an existing transportation corridor may create barriers to terrestrial wildlife movement. Pipeline construction activities create a large amount of temporary disturbance through the volume of people and equipment that become concentrated along a construction corridor. Depending on the location, pipeline construction may also involve large temporary work camps. Combined, these activities will create a large ZOI around pipeline construction zones. However, once construction activities are complete, a pipeline corridor is similar in nature to a wide seismic line disturbance. For a variety of reasons cited by the oil and gas industry, pipeline ROWs have rarely, if ever been allowed to revegetate to a forested condition during the operational life of the pipeline. Pipeline ROWs therefore provide potential vehicle and off-road vehicle access to previously inaccessible areas. In the longer term, the establishment of a pipeline through an area may tend to promote further development of oil and gas resources, as is currently the situation in Northern Canada.

Compressor stations are generally located at various distances along pipeline corridors. Compressor stations may range in size from very small facilities with a direct footprint of less than 1ha to large facilities of several buildings covering multiple hectares for large diameter pipelines. Large compressor stations may be permanently staffed and therefore receive regular vehicle traffic. Noise disturbances created by compressor stations and displacement due to human activity may create a potentially large ZOI around these facilities.

- **Abandonment and Reclamation.** Many shut in wells occur in North Yukon (approximately 40) and several in Southeast Yukon. Wellsites in Yukon have historically been shut-in and abandoned with no reclamation activities taking place. Some wells may have been purposefully left un-reclaimed with the intention of returning for further exploration or drilling at some point in the future. As the history of well-site closure has largely been one of abandonment, the rate and mechanism for revegetation of surface disturbances is not well understood, nor documented, especially for North Yukon. Preliminary observation of recent satellite imagery of abandoned wellsites created in the 1960s and 1970s in the Eagle Plains Region of North Yukon indicate that all wellsites and associated clearings are still persistent and visible on the landscape today. The rate of revegetation on abandoned wellsites and facilities in southeast Yukon would be expected to be similar to northern Alberta and British Columbia.

3.2.3. FORESTRY SECTOR

3.2.3.1. Overview

Through DIAND Forest Resources, forestry is currently a federally managed program in Yukon. The devolution of forest management responsibility from DIAND to the Yukon Territorial Government is anticipated to occur on April 1, 2003. The DIAND Timber Harvest Planning and Operating Guidebook (DIAND 1999) is the primary operational level guidebook for forest management in Yukon. Resource Reports are prepared for specific harvest areas to address timber, environmental and social considerations. Commercial timber harvesting is regulated by the Yukon Timber Regulations of the Territorial Lands Act.

Due to the northern climate, physiography and soils, the amount of productive forested land base suitable for industrial-scale forest management within Yukon is limited, with the majority occurring in southeast Yukon and the remainder scattered throughout southern and central Yukon (Senyk et al. 1988). In southern and central Yukon, the most productive forest lands occur along riparian corridors. Riparian forests on localized sites in some areas of North Yukon can also be productive and have historically been an important source of fuel wood and building materials. Fire has been and continues to be the most important forest disturbance agent in most areas of Yukon, and has been a major consideration for the development of the Annual Allowable Cut (AAC) for Yukon harvest scenarios. Based on a 50-year period of fire mapping, most areas of southeast and central Yukon operate on a 100-150 year fire cycle (DIAND, unpublished data). The current AAC for Yukon is 450,000 m^3 annually (DIAND 1999) but this level of harvest has only been reached once in the past 20 years. The Yukon forest management regime is very different than most other areas of Canada, with limited forest tenure currently existing. Prior to 1995, independent forest harvesters could apply for and generally receive a commercial timber permit for anywhere in Yukon, excluding First Nations Lands, Parks and similar titled land. This practice lead to a dispersed pattern of roads and harvest blocks, creating excessive access. Currently, most forestry activities are planned and administered by DIAND Forest Resources with independent forestry contractors receiving commercial timber permits for specified volumes. Specific areas, termed Harvest Planning Areas (HPAs), are identified and planned for forest harvesting by DIAND. Individual operators are responsible for detailed harvest block layout and harvest strategies. This method of forest management, while still not set within a comprehensive regional forest management planning context, has served to centralize forest harvesting activities, thereby decreasing the amount of dispersed road network created through unplanned harvesting. Due to road building costs and moderate economic returns, most forest harvesting occurs within 10 km of a major road, primarily the Alaska Highway. Lack of access is commonly cited as a limitation to increased forest production in Yukon.

Various levels of forest harvesting have occurred throughout south and central Yukon from the Gold Rush era to present. Most historical forest harvesting was focused on major river corridors to supply river-based shipping transportation with fuel wood. It is estimated that more than 250,000 m^3 of fuel wood was harvested along major Yukon watercourses in 1900 alone (Yukon Department of Renewable Resources 1999). During the past twenty years, industrial-scale forestry activities have generally been concentrated in southeast Yukon in the Watson Lake area (Forest Management Units Y02 – Coal, and Y03 – Upper Liard) and recently in the La Biche River drainage (Forest Management Unit Y01 – La Biche), adjacent to the Kotaneelee Gas Plant. The largest volume of timber harvested in a single operating season occurred during the 1994/95 “timber rush”, which saw 450,000 m^3 being harvested from the Watson Lake area, and the majority shipped as raw logs to British Columbia mills. This large volume increase prompted a short-term harvesting moratorium and the development of increased forest management capacity by DIAND Forest Resources. The 1994/95 operating season also saw a major shift in forest harvesting from productive, lowland riparian forests to moderately productive, upland sites. For the first time, this shift put large-scale, industrial forest harvesting in direct conflict with woodland caribou winter ranges. All major forest harvesting activities in Yukon since the 1994/95 operating season has occurred in upland forest environments. Interest in forest harvesting has been closely tied to timber prices and the sporadic existence of sawmills in the community of Watson Lake, resulting in widely varying annual timber harvest levels.

3.2.3.2. Potential Impacts

As most forest harvesting activities within southern Yukon now occur in mature forests on upland sites, forest harvesting occurs within preferred woodland caribou winter habitats. Forest harvesting creates younger forest stands that generally support lower amounts of terrestrial lichen, the primary winter food source for northern woodland caribou. While the amount of timber that has been harvested in Yukon over the past several years is comparatively low compared to Alberta or British Columbia, a significant network of all season and winter roads has been developed into previously un-roaded areas, thereby allowing access for hunting and harassment by off-road vehicles. In some cases, associated development, such as the Kotaneelee Gas Plant near the La Biche River, has allowed access for forestry activities.

Forest harvesting in two areas of Yukon, when combined with the cumulative effects of other human activities, currently has the potential to negatively impact caribou. The Rancheria area in the winter range of the Little Rancheria Herd near Watson Lake (Florkiewicz et. al. 2002) and the winter range of the Southern Lakes Herd near Whitehorse have received environmental assessments in response to forest harvesting and associated cumulative human activities. The

Rancheria study incorporated an assessment of habitat conditions, in conjunction with the calculation of development footprint.

3.2.4. TRANSPORTATION AND ASSOCIATED INDUSTRIES

3.2.4.1. Overview

The reconstruction and maintenance of the Alaska Highway and other major roads is an important economic activity and a major source of landscape-level disturbance in Yukon. In most Yukon communities outside of Whitehorse, highway construction and maintenance is perhaps the most significant source of local employment. Highways and road infrastructure are regulated by the Yukon Highways Act and administered by the Yukon Government. New road construction is also regulated by the Territorial Lands Act, currently under authority of DIAND, and must undergo environmental assessments. Quarries are also regulated under the Territorial Lands Act.

A second source of transportation-related linear disturbances in Yukon is electrical utility transmission corridors. Transmission lines tend to largely parallel existing road corridors and result in significant (10 – 50 m) linear clearings to accommodate transmission poles and lines. Similar to transportation, The Territorial Lands Act and Yukon Highways Act provide legislation for transmission utility corridors.

3.2.4.2 Potential Impacts

Potential impacts of the transportation industry and electrical transmission lines occur both during and after construction activities. Potential impacts result from three major activities: 1) construction or re-construction, 2) maintenance and 3) in the case of transportation, general highway use.

3.2.4.2.1. Construction and Re-Construction

A major and ongoing activity in Yukon over the past 15 years has been the re-construction of the Alaska Highway. The original Alaska Highway, constructed in 1942 for the purpose of military transport, was constructed quickly and with limited regard for speed or safety considerations. Since that time, most sections of the road have undergone continual paving, straightening, and widening. However, in the past 15 years, major sections of the Highway have been largely re-constructed, either by building an entirely new road corridor apart from the original corridor, or through the creation of a new road within the existing corridor, but immediately adjacent to the original route. With the first scenario (i.e. construction of a new road corridor), abandoned sections of the road commonly become used for public access and in some cases, private residences have become established along sections of the “Old Alaska Highway”. When a new corridor is constructed adjacent to the original alignment, very large linear clearings typically result, sometimes on the order of hundreds of meters wide, potentially creating significant barriers to wildlife movement and crossing. Both scenarios result in potentially large amounts of cumulative habitat loss. Outside of the City of Whitehorse, very little primary road construction has occurred in Yukon over the past 10 years.

Construction or re-construction activities include large seasonal work camps and the use of heavy equipment and in some areas, blasting. High levels of noise, dust and vehicle activity are associated with major construction areas, and it is common for construction to occur 24 hours/day at the height of summer. Potential ZOI around major highway or utility corridor construction zones may therefore be very large, but the significance of this displacement is temporary and becomes reduced after construction activities end. Road construction also results in the development and sometimes long-term maintenance of gravel, sand or rock quarries adjacent to road corridors. Gravel pits are a major contribution to the direct footprint of highway corridors; they are large, slow to revegetate and may not return to pre-disturbance states for very long periods of time (Kennedy 1993). The slow rate of vegetation recovery in gravel pits is an important consideration for the long-term persistence of human features in an area, and therefore of importance to cumulative effects assessment. Revegetation and seeding of road cuts with legumes has also been known to attract ungulates to road corridors, increasing potential risk of mortality from animal-vehicle collisions. For this reason, the use of native species is now a preferred option.

3.2.4.2.2. Maintenance

Highway maintenance is an important and ongoing part of the transportation and electrical transmission industry. Highways require patching, resurfacing, plowing, grading and road-side brushing, activities that occur annually. Salt has historically been used to melt snow and ice on winter roads, but similar to the use of legumes as revegetation mixtures, has resulted in the attraction of ungulates, including woodland caribou, to roadsides, thereby increasing the potential for vehicle-animal collisions. Annually, reported caribou mortality resulting from vehicle collisions ranges from a few to as high as 20 individuals, most occurring in the winter months in the Southern Lakes and Little Rancheria herd winter ranges. For this reason, the use of salt has been a contentious issue between highway maintenance and wildlife managers, and its use is now largely being replaced with less toxic, or in the case of wildlife attraction, less attractive products. Both roads and electrical utility transmission systems require periodic brushing activities along the corridor to improve visibility. Vegetation within transmission line corridors must be kept in a non-forested state to decrease the fire risks. Impacts of these periodic activities on woodland caribou would be expected to be very low.

3.2.4.2.3. General Highway Use

In addition to the domestic traffic load and large amount of vehicle-based transport of freight between southern Canada and Yukon, Alaska and Northwest Territories (Inuvik), over 300,000 travelers visited Yukon in 1998, most arriving by recreational vehicle or car (Yukon Department of Renewable Resources 1999). Along the Alaska Highway, traffic loads vary seasonally, with summer periods receiving the majority of vehicle-based recreation. The level of industrial activity in Yukon and neighbouring northern jurisdictions is a major determinant of the level of non-tourism generated highway traffic. The Alaska Highway passes through several caribou herd winter ranges, and the potential for highway collisions is high, especially in the Southern Lakes and Rancheria areas. For the period 1999-2002, 13 Little Rancheria herd fatalities were recorded as a result of vehicle collisions, all occurring in the winter months (J. Adamcewski, pers. comm.). Fortunately, the majority of recreational-based highway traffic occurs in summer, when herds are not within the winter ranges.

3.2.5. CUMULATIVE INDUSTRIAL FOOTPRINTS AND ENVIRONMENTAL IMPACTS

While southern jurisdictions generally contend with a variety of additive land uses co-occurring on the same land base (e.g. oil and gas exploration and production, forestry, transportation, agriculture, mining, recreation and urban development), large areas of Yukon, due to the geographic / ecological setting, have limited suitability for industrial-scale forest management or agriculture. This creates a situation where some areas of Yukon will likely only be influenced by one or two industrial activities co-occurring on the same land base, thereby reducing potential cumulative environmental effects from multiple industrial activities and footprints.

While cumulative environmental impacts resulting from multiple industries may not occur over all areas of Yukon, many areas have and will continue to experience cumulative impacts from a single industry (i.e. mineral exploration, oil and gas activity, forestry, etc.). However, some areas of Yukon are experiencing cumulative environmental impacts from multiple industries and activities. The Muskwa Plateau and Hyland Highland Ecoregions of southeast Yukon are being impacted by the industrial activities of oil and gas, forestry and transportation, and are potentially influenced by adjacent effects from NWT and British Columbia. The Watson Lake region is experiencing cumulative environmental effects from forestry, transportation and mining. The Southern Lakes region, specifically the Whitehorse area, supports a range of industrial, commercial, residential, agricultural, and transportation land uses within close geographic proximity. The contribution of urban, country-residential and rural development, and the variety of recreational activities that occur in Yukon (wilderness recreation, off-road vehicle use, etc.) have not been addressed in this report but in some cases may have as large or larger contribution to cumulative environmental impacts as industrial activities. These "non-industrial" activities should therefore be included in any cumulative environmental effects assessment.

