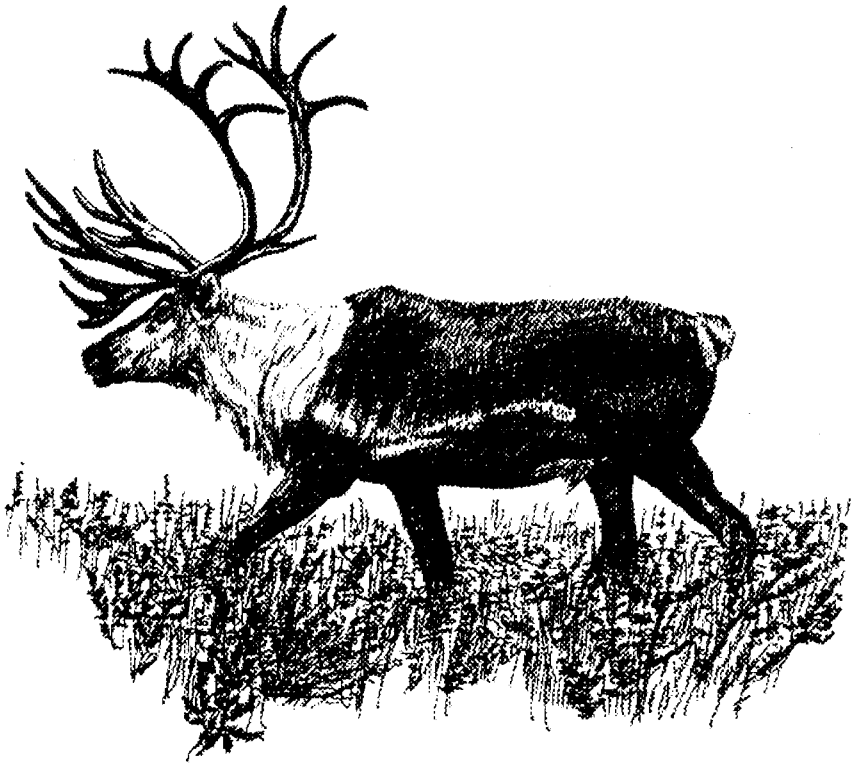
IMPACTS OF HUMAN DEVELOPMENTS AND LAND USE ON CARIBOU: A LITERATURE REVIEW VOLUME I: A WORLDWIDE PERSPECTIVE

by

R.T. Shideler, M.H. Robus, J.F. Winters,
and M. Kuwada

Technical Report 86-2



Alaska Department of Fish & Game
Habitat and Restoration Division

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June 1986

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ACKNOWLEDGEMENTS

Many people have contributed directly and indirectly to the ideas and information presented here. In particular we would like to thank Jim Davis, Ray Cameron, Ken Pitcher, and Ken Whitten of Division of Game, ADF&G, and Steve Albert, Bruce Baker, Al Ott, Lance Trasky, and the late John Clark of the Division of Habitat, ADF&G, for commenting on previous drafts. Eldar Gaare of the Norwegian Direktoratet for Naturforvaltning, Trondheim, kindly provided an update on the status of wild reindeer and human developments in Norway. Dave Klein, University of Alaska Cooperative Wildlife Research Unit, provided unpublished information on the Norilsk pipeline. We would also like to thank Tom Bucceri for drafting the figures, Bob Durr for editing the annotated bibliography, and especially Nancy Fisher for her patience and considerable skill in typing the manuscript.

The preparation of this report has been made possible through allocation of a portion of a 5-year Regional Planning Capital Improvement Budget authorized by the Alaska Department of Fish and Game for the period FY 82-86.

EXECUTIVE SUMMARY - VOLUME I

1. There is no consensus among caribou biologists regarding the relative importance of different influences (i.e., forage, predation, hunting, or dispersal) on caribou population dynamics. This lack of consensus reflects not only a difference in philosophical viewpoints among caribou biologists but also the different influences to which caribou populations in different environments are subjected. Caribou biologists have interpreted caribou population dynamics in terms of three major theories. These theories are not necessarily independent of each other, and many biologists subscribe to more than one of each. However, for the purposes of discussion here we treat each theory as if it were completely separate from the other. The three theories emphasize predation, forage, and dispersal, respectively, as the influence by which caribou populations are regulated.

   Proponents of the "Predation" theory believe that caribou reproduction rates remain high (70-90% in most North American herds) and relatively stable irrespective of forage quantity or quality. They further believe that caribou populations are regulated by changes in calf or adult survival caused by predation, harvest by humans, or the transmission of meningeal disease from white-tailed deer. Although forage may ultimately control caribou populations, the density of animals at which this control would occur has been reached in Fennoscandian but not in North American caribou herds. Adherents of this theory consider the impacts of human land uses on caribou in light of increased predation, harvest, or harassment. In their view, increased access for hunters or predators, reductions in space in which caribou can evade predators, and harassment due to hunting are the most important impacts of human developments.

   Proponents of the second theory, the "Forage" theory, believe that caribou-forage relationships are more important than do proponents of the "Predation" theory. According to adherents of this theory, differences in calf and adult survival among caribou herds can be traced to differences among these herds in forage relationships (e.g., quality, quantity, and availability of forage) as well as predation or harvest; therefore, such forage relationships are important in regulating caribou populations. Traditionally, the emphasis of this theory has been on the importance of lichens because caribou appear to be uniquely adapted to the utilization of lichens. Current thinking is that although lichens may be a staple in the diet of some caribou populations, lichens are not necessary for the survival of all caribou populations. Adherents of the "Forage" theory emphasize that human activities can impact caribou by affecting the animal's ability to utilize forage. The impact can occur by direct destruction of that forage, disruption of access to forage, by interference with the animal's time to spend foraging, or by increasing the animal's energy demands.

Proponents of the third theory, the "Dispersal" theory, believe that density-dependent interactions among individual caribou, or between caribou and their habitat, cause caribou to disperse to new areas before forage conditions reach the point at which the population would decline. The adherents of this theory have not specifically interpreted the impacts of human developments and land uses in terms of this theory.

2. There is ample evidence from thoughout the Northern Hemisphere that caribou populations have declined and their geographic range has contracted from that of historic levels; and that this effect has been due to increased land uses and developments concurrent with the expansion of the human population. In many cases, declines have been caused by hunting and/or a deliberate policy of extermination of wild reindeer in order to facilitate domestic reindeer grazing. Habitat alterations, including reduced access of caribou to habitat as well as direct habitat loss, have also been implicated in extirpations of local caribou populations. In many instances, these influences have been concurrent, and isolating one influence from another is difficult.

3. In Alaska, overharvest was apparently the cause for the extirpation of caribou on the Kenai Peninsula at the turn of the century, and for severe declines in other mainland caribou herds in northern Canada and Alaska.

4. In British Columbia, several small herds of mountain caribou (e.g., Selkirk, Raven Lake) were initially severely depleted by overhunting; however, subsequent (or possibly concurrent) habitat changes, primarily from logging, are considered responsible for continued declines. Other mountain caribou herds in British Columbia declined due to predation (Spatsizi), or to habitat changes that resulted in decreased forage as well as increased predation (Wells Gray).

5. In Fennoscandia and many regions of the Soviet Union, caribou were exterminated in many areas as part of an official policy to support the domestic reindeer industry. Modern caribou distribution in these regions is mostly restricted to areas remote from human development (Soviet Union), and especially where the domestic reindeer industry is absent or of low-intensity (Fennoscandia and Soviet Union). Boundaries on the modern distribution of many herds in both the Soviet Union and Fennoscandia are the result of human activities (e.g., hydroreservoirs, transportation corridors, settlements, areas of intensive forest industries). In the case of wild mountain reindeer of southern Norway, the human activities mentioned above as well as natural topographic features (e.g., fjords, lakes) have created barriers to reindeer movements and have created restricted distribution.

6. In New England and the Lake States, massive habitat changes due to logging, fire, and agriculture occurred during the expansion of settlement in the 19th century. Much of the climax coniferous forest, formerly the home of the eastern woodland caribou, was destroyed and replaced by fire-adapted deciduous forest (mostly aspen) or by transition of coniferous forest in various stages of succession. These habitat changes not only resulted in the loss of an important caribou

winter forage (i.e., arboreal lichens) but also created conditions favorable for the immigration of white-tailed deer to this region, and the subsequent transmittal of meningeal disease from deer to caribou. Although some hunting of caribou undoubtedly occurred, habitat changes alone could have resulted in the woodland caribou decline. Because controls over excess hunting of caribou have been implemented since the early 1900's habitat changes alone are responsible for the continued absence of eastern woodland caribou in the Lake States and New England.

In Ontario, declines of eastern woodland caribou began in the southern part of its range in the late 1800's, and progressed northward as settlement expanded. Habitat destruction and hunting initiated the decline. Wolf predation increased as white-tailed deer expanded north into former caribou range and increased in numbers. Continued habitat destruction and, in some instances, wolf predation, have prevented the recovery of eastern woodland caribou in southern Ontario.

7. The impacts of several individual types of human activities and land uses or developments are discussed. In most cases a direct link between the human activity and a decline in the affected caribou herd has not been established, although the activities have resulted in destruction or alteration of caribou habitat, access to habitat, or ability of caribou to utilize their habitat.

8. In the Soviet Union, agricultural expansion has been blamed for the fragmentation of caribou habitat and subsequent decline of caribou populations. However, elsewhere in the world documentation of direct impacts of agriculture on caribou has been limited to instances in which Fennoscandian domesticated reindeer were inadvertently poisoned with agricultural chemicals.

9. Water, air, and land transport have been implicated as impacts to caribou populations. Water transport has been responsible for direct mortality of caribou in the Soviet Union where ice-breaking freighters on the Yenisey River kept a river channel open on a traditional fall migration route. Caribou drowned or were prevented from crossing the "lead" by jumbled ice along its edge. An indirect impact was that caribou which were unable to cross the river remained in the area far longer than in normal years, and depleted local areas of habitat.

   The primary impact of air transport is harassment of caribou by small aircraft. Disruption of feeding and other caribou activity and the potential for mortality of calves when herds stampede are considered to be the most important potential impacts of aerial harassment. There is no documentation directly linking aerial harassment with mortality or debilitation of individual caribou. There is disagreement over the importance of aerial harassment as an impact on caribou. Season, sex and age classes of caribou present, altitude of the overflying aircraft, and the herd's previous experience with aircraft are all factors likely to affect the caribou's response. Most observations of caribou response to aircraft suggest that if the aircraft were to maintain a flight altitude of 300 m (1,000 ft) during most seasons, and 600 m (2,000 ft) during calving and postcalving, there will be negligible effect on caribou.

Ground transport consists of linear transport systems and off-road uses. Linear transport systems (e.g., roads, pipelines, power transmission lines) have been responsible for impacts to caribou such as direct mortality from collision with vehicles (including trains), disruption of caribou movements because of physical or behavioral barriers, and restrictions in habitat use that are due to caribou avoidance of roads. Behavioral barriers and avoidance of habitat caused by roads have most often been due to the frequent disturbance of caribou by traffic associated with the roads. Behavioral barriers caused by powerlines have been because of the noise and visual presentation of the powerline and clearing associated with it. Hunting, undertaken from roads or railroads, or as pedestrians, or with off-road vehicles, tends to exacerbate the avoidance of linear structures by caribou.

An indirect effect of linear transportation systems is to increase access to caribou range by hunters and predators. In the case of many caribou herds this may have been the major reason for historic declines.