3.2.6. CONCLUSIONS

Based on this discussion of Yukon industrial and related activities, it has been demonstrated that the use of thresholds in the assessment and management of cumulative environmental effects in Yukon is relevant. The history and pattern of development in Yukon has been one of sporadic, incremental growth with dispersed activity occurring along an expanding road network. While the level of cumulative industrial activity in Yukon will overall be less than experienced in neighboring jurisdictions, some areas are currently experiencing, or have the potential to experience, high levels of cumulative environmental impacts such as the Southern Lakes or Liard Basin regions. In these areas, the implementation of thresholds may be the only objective, defensible manner of regulating the rate and pattern of cumulative development activities in order to maintain woodland caribou populations. To achieve this goal, the following section outlines a potential industrial threshold approach for use in Yukon.

3.3. POTENTIAL CUMULATIVE EFFECTS THRESHOLD APPROACHES

3.3.1. EXISTING RESEARCH AND APPROACHES FOR WOODLAND CARIBOU

Thresholds have been used by various agencies in several areas of environmental monitoring and assessment such as water quality and sediment toxicity. These include the World Health Organization Drinking Water Guideline, the United States-Environmental Protection Agency Water Quality Criteria for the Protection of Aquatic Life, the Environment Canada Directive Maximum Admissible Concentration in Drinking Water, and the Environment Canada Mercury Toxic Effect Threshold for the Protection of Aquatic Life (Appleton et al. 2001). Critical limits have also been identified for air pollutants such as sulfur dioxide, ozone, nitrous oxide, and ammonia (Sanders et al. 1995).

Thresholds for human-related influences on wildlife demography have also been discussed recently in the literature. A study that examined the relationship between 29 bird species and agricultural intensification in England and Wales over a period of approximately 30 years suggested there may be a demographic threshold related to high-quality habitat or food resources (Chamberlain et al. 2000). Wang et al. (2001) reported an apparent threshold where small increases in urbanization were associated with dramatic changes in fish species richness and diversity and stream health. Estimations of human use impacts on grizzly bear habitat within Jasper National Park suggested that summer tourist activity may drop habitat effectiveness below a threshold of 80% set by Parks Canada (Hood and Parker 2001).

Impacts of human activity on caribou have been considered within the context of thresholds as well. Bradshaw (1994) predicted that woodland caribou might experience increased winter weight loss after 23 perturbation encounters per winter; however, he did not calculate the relationship between weight loss and potential decreases in reproductive success. Data from barren-ground caribou herds have been used to model influences of weather, insects, and industrial development on body condition, individual reproductive success, and population growth (AXYS et al. 1998; Russell, unpublished data; Gunn et al., unpublished data). Use of such modeling procedures may assist in establishing thresholds for human disturbance of caribou. The greatest body of threshold-related research for woodland caribou pertains to habitat and human footprint thresholds. The following sections discuss this research and approaches taken to date in Yukon and two neighboring jurisdictions, British Columbia and Alberta.

3.3.1.1. Yukon

The Yukon caribou range experiencing the greatest degree of existing human footprint and corresponding government attention with respect to new development is that area occupied by the Little Rancheria caribou herd. This northern mountain woodland caribou herd migrates seasonally from British Columbia to wintering range in southeast Yukon. A set of guidelines have been used since 1996 by Yukon Renewable Resources in assessing development proposals within the Little Rancheria winter range (Florkiewicz et al. 2002). The approach that was taken to develop these guidelines was similar to that of the British Columbia Land and Resource Management Plans (LRMPs) that deal with northern caribou. Core wintering area was defined using information from radio-collared animals and reconnaissance surveys. Emphasis was placed on preserving core winter range, while allowing for some forestry activity in the surrounding areas. No-harvest and no-road-development objectives were recommended for this core area, with limited harvesting considered on a case-by-case basis. The extended winter range, which surrounds the core area, was to have retention of 50% old and mature forest, while retention of 80% old and mature forest was suggested for the migration zone between the winter and summer areas. Three scenarios for changing the guidelines have been proposed (Florkiewicz et al. 2002). The liberal option would be to continue with unplanned incremental development, while the conservative option would halt all development in the Little Rancheria winter range. The intermediate option is to adopt the recommended guidelines. Florkiewicz et al. (2002) recognize that cumulative effects have not been adequately addressed.

A preliminary analysis of cumulative footprint was conducted for the Little Rancheria winter range (Florkiewicz et al. 2002), following that used by Dzus (2001) for boreal caribou in Alberta: Footprint was calculated as the percentage of the range within 250 m of a linear corridor. Total footprint was estimated to be 18% of the core winter range, 18% of the extended winter range, 16% of the entire winter range, and 5% of the migration corridor. Interestingly, only 3.6% of the forest had been harvested for timber. Although the concept of a threshold has been discussed, further consensus is necessary on a method to identify an ecologically valid threshold for total human footprint (J. Adamczewski, pers. comm.; R. Florkiewicz, pers. comm.).

3.3.1.2. British Columbia

Though other factors are also expected to influence caribou demography and distribution, the greatest perceived threat to caribou conservation in BC is habitat loss, fragmentation, and alteration, primarily due to forestry operations in or near caribou habitat (Simpson et al. 1997; D. Heard, pers. comm.). Both southern mountain and northern mountain caribou are closely associated with older forests, where lichen abundance is greatest (Cichowski and Banner 1993; Simpson et al. 1997). Forestry activity in these older forests can, therefore, remove important foraging areas. Spatial separation from predators may be an important life-history strategy for mountain caribou (Seip 1992), but habitat change caused by forestry activity may alter the predator-prey relationship in fragmented areas, thereby increasing predation risk for caribou (T. Kinley, pers. comm.). Disturbance from recreational activities such as snowmobiling may also influence habitat use and energetics for woodland caribou (Simpson et al. 1997; D. Heard, pers. comm.; G. Schultze, pers. comm.).

The cumulative effects threshold concept, though under discussion, has not been adopted for British Columbia's woodland caribou ranges (D. Heard, pers. comm.). Instead, management has focused on maintaining existing core winter range (old forests). Simpson et al. (1994) reported that southern mountain caribou likely require a minimum of 60% of the landscape to be suitable winter habitat for utilization of an area. Although this suggests a habitat occupancy threshold, the adequacy of this minimum value in ensuring population stability or its relevancy for northern mountain caribou herds is unclear. In a recent conservation strategy document (Simpson et al. 1997), proposed provincial management guidelines suggest large no-harvest zones to protect core habitat in high elevation areas. In areas where timber harvest is still to occur, habitat distribution objectives will be met by using extended rotation periods (> 240 years) over the entire range or a combination of reserves and areas of shorter rotation. For northern mountain caribou, most management recommendations are found in the regional LRMPs. These plans typically include development of protected areas for core caribou habitat and guidelines for development in adjacent areas (Florkiewicz et al. 2002). Guidelines deal primarily with retention of minimum area in older seral stages and deferred harvesting for some areas. No quantification of human footprint or occupancy threshold has been completed for northern mountain caribou and a conservation strategy document has not been published.

3.3.1.3. Alberta[1]

The Province of Alberta has drafted three provincial-level caribou conservation strategies over the past two decades: 1) the Woodland Caribou Provincial Restoration Plan (Edmonds 1986), 2) the Strategy for the Conservation of Woodland Caribou in Alberta (Alberta Fish and Wildlife 1993) and 3) the Alberta Woodland Caribou Conservation Strategy (Alberta Woodland Caribou Conservation Strategy Development Committee 1996). Unfortunately, none of these documents have been officially adopted by the Alberta Government (Dzus 2001).

Concern about industrial development in caribou habitat did, however, lead the government to release Information Letter 91-17, a procedural guide for oil and natural gas activity on caribou

[1] Note: Recent advances have been made in developing Habitat Effectiveness Targets for caribou in west-central and boreal regions of Alberta; as a result, this section is currently being modified to address updated methodologies.

range (Alberta Energy 1991). It stated that "…petroleum and natural gas exploration and development activities can occur on caribou range provided that the integrity of the habitat is maintained to support its use by caribou." Information Letter 91-17 also proposed that joint government and industry standing committees should be developed for areas where industry operates in caribou habitat zones in both boreal and west-central Alberta. In boreal caribou ranges, early committees included the Pedigree Standing Committee (formed in 1990), the Northwest Regional Standing Committee on Woodland Caribou (formed in 1992), the Northeast Regional Standing Committee (formed in 1993), the Slave Lake Committee (formed in 1993) and the Red Earth Standing Committee (formed in 1995). The Northwest and Northeast Regional Standing Committees merged in 1999, forming the Boreal Caribou Committee (BCC). In west-central Alberta, the West-Central Alberta Caribou Standing Committee (WCACSC) was struck in 1992 (Hervieux et al. 1996) to develop industrial guidelines that support caribou conservation in that area.

Early research by the Northeast and Northwest Regional Standing Committees focused on caribou population dynamics and habitat use. Upon amalgamation into the Boreal Caribou Research Program (BCRP) in 1996, the focus progressed to the interaction between caribou, wolves, and industrial activity in northern Alberta. Similar research has been conducted by WCACSC, with a strong emphasis on forestry-related issues. These research projects were designed to provide data necessary for assessing basic population status in addition to industrial impacts on woodland caribou in Alberta.

3.3.1.3.1. West-Central Ranges

Woodland caribou in the west-central region of Alberta are of the northern mountain ecotype (though they were assessed with the southern mountain population by COSEWIC) and are similar to caribou that inhabit the northeast portion of the Hart Ranges ecosection of British Columbia; some animals, in fact, move back and forth between the two provinces (Simpson et al. 1994). Unlike northern Alberta, where boreal woodland caribou generally live year-round in peatlands (Bradshaw et al. 1995; Anderson 1999), caribou in west-central Alberta spend their summers in high mountain areas and winters in old, merchantable forest stands that are of interest to forest companies. This direct conflict makes maintenance of an adequate habitat supply an obvious challenge for caribou conservation in these ranges (Dzus 2001). Unfortunately, the Habitat Supply Subcommittee of WCACSC has been unable to reach consensus on how to manage and maintain sufficient habitat (D. Hervieux, pers. comm.). Although they have not published a strategy describing how cumulative effects thresholds will be developed in west-central caribou ranges, the WCACSC Research Subcommittee has proposed a number of methods to develop habitat and population targets for conservation of woodland caribou. Quantification of the following parameters and measures will be necessary (D. Hervieux, pers. comm.): habitat effectiveness, population density, winter home range quality, adult survival and calf recruitment, and resource selection probability functions.

3.3.1.3.2. Boreal Ranges

The first attempt to develop land-use thresholds for caribou habitat in Alberta occurred in the Pedigree area of boreal northwestern Alberta. A Caribou Protection Plan was prepared that proposed limits to total clearing and industrial activity per township (one township is approximately 100 km^2) (PCSC 1991). Although there was limited data available at the time from which to develop thresholds, this was a bold first attempt to develop a plan that captured the importance of cumulative effects in land-use guidelines. The plan, however, was not in place long enough to enable a review of the efficacy of these guidelines in protecting woodland caribou

(AXYS 2001a). Elsewhere in Alberta, initial guidelines were largely focused on the use of timing restrictions as a means to protect caribou (NERSC 1997). Continued population declines suggest that such land-use guidelines in Alberta have proven ineffective in providing for long-term caribou conservation (Dzus 2001).

As results of research became available in the late 1990's, the BCRP was able to recommend changes to industrial practices in caribou habitat zones. They recommended that revised guidelines should address the total amount, intensity and duration of industrial development in caribou habitat and that conservative interim limits to development be set before disturbance thresholds were calculated (BCRP 1999). Attempts to incorporate new research and consolidate guidelines between different caribou ranges were unsuccessful, as draft guidelines were overly complicated and still failed to consider cumulative effects (see Macdonald 2001 for a review).

A recent coarse analysis of human footprint and caribou demography data for boreal caribou ranges (Table 1) indicated there might be a 'breaking point' for habitat effectiveness, beyond which caribou populations begin to decline (BCC 2001). Given this apparent relationship, the renewed focus for conservation of boreal woodland caribou is the maintenance of sufficient effective habitat (BCC 2001). This is anticipated to be achieved through the development of explicit habitat targets and changes in practices for industry and government to meet those targets. The habitat targets will predict the amount of effective habitat that must be present in boreal caribou ranges to support stable or increasing caribou populations (BCC 2001). Although the new Strategic Plan and Industrial Guidelines did not include the word 'threshold', the proposed habitat effectiveness approach undoubtedly represents a reasonable first attempt at identifying a threshold, then working toward ensuring that those ranges currently above the threshold remain so and those below the threshold recover to a point above the threshold. The habitat effectiveness target will be the target minimum for all boreal caribou ranges in northern Alberta and will determine how industry operates in the various ranges. Range-specific factors, such as predator density, hunting pressure, and climatic factors, are not explicitly considered in this approach, although some of these factors may also be influenced by human developments. An overview of how habitat effectiveness targets will be developed for boreal woodland caribou ranges in northern Alberta (James, pers. comm.) is presented below.