10. Forestry and human-caused fire result in direct destruction of caribou habitat and especially lichen habitat which takes much longer to reestablish than other types of caribou forage. In some instances fires and logging may create suitable site conditions for regeneration and even increased abundance of terrestrial lichens. However, in most instances such is not the case for arboreal lichens which rely on mature old-growth conifers for maximum abundance. The effects of human-caused fire are dependent on characteristics of the individual burn, the availability of alternative resources to those caribou whose use of the burn is displaced, and the dependence of the individual herd on lichen habitat. Both positive and negative aspects of fire to caribou have been documented. Related effects, such as increased access to caribou by hunters and predators and habitat changes that result in predator increases, are important impacts of forestry and human-caused fire. Felling of trees containing abundant arboreal lichens may provide a short-term increase in forage abundance--attraction to such areas by caribou and domestic reindeer has occurred. A major impact of modern silvicultural techniques (especially on mountain caribou range in western North America, is the planned replacement of mature old-growth forest with commercially valuable tree species that are managed on short-rotation systems such that arboreal lichen abundance severely declines and deep snow reduces caribou mobility.

11. Domestic reindeer husbandry has had a major impact on caribou in northern Europe and Asia, and a negligible impact on caribou in North America. Direct extermination of caribou by reindeer herders, some forage competition, genetic mixing, and possibly transmission of disease from domestic reindeer to caribou are impacts discussed in the literature. However, of these impacts, direct extermination has been by far the most significant. Large areas of Fennoscandia and the Soviet Union are no longer inhabited by caribou (wild reindeer) because of the policy of extermination of wild reindeer which entered these

areas. Since the extermination of wild reindeer was completed human developments such as agriculture, settlement, and forestry have changed the original habitat so that it is no longer suitable for wild reindeer, and in some cases even for domestic reindeer.

12. Responsible management of caribou must reflect not only a concern for protection of populations (e.g., by controls over hunting) but also on the perpetuation of a sufficient amount of habitat to allow caribou to forage and escape predators effectively.

1.0 GENERAL INTRODUCTION

As Alaska continues to develop its natural resources, human-induced changes will continue to affect the availability and use of habitat by fish and wildlife species in the state. The caribou (Rangifer tarandus) is one of the most popular wildlife species in Alaska, and one of the most important for subsistence and recreational hunting, and for viewing. Experience in assessing the effects of human-induced changes on Rangifer populations elsewhere in the world has indicated that man can significantly alter the relationship between Rangifer and its habitat. In the worst cases, these alterations have resulted in regional and local extirpations. In order to understand these human-induced alterations, and therefore to be better prepared to prevent their occurrence in Alaska, Habitat Division has prepared this report synthesizing the available literature on the effects of human land use and development activities on Rangifer. The report is divided into two volumes. Volume I is a general discussion of the impacts of human land use and development types on Rangifer throughout the world, and includes a brief discussion of the prevailing three theories of Rangifer population dynamics as well as a synthesis of the available impacts literature. Volume II is a discussion of the effects of oil and gas development on the Central Arctic Herd of Alaska's North Slope. Volume II focuses on the type of development that is most intensive in Alaska at this time, although available information from other geographic areas and situations is included where appropriate.

1.1 SCOPE AND ORGANIZATION

Although the emphasis of these two volumes is on impacts to Rangifer that are caused by man's development activities, additional information is included that is designed to assist the reader in evaluating and understanding the impacts information provided. This additional information includes such topics as taxonomy, herd status, aspects of Rangifer life history and habitat utilization, and distribution. The discussion of these topics is limited to that information directly relevant to evaluation of the impacts information. Readers desiring more exhaustive treatment of these general topics should consult Bergerud (1978), Kelsall (1968), Miller (1982), Pullainen (1983), Reimers et al. (1980), and Skoog (1968).

Each volume consists of a narrative followed by an annotated bibliography of selected pertinent references. The references which have been annotated were selected because of their relevance to understanding and evaluating impacts discussed in the report. All references we found which discussed impacts have been annotated. In addition, some references have been annotated that contain information useful in evaluating impacts but which do not in themselves contain impacts information.

1.2 DEFINITION OF IMPACT

For the purposes of this report, an impact is defined as an alteration of Rangifer's environment as a consequence of human land use or development

activities that results in a deleterious change in the relationship between caribou and their habitat (including other species of wildlife, such as predators or competing ungulates). Several considerations are worth mentioning with regard to this definition. First, human development activities do not always cause alterations to Rangifer's environment that are deleterious; for example, in some situations logging can enhance the availability of forage for caribou by providing openings in dense forests which will allow colonization by terrestrial lichens. Second, most biologists agree that, ultimately, the amount of available habitat limits the number of animals supported by that habitat. Other proximate factors (e.g., hunting, predation) may be more important in the short term; however, the amount, distribution, and quality of available habitat ultimately limits populations. Third, the Department's goal is to ensure that caribou habitat is managed for the long-term benefit to the species. This principle is formulated in the Department's "Statement of Policy on Mitigation of Fish and Game Habitat Disruptions" (memo Skoog to Directors, 3/24/82) in which it is stated that the goal of the Department is to "...maintain or establish an ecosystem with the project in place that is as nearly desirable as the ecosystem that would have been there in the absence of the project." One consequence of this goal is that habitat management, as opposed to population management (e.g., seasons and bag limits), must be approached from the standpoint of maximum protection over the long term because many development projects are of a duration of tens or hundreds of years. As a result habitat losses or other effects of development that may accompany these development projects are for all practical purposes irreversible.

2.0 INTRODUCTION TO VOLUME I

The literature regarding a number of man's developments (e.g., hydropower, reindeer grazing, agriculture, settlement) is synthesized in Volume I. Some of these types of development (e.g., agriculture) do not currently conflict significantly with management of Alaska's caribou and their habitat; however, as the state continues to develop its resources and increase in population, these conflicts could occur.

Volume I is organized into four sections. In the "Background" section, information is presented that enables the reader to understand and evaluate the information on impacts presented in the subsequent sections. Such information includes a brief discussion of Rangifer taxonomy, general habitat relationships (including the effects of wildfire), and the three prevailing theories regarding the factors most influential on caribou population dynamics and habitat relationships. The second section, "Examples," is a discussion of the changes in geographic distribution or abundance that have occurred in several regions (e.g., North America, USSR), and the factors that have been considered responsible for these changes. The third section, "Impacts," is a discussion of the literature about impacts of human land use and developments on Rangifer. The last section, "Summary and Discussion," summarizes the previous two sections in light of the background section on the three theories discussed in section 3.2.

In addition to the four sections mentioned above, the annotated bibliography is included as an appendix.

3.0 BACKGROUND

An extensive review of Rangifer life history, ecology, distribution, abundance, and herd status is beyond the scope of this report. The following discussion is limited to salient aspects that we feel are useful in understanding and evaluating the impacts literature.

3.1 TAXONOMY AND NOMENCLATURE

Throughout this review, the terms wild reindeer, caribou, feral reindeer, domesticated reindeer, and Rangifer are used. The terms wild reindeer and caribou are synonymous, and refer to subspecies of Rangifer tarandus that have existed essentially free of domestication. For the purposes of this report, caribou will be used for both caribou and wild reindeer, unless the latter term is needed for clarification. The term feral reindeer applies to wild-living reindeer that have been derived from domestic reindeer stock even though the particular individuals may never have been domesticated (e.g., the reindeer of St. Matthew Island - Klein 1968; reindeer of South Georgia, Falkland Islands - Leader-Williams and Payne 1980). The term domestic reindeer refers to those that are loosely defined as being under the control of humans, although some herds may be in the process of becoming feral. The term Rangifer is used when generally referring to all types of reindeer and caribou. In some areas (e.g., Fennoscandia) all three types of reindeer are present. In other areas (e.g., Iceland [Skarphedinn 1980, Thorisson 1980] and South Georgia [Leader-Williams and Payne 1980]) only feral reindeer are present. A generally accepted schema for Rangifer nomenclature and taxonomy is summarized in table 1. Further information on

Table 1. Subspecies, geographic range, and general habitat utilization of Rangifer tarandus [1)]

Subspecies	Geographic Area	Habitat		Forage Type	
		Summer	Winter	Summer	Winter
R. t. tarandus (wild mountain reindeer)	Southern Norway; Kola Peninsula, USSR	Low to high elev. alpine snowbed meadows	Dwarf shrub/heath; boreal forest	Grazer/browser	Epigenic lichens
R. t. caribou (woodland caribou)	Newfoundland and southern Canada; Northwestern U.S.	Riverbanks, marshes, bogs	Climax subarctic boreal forest	Grazer/browser	Arboreal lichens
R. t. fennicus (wild forest reindeer)	Finland; Karelia, USSR				
R. t. Granti (barren-ground caribou)	Alaska, subarctic Canada	Dwarf shrub/heath; sedge marshes, upland tundra	Dwarf shrub/lichen/ heath; boreal forest	Grazer/browser	Epigenic lichens
R. t. arcticus (tundra reindeer)	Mainland Siberia, USSR				
R. t. valentinae (montane reindeer)	Altai Mtns., USSR	Low to high alpine snowbed meadows	Subalpine climax boreal forest	Grazer/browser	Arboreal lichens
R. t. caribou (mountain caribou)	Western Canada; north western U.S.				
R. t. Pearyi (Peary's caribou)	Arctic island archipelago, Canada	Lowland sedge/moss; dwarf shrub tundra	Dwarf shrub heath	Grazer/browser	Grazer/browser
R. t. platyrhynchos (Svalbard reindeer)	Svalbard, Norway				
R. t. groenlandicus (Greenland caribou)	Greenland				

1) After Pullainen (1983), Reimers et al. (1980), and White et al. (1981).

North American caribou taxonomic status is presented in Calef (1980) and Davis (1980).

Behavioral and genetic differences between wild and domesticated reindeer, and among different reindeer subspecies, have been discussed by Nieminen (1980), Soldal and Staaland (1980), and Thomson (1980). These studies have demonstrated that genetic and behavioral differences between subspecies exist. Unfortunately, these differences have not been sufficiently explored to permit their use in impact assessment, and will be discussed no further in this report.

3.2 PREVAILING THEORIES REGARDING POPULATION DYNAMICS OF RANGIFER

There is no general consensus regarding the relative importance of different factors which limit or control the growth of Rangifer populations. There appear to be three prevailing theories regarding the control of Rangifer populations. For the sake of discussion we are treating each of these theories as if they were separate. In reality there is considerable overlap among theories and the distinctions lie more in the degree of emphasis (as opposed to absolute differences) that each theory places on various population-regulating mechanisms. The reader should be aware that the proponents of each theory tend to emphasize their own views when discussing the impacts of human developments and land uses. The reader should recognize these biases and make his own reasoned evaluation of each theory. In the following discussion, we summarize the salient features of each theory, and then discuss the areas of disagreement, areas of agreement, and the use of each in evaluating the effects of alterations in the caribou's environment that are caused by human land use and developments.