Table 1. Mean annual percentage population change data from Alberta boreal woodland caribou herds and the percentage of each range that is within 250 m of a linear corridor.

Caribou Range	Mean Annual % Population Change*	% of Range within 250 m of a linear corridor**
Caribou Mountains	-2.7	27.9***
Cold Lake	0.0	38.6
West Side Athabasca River	0.0	45.3
East Side Athabasca River	-1.5	51.9
Red Earth	-3.1	55.5
Little Smoky	-10.8	84.7

* Population change data from Boreal Caribou Committee (2001)
** Data from Dzus (2001), except Little Smoky herd data provided by Troy Sorensen, Fish and Wildlife Division, Alberta Sustainable Resource Development
*** Over half the caribou range in this area has experienced large-scale fire disturbance within the last 50 years.

3.3.1.3.2.1. Boreal Caribou Committee Process for Developing Habitat Targets

A current habitat effectiveness value will be calculated for each caribou range. Habitat effectiveness is defined here as the capacity for an area to maintain caribou populations in perpetuity. It can be calculated by first determining the ability of a caribou range to provide for the life history needs of caribou (habitat quality), then by determining how habitat quality is eroded by human developments such as roads, seismic lines, forestry cutblocks, and pipelines. For example, although a 120-year-old forest stand may provide caribou habitat of high quality, the effectiveness of this habitat would be considerably reduced if the stand was beside a busy road with heavy traffic. Development of habitat effectiveness values for caribou ranges in Alberta requires quantification of four variables: 1) habitat quality of different vegetation types, 2) habitat quality of different stand ages, 3) zone of influence of human developments and 4) degree of avoidance associated with human developments.

- **Habitat quality of vegetation types.** Within a given caribou range, habitat is not used uniformly by caribou. Boreal woodland caribou home ranges in northern Alberta are generally found within peatland-dominated landscapes with a high proportion of black spruce (*Picea mariana*) and tamarack (*Larix laricina*) bogs and fens (Bradshaw et al. 1995; Anderson 1999). In contrast, upland areas containing trembling aspen (*Populus tremuloides*) and white spruce (*Picea glauca*) are avoided (Fuller and Keith 1981; Bradshaw et al. 1995, Stuart-Smith et al. 1997, Anderson 1999). Calculations of habitat quality must weight the relative importance of different habitat types.

- **Habitat quality of different stand ages.** Woodland caribou in Alberta are believed to prefer old forests (Bjorge 1984, Stepaniuk 1997) that contain abundant lichen, their main winter food source (Thomas et al. 1996b). Calculations of habitat quality must weight the relative importance of different stand ages to caribou. Any process that destroys lichens and removes old forest, such as forest harvesting or forest fire, is expected to similarly reduce caribou habitat quality in the short term.[2]

- **Zone of influence of human developments.** There is a great volume of literature describing the avoidance of human developments by caribou (see Section 3.1.2). There is also great variation in the zone of influence of human developments described in these studies (UNEP 2001). Managers are encouraged to develop consensus-based workshops to review existing literature and develop meaningful buffers for human developments. This has already been performed in Alberta, where over 20 biologists reached consensus on reasonable zones of influence associated with a number of human developments (Table 2).

Table 2. Zone of Influence (ZOI) or avoidance buffers associated with human developments, as developed at Caribou Biologist Workshops, Edmonton, 2001.

Human Feature	Avoidance Buffer
Road	500 m
Seismic Line	100 m
Pipeline	100 m
Wellsite	250 m
Forestry Cutblock	500 m

[2] Recent research and preliminary analysis of the relationship between boreal caribou habitat selection and fire history in northern Alberta (Dunford, unpublished data) may question our assumptions about the decreased value of peatlands following fire. Analyses are preliminary, however.

- **Degree of avoidance associated with human developments.** Although the zone of influence associated with two human developments may be similar, the degree of avoidance may be markedly different. For example, Dyer et al. (2001) demonstrated almost total exclusion of caribou within 100 m of roads, while areas within 100 m of seismic lines received approximately 50 – 70 % of expected use by caribou. The degree of avoidance, as used in this report, is synonymous with 'Disturbance Coefficient' (AXYS 2001a), although this language is not used by the Boreal Caribou Committee. A literature review and expert workshops can assist the development of these values. Although exact avoidance effects will vary between species and habitat types (UNEP 2001), it should be possible to develop rigorous, yet conservative values accepted by all stakeholders. Future research will play an important role in refining both the Zone of Influence and Degree of Avoidance values.

3.3.1.3.2.2. Boreal Caribou Committee - Progress to Date

Data related to the parameters discussed above are currently being collected and combined for northern Alberta. Once data have been assembled, a current habitat effectiveness value will be calculated for each range using a Geographic Information System (GIS). For each range population, demographic data have been collected over several years (ranging from 4 to 10 years, depending on the area) using mortality rates of collared adults and calf recruitment data from spring calf surveys. Mean annual population change will be plotted against the calculated habitat effectiveness for each range. A regression analysis will be used to determine the relationship between habitat effectiveness and population change. Where the regression line intercepts a particular population change value (perhaps stable, or zero population change), this habitat effectiveness value will become the target for all ranges.

Following development of the habitat effectiveness target, range plans will be developed to ensure this target will be achieved in each of the existing boreal caribou ranges. To ensure success of the range planning process, managers must be able to predict if current best practices will enable habitat targets to be achieved in the future, based on expected development trajectories. ALCES® (A Landscape Cumulative Effects Simulator) is a model that enables resource managers to explore landscapes subjected to various human land-uses and natural disturbance regimes (Forem Technologies 2002). The Boreal Caribou Committee intends to use ALCES® (and potentially other models) to project future changes in caribou habitat effectiveness based on current best practices (Boreal Caribou Committee 2001). A model like ALCES® is capable of projecting both future development schedules and the lifespan of different human features on the landscape. This will enable managers to determine if current best practices are sustainable in perpetuity or will result in the habitat effectiveness target being exceeded.

In ranges that are approaching the habitat target, changes in industrial practices may be required. The new Strategic Plan and Industrial Guidelines (BCC 2001) provided a variety of negotiated industrial 'best practices' to occur within caribou habitat. These included innovations such as guidelines for placement of peat mining operations, use of the Natural Disturbance Model to guide forest harvesting planning (including cutblock size, shape and amount of residual material retained), and narrower (≤ 3 m) seismic lines in ranges with declining caribou populations. Although none of these approaches directly address the underlying issue of cumulative effects, they do provide flexibility in mitigating negative effects of industrial development on caribou and should help to slow increases in the cumulative footprint. In ranges expected to fall below the habitat target, using best practices guidelines may involve adoption of exceptional practices to minimize further footprint as well as restoration projects to remove the influence of existing developments on functional caribou habitat.

The BCC Strategic Plan and Industrial Guidelines (Boreal Caribou Committee 2001) also proposed the development of activity targets. These targets would place an upper desirable limit on the amount of human activity in an area at any one time. This may include things such as limiting the number of vehicles per hour on a road or limiting the number of people working within a given area at any one time. Development of such targets is merely conceptual at this point, however, and will require further research into the influence of human activity on caribou energetics and population dynamics.

The BCC Strategic Plan and Industrial Guidelines recognized that successful implementation of range plans would require development of a new resource management framework. Major recommendations were that range planning should be completed before timber, peat and sub-surface resources were allocated and that the government should develop and manage a spatial data system (GIS) capable of tracking cumulative changes in caribou habitat (Boreal Caribou Committee 2001). Use of a habitat effectiveness target will need to follow the continuous improvement model. Ranges will continue to be monitored and adaptive management will be used to refine threshold targets and assumptions that derive habitat effectiveness values.

3.3.2. A SUGGESTED APPROACH TO DEVELOPING CUMULATIVE EFFECTS THRESHOLDS FOR YUKON WOODLAND CARIBOU RANGE

To date, no jurisdiction in Canada has established, implemented and enforced cumulative effects thresholds for industrial activity in woodland caribou range. Instead, guidelines and regulations have been put in place in an attempt to minimize and mitigate the impacts of individual development projects on caribou. Yukon is currently following a similar management model. Under this system of management, most woodland caribou populations in Canada have been designated as species of Special Concern, Threatened or Endangered (COSEWIC 2002). In many instances, caribou ranges have already been severely impacted and will require a great deal of effort and financial resources to return habitat effectiveness to an acceptable level. Yukon has a unique opportunity to develop and implement cumulative effects thresholds for caribou range prior to large-scale industrial development occurring. Based on experiences from other jurisdictions, this must be initiated now if Yukon wishes to maintain healthy caribou populations in perpetuity.

3.3.2.1. Required Characteristics of Thresholds

Thresholds have been defined as "a point at which a resource undergoes an unacceptable change or reaches an unacceptable level, either from an ecological or social perspective" (AXYS 2001a). Because assessments of cumulative effects in relation to thresholds have the potential to result in either the granting or denial of approval for a proposed project, it is important to ensure that threshold values and the approach taken to develop those thresholds are appropriate. Thresholds must be scientifically defendable, yet transparent and practical for acceptance by regulators who may not have in-depth technical experience relevant to caribou ecology. Based on our literature review and experience in other jurisdictions, any threshold approach developed for Yukon should meet four major requirements:

- **Industrial thresholds developed for caribou range must be related to ecological processes and thresholds for caribou.** Industrial activity can influence caribou in a number of ways (Section 3.1), such as through behavioural changes in caribou and, although consequences of these disturbances on population dynamics are still unclear, it is assumed that human-induced disturbances may adversely affect caribou populations. Population-level effects could foreseeably result from influences on energetics or predator-prey dynamics. As northern and southern mountain woodland caribou are not generally believed to be limited by forage availability or body condition (R. Florkiewicz, pers. comm.; T. Kinley, pers. comm.), the most important factor influencing population dynamics is predation (Gasaway et al. 1983). Woodland caribou populations have evolved and persisted under natural predator limitation in Yukon for thousands of years. Concern for caribou populations arises when the predator-prey relationship is altered by human activity (Gasaway et al. 1983). Industrial footprint has the potential to influence predation risk directly through habitat alteration and fragmentation and associated effects on predator abundance, distribution, and efficiency or the effectiveness of predator avoidance mechanisms (Seip 1992; James and Stuart-Smith 2000; Dyer et al. 2001). Indirect effects of disturbance and development on predation risk are the result of changes in alternative prey availability or decreases in prey body condition and subsequent ability to avoid predators. Therefore, an acceptable approach to setting industrial cumulative effects thresholds in caribou range must address influences of industrial activity on habitat effectiveness and the potential for altering the predator/prey relationship.

- **The approach adopted for developing thresholds must either identify unambiguous thresholds or point to data that strongly suggest the existence of a threshold.** Being able to identify a concise, clearly defined threshold that is backed by technically defensible observational data is fundamental to the threshold approach; failure to do so will likely result in limited political support for the process. For example, a coarse analysis of data collected by the Boreal Caribou Research Program suggests that there is a negative correlation (and possible threshold) between the amount of caribou range located within 250 m of a linear feature (seismic lines, roads, and pipelines) and population rate of change (Table 1). This indication of a potential threshold was an important factor in advancing habitat effectiveness work in boreal caribou ranges in Alberta. The addition of limited data for northern and southern mountain woodland caribou (Figure 2) suggest that these populations may follow a similar pattern.

- **The approach taken to developing thresholds for industrial activity in Yukon caribou range must fully address the cumulative aspects of all activities.** Several land-use controls have been identified as potential cumulative effects assessment thresholds for Yukon (AXYS 2001a, 2001b), including measures of maximum km of road/unit area and maximum linear disturbance densities. Such measures can be used to limit the additive effect of a given feature, but they do not adequately capture the cumulative effect that several different feature types may have on processes such as predator-prey dynamics. For instance, the presence of linear features alone may have little influence on the predator-prey relationship. A linear feature extending from a valley into a subalpine area may have little impact on caribou predation if there is no motivation for wolves to follow the line to the higher elevation. On the other hand, if changes in forest age structure result in higher moose densities on portions of caribou summer range, the presence of the linear feature may allow wolves easier access to a valuable hunting area, thereby also increasing predation risk for caribou. Because various activities and footprints may act synergistically, the threshold approach should address cumulative impacts across a variety of human influences on the landscape.