3.2.1 "Forage" Theory

This theory emphasizes the importance of habitat relationships, in the sense of forage quality and availability, and forage-grazing interactions, in the dynamics of Rangifer populations. In the past, advocates of this theory have emphasized the importance, and in some authors' views, necessity of lichens to winter survival of Rangifer (e.g., Andreev 1984, Buckley 1958, Cringan 1969, Dufresne 1946, Helle and Aspi 1983, Klein 1970, Leopold and Darling 1953, Scotter 1967). Syroechovskii (1984a) notes that the emphasis which some researchers placed on the importance of lichens in the diet of Rangifer may be derived from experience with domestic reindeer, which was extrapolated to caribou. During the process of domestication of wild reindeer, herders selected for those animals which thrived on open, relatively stable habitat that facilitated herding and provided a suitable living area for the herdsmen. Lichen and forest-lichen habitat provided these requirements; therefore, the ability to thrive on a lichen diet became a secondary characteristic of these animals (ibid.). As a consequence of this emphasis on the importance of lichens to domestic reindeer, human-induced effects that reduced the abundance of lichens (e.g., fires, logging, domestic reindeer grazing) have been perceived as a threat to the maintenance of caribou populations.

As knowledge of Rangifer and habitat relationships has grown, the emphasis on the necessity of lichens to Rangifer winter survival has declined somewhat. Most biologists now believe that lichens are not necessary for

survival; however, many authors consider that lichens are important (e.g., Klein 1980b, 1982; Skogland 1983). Evidence that lichens are not necessary for survival includes observations of caribou in several areas that apparently have thrived without lichens available. These areas include South Georgia Island in the Falklands (Leader-Williams and Payne 1980), Iceland (Skarphedinn 1980), Greenland (Thing 1980), Svalbard (Reimers 1980), the High Arctic Islands of Canada (Miller 1982), and Irkutsk, USSR (Grigor'ev and Leon'tev 1984). For some caribou herds in the Soviet Union (e.g., Lena River delta - Syroechovskii 1984a) lichens are a very minor component of the diet, even in winter. Domestic reindeer have also been shown to adapt to a lichen-free diet in some areas as shortages of lichen habitat have developed (ibid.). In general, however, caribou in the Soviet Union feed on a diet of mixed herbage in which lichens comprised only 11-22% of the winter diet of caribou, as compared to 70-80% for domestic reindeer (Mukhachev 1984, Shtil'mark 1984, Syroechovskii 1984a).

Lichens alone have often been considered only a "maintenance" diet, but a mixture of wintergreen plants (e.g., Equisetum, Empetrum, Vaccinium) and lichens is sufficient for animals to gain weight over winter (Klein 1982). In the Trans-Baikal region of the Soviet Union Vodop'yanov (1984) noted that in winter female and calf caribou preferred areas where wintergreen plants (especially Equisetum spp.) are mixed with lichens, as opposed to areas where lichens were found alone. Bergerud (1972) noted that arboreal lichens comprised 54% of the diet of Newfoundland caribou during the severe winter of 1959, but that caribou would eat vascular plants during winter if such plants were available. These observations indicate that lichens are important if only as "emergency" food and may be a dietary staple in some situations. As Klein (1982), Shtil'mark (1984), and Syroechkovskii (1984a) point out, Rangifer is the only ungulate on continental ranges that has become adapted physiologically and behaviorally to utilization of lichen habitat.

Recent research has focussed on aspects of Rangifer habitat relationships that are independent of the controversy surrounding the importance of lichens. This research has shed new light on the effects of nutrition on population regulation. Such research has generated questions about the importance of winter and summer forage quality and limitations on foraging activity (Klein 1980b, Klein and White 1978, White et al. 1981). Nutrition has been shown to influence Rangifer individual body size, pregnancy rates, age at initial conception, and calf survival. The relative importance of winter as opposed to summer nutrition in influencing these characteristics is somewhat controversial. Klein (1970) feels that whereas winter range quality affects primarily population size, summer range quality affects individual size. White et al. (1981) believe that summer range quality affects population size as well as individual body size. However, evidence points to winter and summer nutrition as being important in the regulation of both individual and population size.

Although caribou have been shown to undergo a physiologically-controlled reduction in energy intake during winter (ibid.), the importance of winter nutrition has been shown for caribou and reindeer in a number of situations. Peary caribou endure periodic severe winter conditions that have not only reduced pregnancy rates because females did not apparently reach sufficient body size to conceive the following fall, but were also responsible for

major die-offs because animals starved (Thomas 1982). Svalbard reindeer were once thought to be able to survive because they put on sufficient fat reserves during the summer to carry them through winter (Reimers 1980); however, recent evidence indicates that such reserves can account for only 25% of the animal's energy needs over winter--the remainder must come from winter forage (Tyler 1985). Skogland (1983, 1985) believes that differences in quality of winter range among wild mountain reindeer herds in southern Norway account for the differences in body weights, pregnancy rates, and calf survival among these herds.

The importance of the quality and availability of summer forage in influencing individual size, conception rates, and calf survival has also been considered. Because caribou voluntarily reduce their forage intake during winter, much of their fat reserves must be built up during summer when vascular plant forage nutrients are at their peak (White et al. 1981). Individual body size of female caribou and reindeer has been shown to influence their probability of successful breeding; therefore, several investigators believe that female caribou, and especially primiparous females, must put on sufficient fat reserves during the summer to acquire the threshold body size to enable them to successfully breed the following fall (e.g., Dauphine 1976, Reimers 1983). Additionally, calf survival rates are thought to be influenced by summer nutrition. Calves born in herds where calving occurs prior to vascular plant greenup have a higher rate of survival because the calf begins foraging on their own at about the same time that plants are most nutritious; therefore, calves can make more rapid early weight gains than if they were still dependent on maternal milk (Reimers 1983). In addition to physiological factors there may be behavioral factors that influence calf survival. Maternal behavior toward the calf may be affected by the cow's nutritional level (Espmark 1980, Reimers 1983). In experiments with penned domesticated reindeer, undernourished cows tended to be less tolerant and careful of their calves than well-nourished cows, although there were no statistical differences in maternal behavior between groups except in the case of maternal licking (Espmark 1980).

Recently, more research has focussed on factors that influence foraging activity (i.e., limitations on the animal's ability to optimize its forage intake even when good quality forage is available). Rangifer has apparently adapted to the probability of poor winter nutrition by optimizing forage intake during summer when vascular plant nutrients are at their greatest availability and by entering a physiologically-induced state of lower winter metabolism (White et al. 1981). Modelling of nutrition dynamics of Rangifer herds that are exposed to influences that disrupt foraging (e.g., harassment by insects, humans, and predators) have suggested that such influences could affect the animals' ability to obtain sufficient fat reserves to survive the winter. Thus the ability to accumulate fat reserves in summer is an important evolutionary strategy of Rangifer. This strategy is most pronounced in subspecies that occupy northern extremes in caribou distribution such as Greenland (Thing 1980, Thing and Clausen 1980), Svalbard (Reimers 1980, 1983) and the High Arctic Islands of Canada (Miller 1982, Thomas 1982), and the Soviet Union (Kischinskii 1984). The lack of insect and predator harassment during summer allows these caribou to accumulate large fat reserves in spite of the forage quality being lower on these islands than on most mainland ranges. Klein (1980a) noted that

introduction of domestic reindeer infected with warble and bot flies to Greenland resulted in the spread of flies to native caribou. Harassment by flies caused declines in condition of the native animals (ibid.). However, the only empirical evidence has been gathered by Reimers (1980) who compared the fat cycle of Svalbard caribou (where human, predator, and insect harassment is absent) with that of Hardangervidda caribou which were on much better quality range, but were subjected to more harassment during summer. Reimers (1980) found that Svalbard caribou entered the winter in much better condition than did Hardangervidda caribou, but the latter did not use up fat reserves as quickly as the former, so that by spring Hardangervidda animals were in slightly better condition. Reimers (1980) also speculated that had Svalbard caribou been exposed to the proportional amount of harassment as had the Hardangervidda caribou, the former would have starved. Additional evidence from the Soviet Union indicates that caribou harassed by people and predators during winter reduced the amount of grazing time and the size of feeding craters by one-half (Sokolskii 1984). Vodopyanov (1984) noted that in the Trans-Baikal region, caribou in regions where snowfields were available for insect relief during summer were fatter than reindeer without access to snowfields. Likewise Ovsyukova (1984) noted that feral reindeer on Vrangelya (Wrangell) Island, which is free of predators and "gadflies," had the highest live weight (including fat) of any reindeer slaughtered by Soviet collective farms in 1962. He attributed this result to the absence of harassment by predators and insects. These and other studies suggest that external influences have the potential to disrupt foraging sufficiently to affect nutritional condition of Rangifer.

The previous discussion implies that one must choose between the theory stressing the importance of summer nutrition and that of winter nutrition in affecting caribou populations. In reality there is no a priori reason to believe that both are not true. Severe perturbations of the normal Rangifer energy cycle in either winter or summer can have effects that could extend into a later season. Under conditions of insufficient winter nutrition, calving dates can become extended into the period of maximum nutrient content of vascular plants such that neither the calf nor the cow can "catch up" nutritionally. The calf will be weaker, and thus overall calf survival may decline, and the cow will not have sufficiently good body condition to conceive in the fall. Likewise, insufficient summer nutrition will prevent cows from gaining sufficient weight to conceive, or to give birth to a calf with sufficient body weight for survival. Any interruption in the cycle can have effects that may not be manifested until a later season.

3.2.2 "Predation" Theory

This theory, emphasizes the importance of predation, harvest, or disease in controlling caribou populations. The "Predation" theory contends that different regulation mechanisms affect caribou populations in different vegetative regions (Bergerud 1983). Insular populations (e.g., St. Matthew Island - Klein 1968, Greenland - Thing 1980) where tundra predominates and there are no predators, are controlled by density-independent mechanisms such as severe icing and snow and/or wind conditions which affect food availability. In the Lake States-Acadian Forest, "meningeal disease," caused by a nematode (Parelaphostrongylus tenuis) that is indirectly transmitted to caribou from white-tailed deer (Odocoileus virginianus), is considered responsible for declines of woodland caribou during settlement

(Bergerud 1983), and is likely responsible for the failure of caribou to become re-established in white-tailed deer range (Dauphine 1975). In the boreal forest, which is the heartland of caribou range, predation and overharvest are responsible for controlling caribou populations irrespective of range conditions and capacity (Bergerud 1978, 1980a, 1983). Caribou have co-evolved with wolves as predators; as a consequence, caribou exhibit a uniformly high birth rate (70-90% of females older than 2 years old) irrespective of range conditions, and mobility has become an important predator-evasion strategy (Bergerud 1978, Bergerud et al. 1984). The "Predation" theory rejects the conclusion that habitat (i.e., lichen winter range) destruction per se accompanying human settlement has been responsible for the extirpation or near-extirpation of caribou populations (Bergerud 1974, 1983). This conclusion has been extended to include linear developments (e.g., roads, pipelines) as long as these developments do not include absolute physical barriers to movements and as long as severe harassment (including hunting) is controlled (Bergerud et al. 1984). Ultimately, space to avoid predators is the most important limiting factor provided by the habitat (Bergerud 1980a, Bergerud et al. 1984). This same conclusion was reached by Murie (1935) nearly four decades earlier.

In recent discussions, the "Predation" theory has advocated the concept of "multiple equilibria"--i.e., at different densities of caribou and their predators (primarily wolves) the caribou population can expand or decline and the density of caribou at which this occurs is far lower than that at which relative forage abundance can regulate the population (Bergerud 1980a, 1983). Human harvest and presence of alternate prey can affect the nature of the wolf-caribou relationship; however, the only habitat component that may be restrictive is space (Bergerud 1980a, Bergerud et al. 1984).