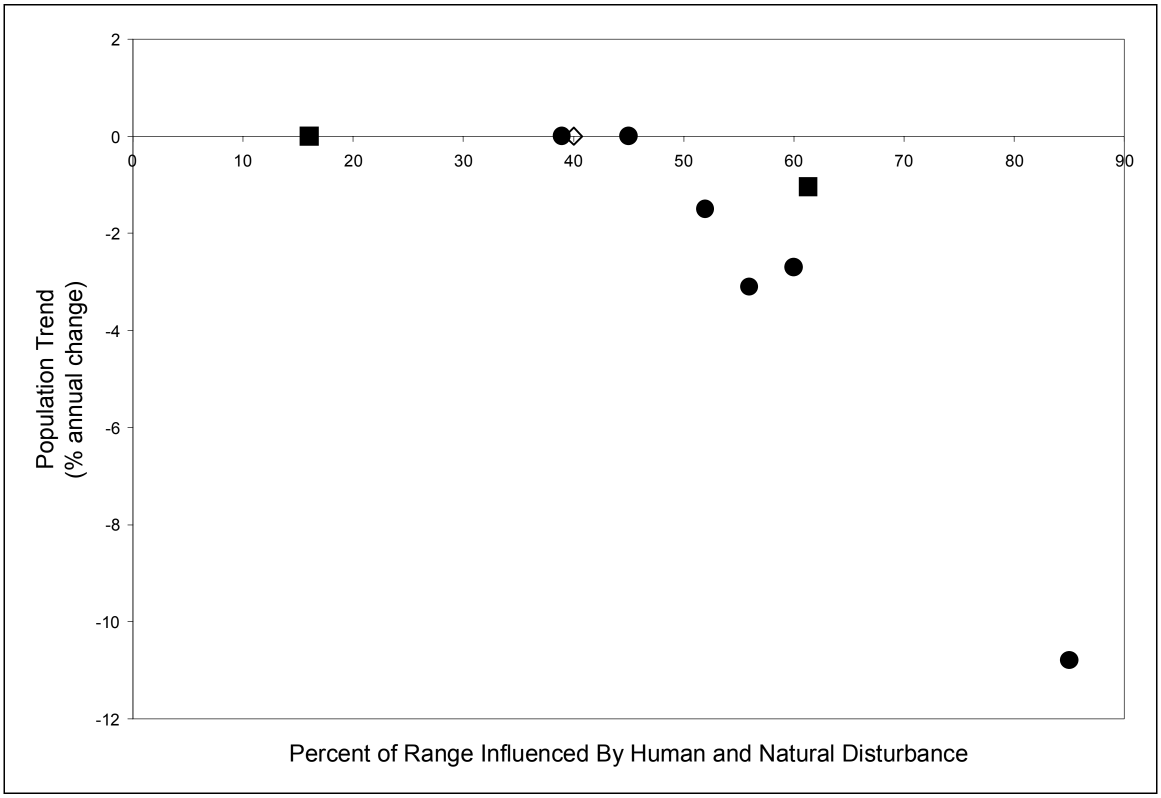


Figure 2. Approximation of woodland caribou habitat disturbance and population rates of change for several herds in western Canada. Data presented for boreal (●) and northern mountain (■) woodland caribou were derived from the Boreal Caribou Committee (2001), Dzus (2001), Florkiewicz et al. (2002), and T. Sorensen (pers. comm.). The datum presented for southern mountain (◇) woodland caribou represents a minimum suitable winter habitat threshold for occupation, as suggested by Simpson et al. (1997).

- **Thresholds must be useable, understandable and acceptable to the various stakeholders.** A workshop was held in November 2000 to identify attributes that stakeholders felt were most appropriate in developing thresholds for use in Yukon. The most desirable attributes of potential thresholds were that they be measurable, practical, and realistic (AXYS 2001b). Measurability of thresholds is key to providing numerical value in assessing the significance of an effect or proposed project and objectivity leads to acceptance of results by all stakeholders. Practical and realistic thresholds are necessary to ensure that costs associated with the screening process remain reasonable and that the cumulative effect measure lends itself to timely and efficient calculation (i.e. required data should be currently available or collectable).

3.3.2.2. Assessment of Major Approaches

In most jurisdictions, threshold approaches have focused on, according to our definition, industrial thresholds or land use and activity thresholds as defined in AXYS (2001a). Measures such as maximum linear disturbance densities, seral stage distributions and minimum habitat areas are common examples. However, as has been demonstrated in the previous sections, most of these threshold values fail to comply with our four criteria established for selecting an integrated cumulative effects threshold approach. Industrial thresholds are designed to limit specific activities in order to reduce potential impacts on woodland caribou – they do not address cumulative impacts of all activities nor are they related to the natural ecology of caribou. Therefore, a more integrated and ecologically-based approach to cumulative effects thresholds must be used.

In other jurisdictions, primarily Alberta, two main approaches have been considered for developing cumulative effects thresholds for industrial impacts in woodland caribou range: 1) habitat effectiveness and 2) energetics. An evaluation of these approaches relative to the required threshold characteristics outlined above reveals that the habitat effectiveness approach may be most appropriate for Yukon. While both approaches can be based on caribou ecology and related to influences on predation risk, changes in habitat and habitat use patterns may be easiest to relate to changes in the predator-prey relationship. Data currently exists from northern Alberta on changes in predator distribution and efficiency and effectiveness of predator avoidance strategies related to habitat and industry. Although it may provide a useful starting point and should be considered in long-term research plans, developing the association between changes in energetics and predation risk is more difficult and requires further research and data collection followed by modeling before thresholds can be identified.

The habitat effectiveness approach can be used to address both the effect of a single footprint class, as well as the effect of a variety of footprint types acting concurrently. This approach allows for a true measure of the total cumulative effect that caribou populations may experience, whereas thresholds related to a single land use (e.g. maximum linear disturbance density) address only part of the cumulative effect issue. An energetic approach to setting thresholds could also address the influence of several activities at once. However, the complexity of the model increases dramatically as more influencing factors are added.

The requirement that the threshold be measurable, practical, and realistic also favours use of a footprint-influenced habitat effectiveness approach. Footprint can be identified and mapped from airphotos, satellite imagery, and hardcopy maps (this is also a major consideration in the usability and acceptance of the approach – maps are excellent visual tools to convey results). Although it may be difficult to quantify the exact value of various habitats, it can be deduced based on existing research. An estimate of the influence of various disturbances can be based on our current understanding of caribou response to footprint type and industrial activities. As new information is gathered improving our understanding of these relationships, it is possible to continually update and improve habitat effectiveness models. Parameters related to the energetics approach are more difficult to measure, and to describe. Although body condition can be determined from captured or killed animals, this type of assessment usually relies on activities such as collaring or hunting, making repeated sampling difficult if not impossible. As a result, it may be difficult to obtain large sample sizes. Additionally, body condition data are related to past experience of the animal, and may not provide adequate information to predict future changes, especially prior to introduction of a disturbance activity. The energetics approach is less practical and realistic than habitat effectiveness in the short term, but may be valuable in the long term. Relative to the habitat effectiveness approach, energetics modelling requires more assumptions about behavioural responses, changes in energy intake and expenditure, and subsequent impacts on reproductive success and predation risk. Once a threshold has been set, however, it may provide a practical way to limit human disturbance during a given period or over a given geographic area. For instance, the energetics approach could be very valuable in determining how extensive an exploration program can be. Bradshaw et al. (1998) completed some work for seismic exploration. It may be possible to apply this information to other activities, given appropriate data, or adapt barren-ground caribou models for use with woodland caribou. To complete this, however, further research will be required into the influence of various disturbances on northern mountain woodland caribou energetics.

Footprint and habitat effectiveness thresholds can be developed to provide an objective, transparent benchmark, as well as a GIS tool for use by a wide range of interested parties. The proponent of a development project will be able to clearly demonstrate how proposed changes to the cumulative footprint will influence habitat effectiveness in relation to the threshold. Resource managers will also be able to model how habitat effectiveness will change over time given various development scenarios, industrial practices and recovery rates. If adequate data-collection standards and procedures are developed, changes in footprint should be easily tracked over time and used to monitor habitat effectiveness. Groundwork for this type of approach is currently being laid in Alberta. Implementing such an approach for Yukon will require consensus among caribou experts on habitat quality values and Zone of Influence numbers that apply to northern mountain woodland caribou herds.

3.3.2.3. Conclusion – A Suggested Approach for Yukon

Based on an evaluation of the many potential options available to developing and setting thresholds, two closely related approaches should be explored for setting cumulative effects thresholds for Yukon woodland caribou range. These are the **habitat effectiveness approach** and **the zone of influence (total footprint) approach**. An example of the habitat effectiveness approach was given in Section 3.3.1.3; the zone of influence (ZOI) approach is essentially a habitat effectiveness approach except that it does not account for differences in habitat quality. The zone of influence approach is a required precursor to the development of habitat effectiveness. Both approaches can be used to limit the influence of industrial activity on the predator-prey relationship, both can be based on available threshold data, both address cumulative impacts from various footprints, both are mappable and both can be designed so they meet the requirements of being measurable, practical, and reasonable. Threshold values and confidence should be compared for the two approaches. Although the ZOI approach is simpler, it may provide just as valuable a threshold as the full habitat effectiveness approach. Alternatively, it may be determined that the ZOI approach does not adequately capture the true impact of cumulative effects on caribou.

4. A RECOMMENDED THRESHOLDS APPROACH FOR YUKON

Based on the four criteria established for selecting a thresholds approach in Yukon, the **habitat effectiveness approach** or the closely-related **zone of influence (total footprint) approach** is recommended. Implementation of these approaches in Yukon will require a variety of data types and the consideration of a number of implementation issues, as described below.

4.1. IMPLEMENTATION

4.1.1. DATA REQUIREMENTS

The two threshold approach options recommended for use in Yukon are thresholds based on habitat effectiveness and thresholds based on total zone of influence (ZOI) of human developments in caribou range ('footprint', regardless of habitat). These two approaches are closely related as the ZOI calculations form the initial part of the habitat effectiveness calculations. To develop these thresholds, data from several ranges or herds is required to demonstrate variation in population parameters in relation to different footprint levels. Preliminary data suggests an apparent 'breaking point' or trend between caribou population change and the human development 'footprint'. Under ideal conditions, data specific to a geographic range should be used to develop the cumulative effects threshold for that area. When such data is not complete or available, it will be necessary to use surrogate values from other caribou herds that are similar in ecology, habitat requirements and/or human impacts. Hence, if sufficient data is not available from caribou populations in Yukon, it may be possible to use interim values from other caribou herds in North America and, in particular, from British Columbia and west-central and boreal Alberta. The development of both total zone of influence and habitat effectiveness thresholds, has four major types of data requirements: 1) geographic bounds of caribou ranges, 2) caribou herd demographic information, 3) human development information and 4) habitat quality (only required for habitat effectiveness approach).

4.1.1.1. Defining Caribou Range Areas

General knowledge of caribou distribution (i.e. range maps) in both winter and summer (for several populations) is a necessary prerequisite for setting thresholds. Caribou range areas may be defined by telemetry data, aerial survey data, traditional knowledge of caribou winter and summer ranges and satellite habitat mapping. It is likely that a combination of these approaches will provide reasonable range maps for Yukon caribou herds. Different threshold levels may need to be set for different areas (i.e. complete protection for core winter area, conservative to liberal thresholds for other areas.)

4.1.1.2. Demographic Information

Specific information is required for caribou populations (e.g., adult mortality, cow/calf ratios, recruitment, rate of change). Thresholds may be based on the response of one or more of these parameters to developments. If thresholds are set before all caribou populations are surveyed, demographic information is still valuable to determine the success of the threshold approach in preventing population declines. Demographic parameters can be obtained from mortality investigation of collared animals and spring calf surveys.

4.1.1.3. Development Information

Three major types of development related information are required in our proposed approach: 1) **cumulative development footprint**, 2) **zone of influence** associated with development features and 3) **degree of avoidance** associated with zones of influence. Human impacts on the landscape such as roads, seismic lines, trails, wellsites and installations, cutblocks, minesites, and urban developments need to be mapped for each range. These data may be obtained from existing maps, aerial photography, satellite imagery and digital coverages provided by industry. Both ZOI surrounding human developments and degree of avoidance associated with human developments (i.e. disturbance coefficients as defined in AXYS 2001a) must be deduced from existing literature and from expert opinion. A workshop for northern mountain caribou biologists from government and industry could use a Delphi process to reach consensus on zone of influence values. Preliminary zones of influence values for major industrial development types from Alberta are included in Table 2. Research may be necessary to refine these values for a given area and type of development. GIS can be used to calculate the total ZOI around the existing developments in each range through the use of buffering techniques. The influence of fire will also need to be included in these calculations (i.e. fire is an additional disturbance).

4.1.1.4. Habitat Quality

Additional variables need to be quantified to develop habitat effectiveness targets. Habitat quality values (of different forest cover types and age classes) can be assigned to habitat units identified through a habitat mapping exercise. Habitat units may be obtained from forest inventory mapping, ecosystem classification mapping or some other method appropriate to the range. The value assigned to each class can be based on empirical data and expert opinion. Empirical data may be provided from detailed telemetry or tracking research. Expert opinion may be based on both scientific and traditional knowledge of the value of various areas for caribou.

4.1.2. SETTING THE THRESHOLD

4.1.2.1. Zone of Influence Approach

A maximum ZOI threshold can be explored by plotting total ZOI in each range against one of the population parameters. Use of different parameters should be examined to determine which gives the most defensible threshold value. The actual threshold values will need to be set by examining the data and coming to a consensus on appropriate values.

4.1.2.2. Habitat Effectiveness Approach

Once habitat values are determined for each class, the total habitat worth for the range (assuming no footprint) can be determined by multiplying the habitat value by the area and summing across all habitat classes. The ZOI is then used to calculate the amount of habitat effectiveness removed by the disturbances. The remaining habitat effectiveness can be expressed as a percentage of the 'pristine' value. These values can then be plotted against population parameters to identify a threshold. Different thresholds may be required for total, summer or winter ranges. Again, consensus will be required to decided upon threshold values but must be based on demonstrable population responses.