3.2.3 "Dispersal" Theory

This theory is an extension of Skoog's (1968) belief that movement between major Alaskan herds has been an important feature of caribou population dynamics; and that in most cases such movement, rather than predation or harvest, has produced the changes in distribution and numbers which he observed for Alaskan herds.

Proponents of the "Dispersal" theory adopts the premise of Skoog (1968) that at a certain population density (5 caribou/mi^2), social stimuli within the herd cause some animals to emigrate to other herds, or to marginal ranges elsewhere. However, in contrast to the views of Skoog (1968), proponents of the "Dispersal" theory suggest that the stimulus for emigration is declining range condition rather than social stimuli (Haber and Walters 1980). The chief distinction between the points of view of the "Predation" and the "Dispersal" theory adherents is that the former believes that multiple-equilibria occur at different caribou densities irrespective of habitat considerations, whereas the latter believes that at densities of 5 caribou/mi^2, caribou react to declining range condition by emigrating to adjacent areas (Bergerud 1980a, 1983). Proponents of the "Dispersal" theory have not specifically addressed the effects of human development activities on caribou habitat or populations.

3.2.4 Discussion

In order to clarify the discussion the three theories of caribou population regulation have been presented as if they were mutually exclusive positions. In reality, in most cases the viewpoints of caribou biologists about the regulation of individual caribou herds reflect a combination of the three theories. For example Kelsall and Klein (1982) agree that the first priority for management of the Porcupine Herd is to accurately assess the level of hunting and predation there--a defacto admission that forage is not limiting the growth of this large and expanding herd. Bergerud (1978) states that "large caribou herds need vast space to make suitable range adjustments to winter food shortages [emphasis added], insect attacks and predators...," "... Rangifer is the only ungulate that can use the lichen pastures of the North." Bergerud (1978) also notes that calving grounds should be protected from human harassment. These statements suggest that there is agreement between these two theories on the importance of forage and predation/harvest as factors that may ultimately regulate caribou populations; on the necessity to prevent harassment by humans, especially on calving grounds; and the importance of maintaining access to habitat. The concept of "multiple equilibria" (Bergerud 1983) is a synthesis of the "Forage" and "Predation" theories--Arctic caribou herds are only regulated by forage at densities that have yet to be reached by any North American herd, and which are far above that at which predation and harvest by humans have regulated these populations to date .

Although biologists agree that forage, predation, harvest, and possibly disperal are aspects of caribou population regulation, these same biologists disagree on the relative importance of these aspects, and on their relevance to the interpretation of past effects of human developments on caribou populations and habitat. Proponents of the "Predation" theory define "habitat" as space in which caribou can evade predators. Proponents of the "Forage" and "Dispersal" theories define "habitat" as forage. Therefore, the latter are more likely to interpret the effects of human activities in terms of effects on forage, whereas the latter are more likely to emphasize those effects which lead to an increase in predation or harvest.

4.0 EXAMPLES: MAJOR CHANGES IN DISTRIBUTION OR ABUNDANCE

In the following section, the impacts of human developments and land use activities on wild Rangifer populations are presented and discussed. Examples of extirpations of caribou which have been linked to human developments and land use are also presented. These are general accounts, most of which are based on historical anecdotes and little actual data. Examples from North America, the Soviet Union, and Fennoscandia are included.

Although the intent of this review is not to provide a detailed account of historic and current caribou status, there are recent cases of major changes in caribou distribution and abundance that have been attributed to human activities. Many of these changes have been extirpations of a regional scope. These are especially instructive because they provide examples of one extreme in the continuum of influences that humans have on caribou. Reconstructing the causes of such extreme responses by caribou can assist us in preventing their recurrence. Examples from North America (New England-Southeastern Canada and the Lake States-Ontario region; Rocky

Mountains region of Canada and the US; and Kenai Peninsula of Alaska), the Soviet Union, and Fennoscandia are presented.

4.1 NEW ENGLAND AND LAKE STATES

The extirpation of eastern woodland caribou in northern New England, southeastern Canada, the northern Lake States (northern Minnesota, Michigan, and Wisconsin) and southern Ontario (figure 1) is one of the most dramatic examples of the impact of human land uses on caribou, and one of the most frequently discussed (e.g., Bergerud 1974, Cringan 1969). Unfortunately, it is also one of the most complicated; and in order to understand why caribou were extirpated, one must also understand the patterns of land use in the region and the effects of land uses on other species in the same region, principally moose (Alces alces americana) and white-tailed deer (Odocoileus virginianus), but also wolves (Canis lupus) and other predators. Finally, it should be noted that the following re-creation of events (table 2) is dependent on numerous sources that cannot be verified; therefore, subjective interpretation has been necessary.

1600-1800. From the period of approximately 1600-1800, the influence of settlers from Europe on the landscape was relatively minor (McCabe and McCabe 1985). Most settlements by Europeans were along the Atlantic Seaboard or the upper St. Lawrence River. Although landscapes in the immediate area of these settlements were severely altered by clearing for farms and by occasional wildfires, most of the northern forest was still considered "forest primeval" (Irland 1982, McCabe and McCabe 1985). The "primeval" forest was not entirely free of human influences.

Woodland Indians cleared land for semisedentary agriculture by cutting trees and "controlled burning." Fire also was used in some areas to drive prey, primarily white-tailed deer, as a method of defense from neighboring tribes, and as wildlife habitat enhancement (McCabe and McCabe 1985). Estimates vary, but is seems reasonable that thousands of square miles of forest (mostly northern and southern hardwoods) in the eastern US were burned each year (McCabe and McCabe 1985, Trefethen 1961). This practice continued through the early period of settlement by Europeans, and was partially responsible for the pattern of distribution of white-tailed deer, and possibly moose, in the New England-Lake States region at the time of settlement (Flader 1983, McCabe and McCabe 1985). Natural influences such as severe windstorms (which created blowdown areas), insect infestations, and lightning fires also helped reduce the homogeneity of vast areas of mature forest in the Lake States-Ontario region.