4.2. DEVELOPMENT OF RANGE PLANS

Predictive models can assist in developing range plans by exploring a given range and its habitat effectiveness with respect to the projected development trajectory. By changing assumptions concerning development rates and practices, predictions of the future value of a range can be made. This can help managers develop long-term plans that will maintain a range below a threshold. To do this successfully, it is necessary to quantify the persistence of human developments on the landscape; for example, what is the duration from the development of a minesite to its reclamation and subsequent reoccupation by caribou?

Additional data will be needed to do such modeling, including expected development rates and proposed industrial practices. Overlap of mineral and oil and gas deposits with caribou ranges will enable predictions of development potential within caribou ranges. Timber supply analyses can similarly predict habitat effectiveness outcomes of timber harvest within caribou range over an entire rotation period.

It is important to recognize that although such predictive modelling values may be valuable, **it will nonetheless be necessary to conduct long-term population monitoring on Yukon caribou ranges to test assumptions and adjust habitat effectiveness values and thresholds accordingly**. Data from Yukon caribou ranges experiencing high, moderate, and low levels of industrial footprint would be most beneficial in such an adaptive management process. Development of cumulative effects thresholds is not a static process but rather an evolving one, requiring periodic updates of data, particularly those related to changing human footprint in caribou ranges. This will require high-level commitments (voluntary or legislated) from both government and industry for regular access to or submission of spatially referenced digital activity files on caribou range in Yukon. Submissions should include proposed and ‘as built’ digital maps. Such a process may require data sharing agreements, coordinated by an unbiased, mutually agreed upon individual or contractor.

Implementation of thresholds provides a framework to enable resource managers to make appropriate land-use decisions in Yukon. Development of thresholds is complementary with the development of ground rules or ‘best practices’, which will define operating procedures and spatial and temporal distribution of industrial activities within caribou habitat.

4.3. YUKON IMPLEMENTATION ISSUES

4.3.1. DATA

Similar to many jurisdictions, there is a perception that Yukon’s current amount and quality of data is too poor to allow the development and implementation of woodland caribou activity thresholds. However, upon reviewing the major types of data inputs required for the development of activity thresholds, Yukon already possesses, or is in the process of acquiring, most of the required data sources. Table 3, below, lists relevant Yukon spatial and aspatial data sources and provides a brief assessment and description of each. Most required data is present in some form to undertake the zone of influence (footprint) thresholds approach. The lack of consistent habitat mapping is currently the major barrier to the implementation of the habitat effectiveness approach, although a number of different options are possible to solve this data limitation.

Table 3. Data types required for the development of woodland caribou cumulative effects thresholds, with a general list of Yukon data sources and associated assessment.

Data Type	Source	Assessment	Description
Caribou Ranges	• YTG and CWS Herd Surveys • Traditional and Community Knowledge	Moderate	• Some herds of special management concern have received detailed study and their ranges have been reasonably well defined. In conjunction with community knowledge, much is known about some ranges. • Remote herds or herds not considered to be at risk have received lower levels of study and their geographic ranges have not been well defined.
Caribou Herd Demographics	• YTG and CWS Herd Surveys • Traditional and Community Knowledge	Poor-Moderate	• Some herds of special management concern have received detailed study and their population status and trend is known. • Remote herds or herds not considered to be at risk have received lower levels of study and their population status and trend is not known.
Human Development - Footprint	• Various government agencies • NTDB (1:50,000 and 1:250,000) • Satellite imagery	Moderate-High	• Yukon is ahead of many southern jurisdictions with respect to mapping human development (footprint) data. • The location of most forestry, oil and gas, mining, transportation and urban/rural features are available as digital spatial data layers, many with associated attribute data (type of feature, when constructed, when harvested, etc.)
Human Development - Zones of Influence (ZOI)	• Expert and local knowledge • Empirically-derived data from neighbouring jurisdictions	Moderate	• While there is limited “formal” ZOI data for Yukon, local caribou biologists and residents could contribute a large amount of expertise to ZOI associated with transportation, mining, forestry and urban/residential features. • As the Yukon experience with the oil and gas is currently limited, ZOI associated with oil and gas features may be required from Alberta and BC.

Habitat Mapping* / Habitat Quality	• Many different sources from multiple agencies • Satellite imagery	Poor-Moderate	• A variety of land cover, forest cover, vegetation and habitat mapping sources exist for different areas of Yukon. Most have used different nomenclature, scales and mapping concepts, making it difficult to utilize for regional cumulative effects assessments. • A recent initiative is working towards the development of a standardized Ecosystem Classification and Mapping Framework for Yukon, which will eventually allow habitat values to be assigned to a set of well-defined habitat types, a critical component of the Habitat Effectiveness approach.

* Requirement only for development of Habitat Effectiveness approach only.

4.3.2. COORDINATION

The management and distribution of spatial and / or quantitative information necessary for the setting and monitoring of habitat effectiveness or industrial footprint thresholds is an important consideration for any implementation plan. AXYS (2001a) also stated the importance of a common, general "Regional Database" in cumulative effects assessment and management issues for Yukon. **Three major activities must occur to be able set and monitor zone of influence and habitat effectiveness thresholds-related information:**

1) Characterize the current land base in terms of industrial footprint and zones of influence. Habitat condition will also be required for the habitat effectiveness approach. It is necessary to provide a current snapshot, or baseline, against which future development projects will be evaluated.
2) Acquire new development and disturbance footprints as they are generated, and add these to the existing land base information, to provide a running tally of cumulative disturbance footprint.
3) Recalculate a new value of habitat effectiveness based on the inclusion of additional cumulative footprint, the recovery of old anthropogenic disturbances to different habitat values and the change in undisturbed habitat value due to successional processes (i.e. young burns turn to old forest). Understanding recovery from disturbance is a critical component of this approach.

In essence, a **landscape "tracking system" must be implemented**. In Yukon, most of the necessary requirements for the development of such a landscape tracking system are already in place, or are in the process of being implemented. Major benefits in Yukon include the following data management-related considerations:

- Data and Software Standardization. ArcGIS (ArcInfo, ArcView) has become the territorial and federal government standard for spatial data storage and manipulation. Over the past several years, a convergence in spatial data formats and platforms has occurred, facilitating spatial data exchange and use between major agencies and sectors.
- Central Coordinating Agency for GIS and Spatial Information. Geomatics Yukon has been formed to provide a central, coordinated approach to the development of data standards, facilitate data sharing, and provide a "central storehouse" of Yukon spatial information. Individual agencies still create and manage their respective data layers but Geomatics Yukon may in the future provide a common interface to the various agencies. A detailed metadata project has also been initiated for Yukon through this agency, which will allow greater accessibility of main data sources to a variety of users.
- Pace of Development. Currently, the creation of new development footprint in Yukon is happening at a much slower pace than adjacent jurisdictions. Time exists now to get appropriate structures and systems in place to manage potential thresholds information. However, priority areas do exist.

While most of the major components required to implement a thresholds-based assessment regime are present in Yukon, the coordination of such activities is currently the major barrier. **Two major issues regarding the monitoring and assessing components of thresholds-related information must be answered in a formal woodland caribou activity thresholds implementation plan:**

1) Who would be responsible for integrating cumulative landscape disturbances in a common spatial data format (i.e. landscape tracking, or monitoring)?
2) Who would be responsible for recalculating habitat effectiveness or cumulative footprint indices to compare against defined thresholds as new development projects require assessment?

Ideally, in order to facilitate scenario-based planning, the cumulative landscape disturbance and habitat information would be made available to industry to allow internal review of development projects and to run different scenarios based on different project parameters. Individually, most Yukon agencies have the necessary information to develop and implement thresholds; the challenge will be to find ways to integrate information from the various agencies for continued monitoring and examination of habitat effectiveness thresholds on a continual basis.

4.3.3. EXISTING MANAGEMENT STRUCTURES

The political and policy framework of Yukon is unique within Canada. The Umbrella Final Agreement sets out roles and responsibilities for Federal, Territorial and First Nation governments, and in doing so, has created a number of management structures that must be taken into consideration for the potential implementation of woodland caribou zone of influence or habitat effectiveness thresholds. Existing management structures within Yukon present both obstacles and opportunities for the implementation of a thresholds-based management regime.

4.3.3.1. Yukon Fish and Wildlife Board

The Yukon Fish and Wildlife Board (YFWB) is the territorial coordinating body for Renewable Resource Councils (RRCs) throughout Yukon. In collaboration with Yukon Regional Biologists and resource managers, the Board is active in the setting of hunting quotas for game animals, establishing funding and research priorities, and plays an important role in the creation of wildlife-related legislation. The YFWB could provide an important coordinating role for the development of a thresholds-based assessment regime in Yukon, and could provide an important link to the RRCs and First Nation management initiatives. Gaining support and input from the YFWB will be an important component of thresholds implementation within Yukon.

4.3.3.2. Renewable Resource Councils

The existence of community-based Regional Renewable Resource Councils (RRCs) in all Traditional Territories with settled land claims is an important part of the Yukon resource management regime. RRCs are formed largely of community members, many of whom have limited technical resource management backgrounds but frequently possess a high level of local wildlife knowledge. In order for the thresholds approach to be adopted in Yukon, a mechanism must be found for RRCs to become fully participatory members in the setting and implementing of thresholds and thresholds-related information for local herds. While the existence of RRCs provide important community input to resource management issues in Yukon, they also have resulted in a dispersed "information base" and decision-making function. Centralisation of information is a fundamental component of a threshold-based approach, although development of specific range plans may be coordinated effectively through individual RRCs.

4.3.3.3. First Nation Lands and Resources Departments

With the majority of Land Claim Agreements settled in Yukon, a large proportion, approximately 10-15%, of the Yukon land base is under direct First Nations ownership. Many woodland caribou ranges use portions of First Nations settlement lands. First Nations Lands and Resources Departments will therefore be important participants in a thresholds implementation plan for a specific woodland caribou herd. Most First Nations Land Claims Agreements also include the establishment of Special Management Areas (SMAs) or Habitat Protection Areas (HPAs), which effectively serve as protected areas with varying types and levels of human activity. Some SMAs and HPAs have been established to protect portions of woodland caribou herd ranges. While these management structures potentially represent important partners for the development of thresholds-related assessment tools, the centralization of resources and information is generally not viewed favorably by the First Nations. Sensitivity surrounding wildlife-related information within Traditional Territories must also be recognized.

4.3.3.4. Regional Land Use Planning

The Yukon Land Use Planning Council is responsible for the coordination of Regional Land Use Planning activities in Yukon. To date, Regional Planning Commissions have been established in two Yukon Planning Regions, Vuntut (North Yukon), and Teslin. Regional Land Use Planning initiatives may be an excellent opportunity to engage all major stakeholders participating in the development of woodland caribou activity thresholds within a defined land base. Through these exercises, threshold levels could also be tailored to specific land zoning designations, allowing for the determination of threshold values that reflect desired land uses. Regional Land Use Planning in Yukon will not directly set and solve thresholds related issues, however the Regional

Planning Commissions and may provide the required facilitation and coordination to develop and implement activity thresholds for specific areas of Yukon. Additional fish and wildlife and forestry planning activities may occur concurrent with regional planning initiatives, also presenting additional opportunities.

4.3.3.5. Protected Area Planning

Depending on definition, approximately 15 percent of Yukon is currently encompassed by various levels of protected areas, including National Parks, Territorial Parks, Special Management Areas and Habitat Protection Areas, with additional areas under interim protection (Yukon Department of Renewable Resources 1999). The largest proportion of protected areas is currently managed by Parks Canada and is located in North Yukon (Ivvavik and Vuntut National Parks) and the Kluane Region (Kluane National Park and Reserve). The majority of the Boreal Cordillera, within Yukon woodland caribou ranges, is unprotected. Combined, the development of protected areas through the Yukon Protected Areas Strategy and First Nations protected areas established under Land Claims Agreements have the ability to provide core protected areas for woodland caribou ranges and should be considered an important component of a thresholds implementation plan for specific herd ranges. Similar to the land use planning concept, habitat effectiveness targets could be developed for different types of park zones within a management planning context.

5. CONCLUSIONS

To date, no jurisdiction in Canada has established, implemented and enforced cumulative effects thresholds for industrial activity in woodland caribou range. Instead, guidelines and regulations have been put in place in an attempt to minimize and mitigate the impacts of individual development projects on caribou. Under this system of management, many caribou populations throughout the provinces are either the focus of concern or have been extirpated from former ranges. In some situations, caribou ranges have already been severely impacted and will require a great deal of effort, financial resources, and political will to return habitat effectiveness to an acceptable level. Yukon has a unique opportunity to develop and implement cumulative effects thresholds for caribou range prior to large-scale industrial development over significant areas. This must be initiated now if Yukon wishes to have healthy caribou populations in perpetuity.

Based on a literature review, experience from other jurisdictions and consideration of the Yukon situation, the most appropriate method for developing cumulative effects thresholds for Yukon caribou range is the habitat effectiveness approach, whether that is based on a full habitat effectiveness model or just total zone of influence. This approach addresses the influence of industrial activity on caribou ecology, includes cumulative effects from several disturbance types, can be related to clear thresholds, and generally meets the criteria of being usable and acceptable by a wide range of stakeholders.

Although habitat effectiveness calculations incorporate, in a general sense, the importance of human features in changing mortality rates due to humans and other predators, and the effects of spatial distribution of harvest on caribou habitat effectiveness, there are obvious limitations to this relatively simple threshold approach. Range-specific factors, such as predator density or distance to human settlements, may influence caribou recruitment and survival differently, despite ranges having similar habitat effectiveness values. Despite these limitations, setting of thresholds represents a risk management exercise for development of industrial activity in caribou range, and is a more defensible management technique than the alternative approaches (project specific mitigation strategies), which have largely failed in other jurisdictions

Most elements required for the development and implementation of the habitat effectiveness approach within Yukon already exist. The data required to set a threshold for Yukon caribou range are either already in existence, or could be acquired in a timely fashion. The technical expertise and technological resources required to implement thresholds currently exist in Yukon and are fully capable of developing the tools needed to assess proposed projects and undertake long-term range planning. The coordination of these activities among government agencies and existing management structures will be the greatest challenge to implementing a threshold approach for Yukon.

NEXT STEPS

Within Yukon, it is unlikely that a single habitat effectiveness or zone of influence threshold value will be used in isolation of complimentary management techniques, but the development of such thresholds and the appropriate framework for their implementation will provide regulatory authorities with an objective management tool. The decision-making framework associated with this tool will ultimately determine the effectiveness of the threshold approach to cumulative effects assessment and management.

To facilitate the development of effective decision-making frameworks, and for the threshold approach outlined within this paper to gain acceptance, the approach must first be demonstrated within a Yukon management setting. The following initiatives are recommended:

1. Establish a pilot area
- Need to balance urgency with data availability and existence of management structures (i.e. Land Claim Settlements in place, Renewable Resource Councils functioning)
- Southern Lakes and Rancheria are logical choices, although appropriate management structures may not yet be in place.

2. Within the pilot area, begin work on the zone of influence (cumulative footprint) approach.
- decide upon a standard set of disturbance features and GIS techniques for feature coding and attributing.
- gain consensus for the ZOI values (Table 2 can be used as an initial guide)
- create direct cumulative footprint and ZOI maps

3. Continue development of habitat mapping / ecosystem mapping concepts and products for future use within a full habitat effectiveness framework for the pilot area.

6. REFERENCE LIST

Adamczewski, J.Z., Gates, C.C., Hudson, R.J., and Price, M.A. 1987. Seasonal changes in body composition of mature female caribou and calves (*Rangifer tarandus groenlandicus*) on an arctic island with limited winter resources. Can. J. Zool. **65:** 1149-1157.

Adamczewski, J.Z., Gates, C.C., Soutar, B.M., and Hudson, R.J. 1988. Limiting effects of snow on seasonal habitat use and diets of caribou (*Rangifer tarandus groenlandicus*) on Coats Island Northwest Territories Canada. Can. J. Zool. **66:** 1986-1996.

Adamczewski, J.Z., Hudson, R.J., and Gates, C.C. 1993. Winter energy balance and activity of female caribou on Coats Island, Northwest Territories: the relative importance of foraging and body reserves. Can. J. Zool. **71:** 1221-1229.

Adams, L.G., Singer, F.J., and Dale, B.W. 1995. Caribou calf mortality in Denali National Park, Alaska. J. Wildl. Manage. **59:** 584-594.

Alberta Energy. 1991. IL 91-17 Procedural guide for oil and gas activity on caribou range. Department of Energy, Government of Alberta, Edmonton, AB. Available online at http://www.energy.gov.ab.ca/room/updates/letters/1991/91-17.htm.

Alberta Fish and Wildlife Services. 1993. Strategy for conservation of woodland caribou in Alberta. As cited by Hervieux et al. 1996.

Alberta Woodland Caribou Conservation Strategy Development Committee. 1996. Alberta's woodland caribou conservation strategy. Unpublished Report. Edmonton, AB.

Allaye-Chan, A.C. 1991. Body condition variations among adult females of the Porcupine Caribou Herd. *In* Proceedings of the 4th North American Caribou Workshop, St. John's, NF, *Edited by* C.E. Butler and S.P. Mahoney. Newfoundland and Labrador Wildlife Division, St. John's, NF. pp. 103-108.

Anderson, R.B. 1999. Peatland habitat use and selection by woodland caribou (*Rangifer tarandus caribou*) in northern Alberta. M.Sc. Thesis, University of Alberta, Edmonton, AB.

Appleton, J.D., Williams, T.M., Orbea, H., and Carrasco, M. 2001. Fluvial contamination associated with artisanal gold mining in the Ponce Enríquez, Portovelo-Zaruma and Nambija Areas, Ecuador. Water, Air, and Soil Pollution. **131:** 19-39.

Arnold, G.W. 1985. Regulation of forage intake. *In* Bioenergetics of Wild Herbivores. *Edited by* R.J. Hudson and R.G. White. CRC Press, Inc., Boca Raton, FL. pp. 81-102.

AXYS Environmental Consulting Ltd. 2001a. Thresholds for addressing cumulative effects on terrestrial and avian wildlife in the Yukon. Report prepared for Department of Indian and Northern Affairs, Environmental Directorate and Environment Canada, Whitehorse, YT.

AXYS Environmental Consulting Ltd. 2001b. Wildlife CEA thresholds: phase II workshop summary. Report prepared for Department of Indian and Northern Affairs, Environmental Directorate, Whitehorse, YT.

AXYS Environmental Consulting Ltd. and Penner and Associates. 1998. Environmental effects report: wildlife. Report prepared for Diavik Diamonds Project, Yellowknife, NWT.

Batcheler, C.L. 1968. Compensatory responses of artificially controlled mammal populations. Proceedings of the New Zealand Ecological Society. **15:** 25-30.

BC Ministry of Transportation and Highways. 1995. Wildlife accident reporting system annual report 1994. British Columbia Highway Environment Branch, Victoria, BC.

Boreal Caribou Committee (BCC). 2001. Strategic plan and industrial guidelines for boreal caribou ranges in northern Alberta. Report prepared by the Boreal Caribou Committee, Edmonton, AB. Available online at http://www.deer.rr.ualberta.ca/caribou/BCRP.htm.

Boreal Caribou Research Program (BCRP). 1999. Research summary. Report prepared by the Boreal Caribou Research Program, Edmonton, AB.

Bergerud, A.T. 1974a. Relative abundance of food in winter for Newfoundland caribou. Oikos **25**: 379-387.

Bergerud, A.T. 1974b. Decline of caribou in North America following settlement. J. Wildl. Manage. **38:** 757-770.

Bergerud, A.T. 1974c. The role of the environment in the aggregation, movement and disturbance behavior of caribou. *In* The Behavior of Ungulates and its Relation to Management, *Edited by* V. Geist and F. Walther. International Union for Conservation of Nature and Natural Resources, Morges, Switzerland. pp. 552-584.

Bergerud, A.T. 1975. The reproductive season of the Newfoundland caribou. Can. J. Zool. **53:** 1213-1221.

Bergerud, A.T. 1978. The status and management of caribou in British Columbia. Report prepared by British Columbia Fish and Wildlife Branch, Victoria, BC.

Bergerud, A.T. and Ballard, W.B. 1988. Wolf predation on caribou: the Nelchina herd case history, a different interpretation. J. Wildl. Manage. **52:** 344-357.

Bergerud, A.T. and Elliott, J.P. 1998. Wolf predation in a multiple-ungulate system in northern British Columbia. Can. J. Zool. **76:** 1551-1569.

Bergerud, A.T., Ferguson, R., and Butler, H.E. 1990. Spring migration and dispersion of woodland caribou at calving. Anim. Behav. **39:** 360-368.

Bergerud, A.T., Jakimchuk, R.D., and Carruthers 1984. The buffalo of the north: caribou (*Rangifer tarandus)* and human developments. Arctic **37:** 7-22.

Bergerud, A.T. and Page, R.E. 1987. Displacement and dispersion of parturient caribou at calving as antipredator tactics. Can. J. Zool. **65:** 1597-1606.

Bjorge, R.R. 1984. Winter habitat use by woodland caribou in west central Alberta, with implications for management. *In* Fish and wildlife relationships in old-growth forests. Proceedings of a symposium. *Edited by* W.R. Meehan, T.R. Merrel Jr., and T.A. Hanley. American Institute of Fishery Research Biologists, Juneau, AK. pp. 335-342.

Bloomfield, M. 1979. The ecology and status of mountain caribou and caribou range in Central British Columbia. M.Sc. Thesis, University of Alberta, Edmonton, AB.

Bowyer, R.T. 1991. Timing of parturition and lactation in southern mule deer. J. Mamm. **72:** 487-492.

Bradshaw, C.J.A. 1994. An assessment of the effects of petroleum exploration on woodland caribou (*Rangifer tarandus caribou*) in northeastern Alberta. M.Sc. Thesis, University of Alberta, Edmonton, AB.

Bradshaw, C.J.A., Boutin, S., and Hebert, D.M. 1997. Effects of petroleum exploration on woodland caribou in northeastern Alberta. J. Wildl. Manage. **61:** 1127-1133.

Bradshaw, C.J.A., Boutin, S., and Hebert, D.M. 1998. Energetic implications of disturbance caused by petroleum exploration to woodland caribou. Can. J. Zool. **76:** 1319-1324.

Bradshaw, C.J.A., Hebert, D.M., Rippin, A.B., and Boutin, S. 1995. Winter peatland habitat selection by woodland caribou in northeastern Alberta. Can. J. Zool. **73:** 1567-1574.

Brown, W.K. and Hobson, D.P. 1998. Caribou in west-central Alberta - information review and synthesis. Report prepared for the West-central Alberta Caribou Standing Committee by Terrestrial & Aquatic Environmental Managers Ltd., Calgary, AB.

Brown, W.K. and Ross, I. 1994. Caribou-vehicle collisions: a review of methods to reduce caribou mortality on Highway 40, west-central Alberta. Published report. Prepared by Terrestrial and Aquatic Environmental Managers Ltd. for Alberta Environmental Protection, Fish and Wildlife Services and Alberta Transportation and Utilities, Research and Development Branch, Calgary, AB.

Brown, W.K. and Theberge, J.B. 1990. The effect of extreme snowcover on feeding-site selection by woodland caribou. J. Wildl. Manage. **54:** 161-168.

Calef, G.W., DeBock, E.A., and Lortie, G.M. 1976. The reaction of barren-ground caribou to aircraft. Arctic **29:** 201-212.

Cameron Raymond D. 1994. Reproductive pauses by female caribou. J. Mamm. **75:** 10-13.

Cameron, R.D., Smith, W.T., Fancy, S.G., Gerhart, K.L., and White, R.G. 1993. Calving success of female caribou in relation to body weight. Can. J. Zool. **71:** 480-486.

Cameron, R.D. and Ver Hoef, J.M. 1994. Predicting parturition rate of caribou from autumn body mass. J. Wildl. Manage. **58:** 674-679.

Carruthers, D.R. and Jakimchuk, R.D. 1987. Migratory movements of the Nelchina Caribou Herd in relation to the Trans-Alaska Pipeline. Wildl. Soc. Bull. **15:** 414-420.

Chamberlain, D.E., Fuller, R.J., Bunce, R.G.H., Duckworth, J.C., and Shrubb, M. 2000. Changes in the abundance of farmland birds in relation to the timing of agricultural intensification in England and Wales. J. Appl. Ecol. **37:** 771-788.

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

Cichowski, D.B. and Banner, A. 1993. Management strategy and options for the Tweedsmuir-Entiako caribou winter range. Report No. 79. Minst. For., Land Manage., Victoria, BC.

Clutton-Brock, T. H., Guinness, F. E., and Albon, S. D. 1982. Red Deer: behavior and ecology of two sexes. The University of Chicago Press, Chicago, IL.

COSEWIC. 2001. Canadian Species at Risk, May 2001. Committee on the Status of Endangered Wildlife in Canada.

COSEWIC. 2002. COSEWIC Status Assessments, May 2002. Committee on the Status of Endangered Wildlife in Canada. Available online at http://www.cosewic.gc.ca.

Crete M. and Manseau M. 1996. Natural regulation of cervidae along a 1000 km latitudinal gradient: Change in trophic dominance. Evolutionary-Ecology. **10:** 51-62.

Cronin, M.A., Ballard, W.B., Bryan, J.D., Pierson, B.J., and McKendrick, J.D. 1998. Northern Alaska oil fields and caribou: A commentary. Biol. Cons. **83:** 195-208.

Cronin, M.A., Ballard, W.B., Truett, J., and Pollard, R. 1994. Mitigation of the effects of oil field development and transportation corridors on caribou. Final Report to the Alaska Caribou Steering Committee. LGL Alaska Research Associates, Inc., Anchorage, Alaska.

Cronin, M.A., Pierson, B.J., Johnson, S.R., Noel, L.E., and Ballard, W.B. 1997. Caribou population density in the Prudhoe Bay region of Alaska. The Journal of Wildlife Research **2:** 59-68.

Cumming, H.G. 1992. Woodland caribou: facts for forest managers. Forestry chronicle **68:** 481-491.

Cumming, H.G. and Hyler, B.T. 1996. Experimental log hauling through a traditional caribou wintering area. Rangifer Special Issue. **No. 10:** 241-258.

Curatolo, J.A. and Murphy, S.M. 1986. The effects of pipelines, roads and traffic on the movement of caribou, *Rangifer tarandus*. Can. Field-Nat. **100:** 218-225.

Darby, W.R. and Duquette, L.S. 1986. Woodland caribou and forestry in northern Ontario, Canada. Rangifer **Special Issue No.1:** 87-93.

Darby, W.R. and Pruitt, W.O. JR. 1984. Habitat use, movements and grouping behavior of woodland caribou (*Rangifer tarandus caribou*) in southeastern Manitoba Canada. Can. Field-Nat. **98:** 184-190.

Dau, J.R. and Cameron, R.D. 1986. Effects of a road system on caribou distribution during calving. Rangifer **Special Issue No.1:** 95-101.

Dauphiné, T.C., 1976. Biology of the Kaminuriak population of barren-ground caribou, part 4: growth, reproduction and energy reserves. Canadian Wildlife Service Report Series No 38, Ottawa, ON.

DIAND. 1999. Timber harvest planning and operating guidebook. Forest Resources Branch, Indian and Northern Affairs Canada, Whitehorse, YT. May 1, 1999.

Downes, C.M., Theberge, J.B., and Smith, S.M. 1986. The influence of insects on the distribution, microhabitat choice and behavior of the Burwash Yukon Canada caribou (*Rangifer tarandus caribou*) herd. Can. J. Zool. **64:** 622-629.

Dyer, S.J. 1999. Movement and distribution of woodland caribou (*Rangifer tarandus caribou*) in response to industrial development in northeastern Alberta. M.Sc. Thesis, University of Alberta, Edmonton, Alberta, Canada.

Dyer S.J., O' Neill J.P., Wasel S.M., and Boutin S. 2001. Avoidance of industrial development by woodland caribou. J. Wildl. Manage. **65:** 531-542.

Dzus, E. 2001. Status of Woodland Caribou (*Rangifer tarandus caribou*) in Alberta. Alberta Environment, Fisheries and Wildlife Management Division, and Alberta Conservation Association, Wildlife Status Report No. 30, Edmonton, AB.

Eccles, T.R. and Duncan, J.A. 1986. Wildlife Monitoring Studies Along the Norman Wells-Zama Oil Pipeline, April 1985 - May 1986. Report prepared by Environmental Research Associates for Interprovincial Pipeline (NW) Limited, AB.

Eccles, R., Searing, G., Duncan, J., and Thompson, C. 1985. Wildlife Monitoring Studies Along the Norman Wells-Zama Oil Pipeline, January - March 1985. Report prepared by Environmental Research Associates for Interprovincial Pipeline (NW) Limited, AB.

Edmonds, E.J. 1986. Draft woodland caribou provincial restoration plan. Unpubl. report. Alberta Fish and Wildlife, Edmonton, AB.

Edmonds, E.J. 1988. Population status distribution and movements of woodland caribou in west central Alberta Canada. Can. J. Zool. **66:** 817-826.

Edmonds, E.J. 1991. Status of woodland caribou in western North America. Rangifer **Special Issue No.7:** 91-107

Edmonds, E.J. and Bloomfield, M. 1984. A study of woodland caribou (*Rangifer tarandus caribou*) in West Central Alberta, 1979 to 1983. Published report. Alberta Energy and Natural Resources, Fish and Wildlife Division,

Edmonds, E.J. and Hobson, D. 1995. Effectiveness of mitigation programs implemented to decrease vehicle-related mortality of woodland caribou in west central Alberta. Report prepared by Natural Resources Service, Fish & Wildlife, Edson, AB.

Edmonds, E.J. and Smith, K.G. 1991. Mountain caribou calf production and survival, and calving and summer habitat use in west-central Alberta. Wildlife Research Series **No. 4**. Alberta Fish and Wildlife Division, Edmonton, AB.

Eloranta, E. and Nieminen M. 1986. Calving of the experimental reindeer herd in Kaamanen during 1970-85. Rangifer Special Issue **No. 1:** 115-121.

Espmark, Y. 1980. Effects of maternal pre-partum undernutrition on early mother-calf relationships in reindeer. *In* Proceedings- 2nd InternationalReindeer/caribou Symposium, University of Trondheim, Norway. pp. 485-496.

Fancy S.G. 1983. Movements and activity budgets of caribou near oil drilling sites in the Sagavanirktok river floodplain, Alaska. Arctic **36(2):** 193-197.

Fancy, S.G. and White, R.G. 1987. Energy expenditures for locomotion by barren-ground caribou. Can. J. Zool. **65:** 122-128.

Florkiewicz, R.F., Flynn, N., MacLean, N., Francis, S.R., Adamczewski, J.Z., and Loewen, V. 2002. Assessment of winter habitat, movement and distribution of the Little Rancheria caribou herd in Yukon. Department of Renewable Resources, Government of Yukon, Whitehorse, YT.

Forem Technologies. 2002. A Landscape Cumulative Effects Simulator (ALCES). Forem Technologies, Bragg Creek, Alberta. URL: http://www.foremtech.com.

Fuller, T.K. and Keith, L.B. 1980. Wolf population dynamics and prey relationships in Northeastern Alberta. J. Wildl. Manage. **44:** 583-602.

Fuller, T.K. and Keith, L.B. 1981. Woodland caribou population dynamics in northeastern Alberta. J. Wildl. Manage. **45:** 197-213.

Gasaway, W.C., Stephenson, R.O., Davis, J.L., Shepherd, P.E.K., and Burris, O.E. 1983. Interrelationships of wolves, prey, and man in interior Alaska. Wildl. Monogr. **84:** 1-50.

Geist, V. 1971a. Mountain sheep: a study of behavior and evolution. University of Chicago Press. Chicago, IL.

Geist, V. 1971b. Is big game harassment harmful? Oilweek **22(17):** 12-13.

Geist, V. 1978. Behavior. *In* Big game of North America: ecology and management. *Edited by* J.L. Schmidt and D.L. Gilbert. Stackpole books, Harrisburg, PA. pp. 283-296.

Harrington, F.H. 1996. Human impacts on George River Caribou: an overview. Rangifer **16:** 277-278.

Harrington, F.H. and Veitch, A.M. 1991. Short-term impacts of low-level jet fighter training on caribou in Labrador. Arctic **44:** 318-327.

Harrington, F.H. and Veitch, A.M. 1992. Calving success of woodland caribou exposed to low-level jet fighter overflights. Arctic **45:** 213-218.

Haukioja, E. and Salovaara, R. 1978. Summer weight of reindeer (*Rangifer tarandus*) calves and its importance for their future survival. Rep Devo Subarctic Res Stat **14:** 1-4.

Hayes, R.D. and Harestad, A.S. 2000. Demography of a recovering wolf population in the Yukon. Can. J. Zool. **78:** 36-48.

Hegmann, G., Cocklin, C., Creasey, R., Dupuis, S., Kennedy, A., Kingsley, L., Ross, W., Spaling, H., and Stalker, D. 1999. Cumulative effects assessment practitioners guide. Report prepared by AXYS Environmental Consulting Ltd. and the CEA Working Group for the

Canadian Environmental Assessment Agency, Hull, Quebec.

Henshaw, J. 1968. The activities of the wintering caribou in northwestern Alaska in relation to weather and snow conditions. Int. J. Biometeorol. **12:** 21-27.

Hervieux, D., Edmonds, J., Bonar, R., and McCammon, J. 1996. Successful and unsuccessful attempts to resolve caribou management and timber harvesting issues in west central Alberta. Rangifer Special Issue No. 9: 185-190.

Holleman, D.F., Luick, J.R., and R.G. White. 1979. Lichen intake estimates for reindeer and caribou during winter. J. Wildl. Manage. 43:192-201.

Hood, G.A. and Parker, K.L. 2001. Impact of human activities on grizzly bear habitat in Jasper National Park. Wildl. Soc. Bull. 29: 624-638.

Horejsi, B.L. 1981. Behavioral response of barren ground caribou to a moving vehicle. Arctic **34:** 1890-185.

Jacobsen, E., and Skjenneberg, S. 1975. Some results from feeding experiments with reindeer. *In*: Proceedings of the 1st International Reindeer/Caribou Symposium. *Edited by* J.R. Luick, P.C. Lent, D.R. Klein and R.G. White. University of Alaska, Special Report, Fairbanks, AK. pp95-107.

Jalkotzy, M.G., Ross, P.I., and Nasserden, M.D. 1997. The effects of linear developments on wildlife: a review of selected scientific literature. Report prepared by Arc Wildlife Services Ltd., Calgary, AB.

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

James, A.R.C. and Stuart-Smith, A.K. 2000. Distribution of caribou and wolves in relation to linear corridors. J. Wildl. Manage. **64:** 154-159.

Johnson, D.R. 1985. Man-caused deaths of mountain caribou *rangifer-tarandus* in southeastern British-Columbia Canada. Can. Field-Nat. **99:** 542-544.

Johnson, D.R. and Todd, M.C. 1977. Summer use of a highway crossing by mountain caribou. Can. Field-Nat. **91:** 312-314.

Kelsall, J.P. and Telfer, E.S. 1971. Studies of the physical adaptations of big game for snow. *In* Proceedings of the Snow and Ice in Relation to Wildlife and Recreation Symposium. *Edited by* A.O. Haugen. Iowa Cooperative Wildlife Research Unit of Iowa State University, Ames, IA. pp. 134-146.

Kennedy, C.E. 1993. Guidelines for reclamation / revegetation in the Yukon. Yukon Department of Renewable Resources, Fish and Wildlife Branch, Habitat Management Section, Whitehorse, YT.

Klein, D.R. 1971. Reaction of reindeer to obstructions and disturbances. Science **173:** 393-398.

Klein, D.R. 1980. Reaction of caribou and reindeer to obstructions- A reassessment . *In* Second international reindeer/caribou symposium, *Edited by* E. Reimers, E. Gaare, and S. Skjenneberg. Trondheim, Norway. pp. 519-527.

Klein, D.R. 1982. Fire, lichens, and caribou. J. Range Manage. **35:** 390-395.

Klein, D.R. 1992. Comparative ecological and behavioral adaptations of *Ovibos moschatus* and *Rangifer tarandus*. Rangifer **12:** 47-55.

Kuck, L., Hompland, G.L., and Merrill, E.H. 1985. Elk calf response to simulated mine disturbance in southeast Idaho. J. Wildl. Manage. **49:** 751-757.

LaPerriere, A.J. and Lent, P.C. 1977. Caribou feeding sites in relation to snow characteristics in northeastern Alaska. Arctic **30:** 101-108.

Lawhead, B.E., and R.D. Cameron. 1988. Caribou distribution on the calving grounds of the Central Arctic Herd. Report to ARCO Alaska Inc., Anchorage, prepared by Alaska Biological Research, Fairbanks.

Luick, B.R. and White, R.G. 1986. Oxygen consumption for locomotion by caribou (*Rangifer tarandus granti*) calves. J. Wildl. Manage. **50:** 148-152.

Lyon, L.J. 1979. Habitat effectiveness for elk as influenced by roads and cover. J. Forest. **October:** 658-660.

MacDonald, J.D. 2001. An evaluation of the woodland caribou management process in Alberta. Master of Environmental Design thesis, University of Calgary, Calgary, AB.

Maier, J.A.K., Murphy, S.M., White, R.G., and Smith, M.D. 1998. Responses of caribou to overflights by low-altitude jet aircraft. J. Wildl. Manage. **62:** 752-766.

McCauley, E., Wilson, W.G., and De Roos, A.M. 1993. Dynamics of age-structured and spatially structured predator-prey interactions: Individual based models and population level formulations. American Naturalist. **142:** 412-442.

McEwan, E.H. 1968. Growth and development of the barren-ground caribou. II. Postnatal growth rates. Can. J. Zool. **46:** 1023.

McEwan, E.H. and Whitehead, P.E. 1970. Seasonal changes in the energy intake in reindeer and caribou. Can. J. Zool. **48:** 905-938.

Mercer, E., Mahoney, S., Curnew, K., and Finlay, C. 1985. Distribution and abundance of insular Newfoundland caribou and the effects of human activities. *In* Proceedings of the 2nd North American Caribou Workshop, *Edited by* T.C. Meredith and A.M. Martell. Centre for Northern Studies and Research, McGill University, Montreal. pp. 15-32.

Miller, F.L. and Gunn, A. 1979. Responses of Peary Caribou and muskoxen to turbo-helicopter harassment, Prince of Wales Island, Northwest Territories 1976-1977. Canadian Wildlife Service Occasional Paper No. 40, Edmonton, AB.

Miller, F.L., Jonkel, C.J., and Tessier, G.D. 1971. Group cohesion and leadership response by barren-ground caribou to man-made barriers. Arctic **25:** 193-202.

Mougeot, C. 1996. Natural land reclamation for mineral exploration properties and placer mines in Yukon. Report prepared for DIAND. Report QS-Y106-000-EF-A1. Whitehorse, YT.

Mougeot, C. and Withers, S. 2001. Assessment of long-term vegetation and site conditions at reclaimed Yukon mineral exploration sites. Report prepared for Mining Environment and Research Group (MERG), Project MERG-007. Whitehorse, YT.

Murphy, S.M. 1988. Caribou behavior and movements in the Kuparuk Oilfield: Implications for energetic impact analyses. *In* Reproduction and calf survival. Proceedings of the 3rd North American Caribou Workshop, *Edited by* R. Cameron and J.L. Davis. Alaska Department of Fish and Game, Juneau. pp. 196-210.

Murphy, S.M. and Curatolo, J.A. 1987. Activity budgets and movement rates of caribou encountering pipelines roads and traffic in northern Alaska USA. Can. J. Zool. **65:** 2483-2490.

Murphy, S.M., Russell, D.E., and White, R.G. 2000. Modeling energetic and demographic consequences of caribou interactions with oil development in the Arctic. Brief communication *in* Rangifer Special Issue 12: 107-109. Proceedings of the Eighth North American Caribou Workshop. Whitehorse, Yukon, Canada. 20-24 April 1998.

Nellemann, C. and Cameron, R.D. 1998. Cumulative impacts of an evolving oil-field complex on the distribution of calving caribou. Can. J. Zool. **76:** 1425-1430.

Nellemann C., Jordhoy P., Stoen O.G., and Strand O. 2000. Cumulative impacts of tourist resorts on wild reindeer (*Rangifer tarandus tarandus*) during winter. Arctic. **53:** 9-17.

Nellemann, C., Vistnes, I., Jordhoy, P., and Strand, O. 2001. Winter distribution of wild reindeer in relation to power lines, roads and resorts. Biol. Cons. **101:** 351-360.

Noel L.E., Pollard R.H., Ballard W.B., and Cronin M.A. 1998. Activity and use of active gravel pads and tundra by Caribou, *Rangifer tarandus granti*, within the Prudhoe Bay oil field, Alaska. Can. Field-Nat. **112:** 400-409.

Northeast Regional Standing Committee on Woodland Caribou (NERSC). 1997. Land use strategies for industrial activity in key caribou areas of the northeast boreal region for 1997/98. Annual operating guidelines. As approved by Alberta Environmental Protection, Northeast Boreal Region Environmental Resource Committee, Lac La Biche, AB.

Oberg, P.R. 2001. Responses of mountain caribou to linear features in a west-central Alberta landscape. M.Sc. Thesis, University of Alberta, Edmonton, AB.

Ouellet J.P., Ferron J., and Sirois L. 1996. Space and habitat use by the threatened Gaspe caribou in southeastern Quebec. Can. J. Zool. **74:** 1922-1933.

Ouellet, J.P., Heard, D.C., Boutin, S., and Mulders, R. 1997. A comparison of body condition and reproduction of caribou on two predator-free arctic islands. Can. J. Zool. **75:** 11-17.

Pedigree Caribou Standing Committee (PCSC). 1991. Caribou protection plan for oil and gas activity in the Pedigree region of northwestern Alberta. Report prepared by the Delta Environmental Management Group Ltd., Calgary, AB.

Pruitt W.O., Jr. 1959. Snow as a factor in the winter ecology of the barren ground caribou (*Rangifer arcticus*). Arctic **12:** 158-179.

Rachlow, J.L. and Bowyer, R.T. 1991. Interannual variation in timing and synchrony of parturition in Dall's sheep. J. Mamm. **72:** 487-492.

Reimers, E. 1982. Winter mortality and population trends of reindeer *Rangifer tarandus platyrhynchus* on Svalbard Norway. Arct. Alp. Res. **14:** 295-300.

Reimers, E. 1983. Reproduction in wild reindeer in Norway. Can. J. Zool. **61:** 211-217.

Renecker, L.A. and Hudson, R.J. 1993. Morphology, bioenergetics and resource use: patterns and processes. *In* Hoofed Mammals of Alberta. *Edited by* J.B. Stelfox. Lone Pine Publishers, Edmonton, AB. pp. 141-156.

Rettie, W.J. and Messier, F. 1998. Dynamics of woodland caribou populations at the southern limit of their range in Saskatchewan. Can. J. Zool. **76:** 251-259.

Robbins, C.T., Podbielancik-Norman, R.S., Wilson, D.L., and Mould, E.D. 1981. Growth and nutrient consumption of elk calves compared to other ungulate species. J. Wildl. Manage. **45:** 172-186.

Robbins, C.T. 1983. Wildlife feeding and nutrition. Academic Press, New York, NY

Roby, D.D. 1978. Behavioral patterns of barren-ground caribou of the Central Arctic Herd adjacent to the Trans-Alaska Pipeline. M.S. Thesis, University of Alaska, Fairbanks, AK.

Rognmo, A., Markussen, K.A., Jacobsen, E., Grav, H.J., and Blix, A.S. 1983. Effects of improved nutrition in pregnant reindeer on milk quality, calf birth weight, growth, and mortality. Rangifer **3:** 10-18.

Russell, D.E., Gerhart, K.L., White, R.G., and Van De Wetering, D. 1998. Detection of early pregnancy in caribou: Evidence for embryonic mortality. J. Wildl. Manage. **62:** 1066-1075.

Sanders, G.E., Skärby, L., Ashmore, M., and Fuhrer, J. 1995. Establishing critical levels for the effects of air pollutants on vegetation. Water, Air & Soil Pollution. **85:** 189-200.

Schaefer, J.A., Veitch, A.M., Harrington, F.H., Brown, W.K., Theberge, J.B., and Luttich, S.N. 1999. Demography of decline of the Red Wine Mountains Caribou Herd. J. Wildl. Manage. **63:** 580-587.

Schneider, R.R., Wynes, B., Wasel, S., and Dzus, E. 1999. Rate of movement of caribou in northern Alberta relative to snow depth and time of year. Report prepared by the Boreal Caribou Research Program, Edmonton, AB.

Segal, A.N. 1962. The periodicity of pasture and physiological functions of reindeer. *In* Reindeer of the Karelian ASSR, Akad. Nank Petorzaodsk. Translation by the Department of the Secretary of State, Bureau of Translation, Canada, pp. 130-150.

Seip, D.R. 1991. Predation and caribou populations. Rangifer Special Issue. **No. 7:** 46-52.

Seip D.R. 1992. Factors limiting woodland caribou populations and their interrelationships with wolves and moose in southeastern British Columbia. Can. J. Zool. **70:** 1494-1503.

Seip, D.R. and Cichowski, D.B. 1996. Population ecology of caribou in British Columbia. Rangifer **16:** 73-80.

Senyk, J.B., Wiken, E.P., Ironside, G.R., and Pierce, T.W. 1988. Land capability for forestry: Yukon 1:1,000,000 scale map series. Canada Land Inventory, Inland Waters and Lands, Whitehorse, YT.

Shalter, M.D. 1984. Predator-prey behavior and habituation. *In* Habituation, sensitization and behavior. *Edited by* H.V.S. Peeke and L. Petrinovich. Academic Press, New York. pp. 349-391.

Shank, C.C. 1979. Human-related behavioural disturbance to northern large mammals: a review and bibliography. Unpublished report prepared for Foothills Pipelines (South Yukon) Ltd. Calgary, AB.

Simpson, K. 1987. The effects of snowmobiling on winter range use by mountain caribou. B.C. Ministry of Environment, Parks and Wildlife Working Report No. 25.

Simpson, K., Kelsall, J.P., and Leung, M. 1994. Integrated management of mountain caribou and forestry in southern Bitish Columbia. Report prepared by Ministry of Environment, Lands and Parks, Victoria, British Columbia.

Simpson, K., Terry, E., and Hamilton, D. 1997. Toward a mountain caribou management strategy for British Columbia : habitat requirements and sub-population status. Wildlife Working Report No. WR-90. Ministry of Environment, Lands and Parks, Wildlife Branch, Victoria, BC.

Skogland, T. 1984. The effects of food and maternal conditions on fetal growth and size in wild reindeer. Rangifer **4:** 39-45.

Skogland, T. 1985. The effects of density-dependent resource limitations on the demography of wild reindeer. J. Anim. Ecol. **54:** 359-374.

Skogland, T. 1986. Density dependent food limitation and maximal production in wild reindeer *Rangifer tarandus* herds. J. Wildl. Manage. **50:** 314-319.

Skogland, T. and Grovan, B. 1988. The effects of human disturbance on the activity of wild reindeer in different physical condition. Rangifer **8:** 11-19.

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

Smith, W.T. and Cameron, R.D. 1983. Responses of caribou to industrial development on Alaska's Arctic slope. Acta Zool Fennica **175:** 43-45.

Smith, W.T. and Cameron, R.D. 1985. Reactions of large groups of caribou to a pipeline corridor on the arctic coastal plain of Alaska USA. Arctic. **38:** 53-57.

Steen, E. 1968. Some aspects of nutrition of semi-domestic reindeer. *In* Comparative nutrition of wild animals. *Edited by* M.A. Crawford. Symposium of the Zoological Society of London, No. 21. London, UK. pp. 117-128.

Stepaniuk, D.W. 1997. Planning for woodland caribou winter habitat needs in west-central Alberta. M.Sc. Thesis, University of Alberta, Edmonton, AB.

Stuart-Smith, A.K., Bradshaw, C.J.A., Boutin, S., Hebert, D.M., and Rippin, A.B. 1997. Woodland caribou relative to landscape patterns in northeastern Alberta. J. Wildl. Manage. **61:** 622-633.

Thomas, D.C., Barry, S.J., and Alaie, G. 1996a. Fire-caribou-winter range relationships in northern Canada. Rangifer. **16:** 57-67.

Thomas, D.C., Edmonds, E.J., and Brown, W.K. 1996b. The diet of woodland caribou populations in west-central Alberta. Rangifer **Special Issue 9:** 337-342.

Thurber, J.M., Peterson, R.O., Drummer, and Thomasma, S.A. 1994. Gray wolf response to refuge boundaries and roads in Alaska. Wildl. Soc. Bull. **22:** 61-68.

Tyler, N.J.C. 1991. Short-term behavioural responses of svalbard reindeer *Rangifer tarandus platyrhynchus* to direct provocation by a snowmobile. Biol. Cons. **56:** 179-194.

United Nations Environment Programme (UNEP). 2001. C. Nelleman, L. Kullerud, I. Vistnes, B.C. Forbes, E. Husby, G.P. Kofinas, B.P. Kaltenborn, J. Rouaud, M. Magomedova, R. Bobiwash, C. Lambrechts, P.J. Schei, S. Tveitdal, O. Grøn, and T.S. Larsen. GLOBIO: Global methodology for mapping human impacts on the biosphere. UNEP/DEWA/TR. 01-3.

Valkenberg, P. and Davis, J.L. 1985. The reaction of caribou to aircraft: a comparison of two herds. *In* Proceedings of the First North American Caribou Workshop. *Edited by* A.M. Martell and D.E. Russell. Canadian Wildlife Service Special Publication, Ottawa, ON. pp. 7-9.

van Zwoll, W. 1983. Ghosts of the Selkirks. Washington Wildlife. **33:** 26-29.

Varo, M. and Varo, H. 1971. The milk production of reindeer cows and the share of milk in the growth of reindeer calves. J. Sci. Agri. Soc. Fin. **43:** 1-8.

Wang, L., Lyons, J., Kanehl, P., and Bannerman, R. 2001. Impacts of urbanization on stream habitat and fish across multiple spatial scales. Envir. Manage. **28:** 255-266.

West Central Alberta Caribou Standing Committee (WCACSC). 1996. 1996/97 operating guidelines for industrial activity in west central Alberta. Unpublished report. WCACSC, Grand Prairie, AB.

Whitten, K.R., Garner, G.W., Mauer, F.J., and Harris, R.B. 1992. Productivity and early calf survival in the Porcupine Caribou Herd. J. Wildl. Manage. **56:** 201-212.

Whitten, K.R. and Cameron, R.D. 1983. Movements of collared caribou, *Raniger tarandus*, in relation to petroleum development on the Arctic Slope of Alaska. Can. Field-Nat. **97:** 143-146.

Yarmaloy, C., Bayer, M., and Geist, V. 1988. Behaviour responses and reproduction of mule deer, *Odocoileus hemionus*, does following experimental harassment with an all-terrain vehicle. Can. Field-Nat. **102:** 425-429.

Yukon Department of Renewable Resources. 1999. Yukon State of the Environment Report 1999. Government of Yukon, Whitehorse, YT.

Yukon Territorial Government. 2000. Yukon Oil and Gas. Department of Economic Development, Oil and Gas Branch, Whitehorse, YT.

Zhigunov, P.S. (ed.) 1961. Reindeer husbandry. English translation from Russian by the Department of Commerce, Springfield, VA.

PERSONAL COMMUNICATION

Jan Adamczewski, Regional Biologist, Fish and Wildlife Branch, Yukon Territory Government, Whitehorse, YT.

Rob Florkiewicz, Regional Biologist, Fish and Wildlife Branch, Yukon Territory Government, Whitehorse, YT.

Doug Heard, Wildlife Specialist, Fish and Wildlife Science and Allocation Section, Ministry of Water, Land and Air Protection, Government of British Columbia, Prince George, BC.

Dave Hervieux, Wildlife Biologist, Fish and Wildlife Branch, Sustainable Resource Development, Government of Alberta, Grande Prairie, AB.

Adam James, Endangered Species Biologist, Fish and Wildlife Division, Sustainable Resource Development, Government of Alberta, Peace River, AB.

Trevor Kinley, Caribou Biologist, Sylvan Consulting Ltd., Invermere, BC.

George Schultze, Wildlife Officer, Fish and Wildlife Science and Allocation Section, Ministry of Water, Land and Air Protection, Government of British Columbia, Telkwa BC.

Troy Sorensen, Wildlife Biologist, Fish and Wildlife Division, Sustainable Resource Development, Government of Alberta, Whitecourt, AB.