At the close of the 18th century, forest associations of the northeastern and northcentral US and southern Canada were the Boreal Forest in the extreme north, the Lake States-Acadian Forest in the middle, and the Northern Hardwoods forest in the southern portion of the region (figure 1 and table 3). Most of the human-induced changes in wildlife habitat were confined to the Northern Hardwoods Forest and Lake States-Acadian Forest (Flader 1983, McCabe and McCabe 1985). The Boreal Forest was considered almost the exclusive domain of woodland caribou, although moose were also found in disturbed areas and in the transition between Northern Hardwoods/Lake States-Acadian Forest (Baker 1983, deVos and Peterson 1951, Dodds 1974, Flader 1983). In the northern Lake States, habitat alterations

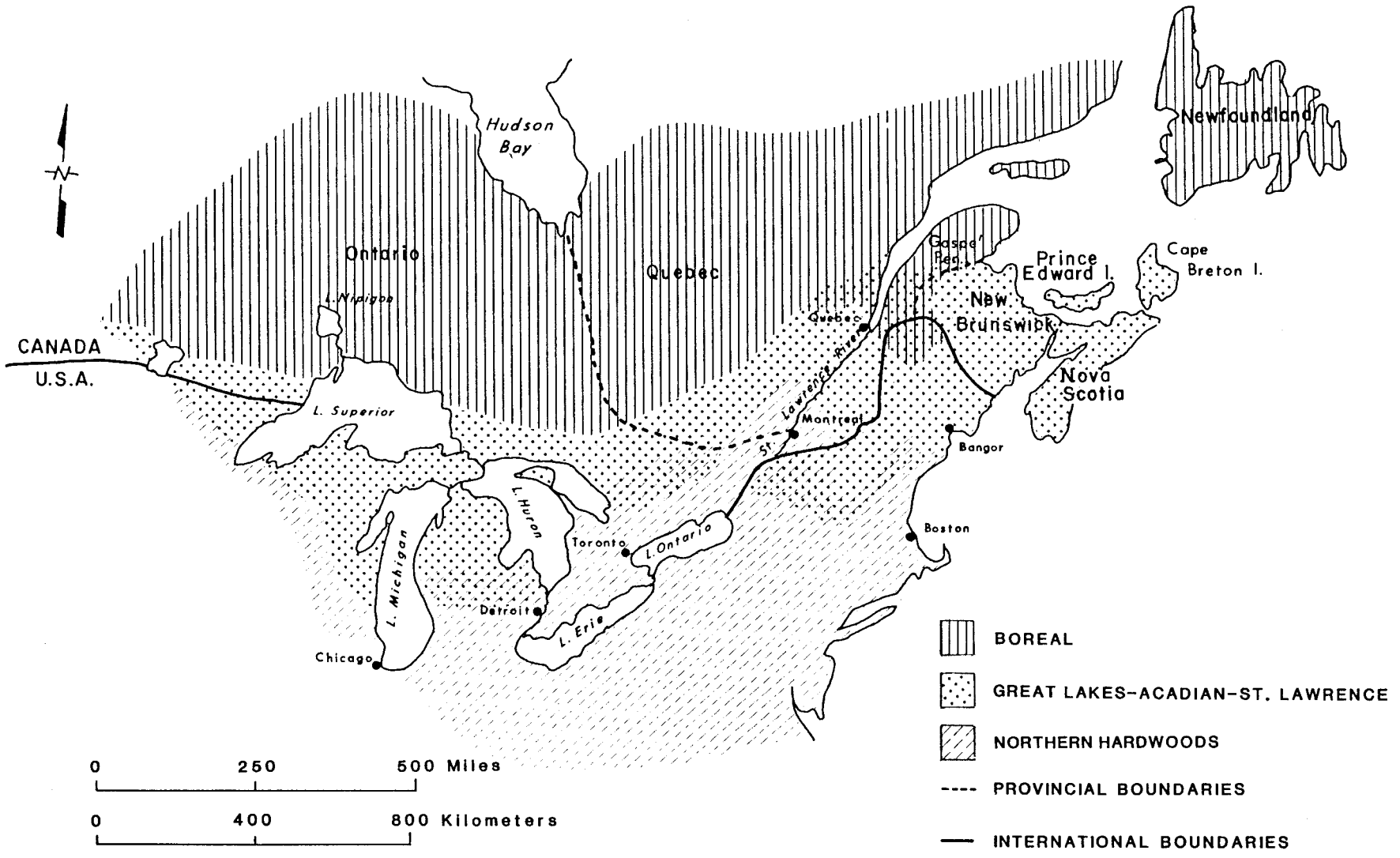


Figure 1. Original forest types of New England, Lake States & S.E. Canada.
(Adapted from map by A.W. Kuchler in Espenshade 1983, and vegetation classifications by Blouch 1985, Cringan 1969, Flader 1983 , Hazard 1982, Huot 1985, Mattfeld 1985,and Rowe 1972)

Table 2. Chronicle of caribou, moose, and white-tailed deer population changes in northern US and southern Canada, 1800-1950.

Date	Caribou	Moose	White-tailed Deer	Other
1800	Extirp. in NY (Cringan 1969); common in conifer forests of northern Minn. (Hazard 1982)	Declining in New England; extirpated S. of NY (Dodds 1974), and in Mass. (Godin 1977); much reduced in southeastern Canada (Banfield 1974); common in northcentral Minn. (Gunderson and Beer 1953)	Common but not abundant in eastern US (Schmidt 1978); restricted to southern hardwood oak/hickory forest (Godin 1977); in Minn., common only in south (Gunderson and Beer 1953)	
1830-39	Extirp. in Vt. (Cringan 1969); common but not abundant in Mich. U.P. (Baker 1983)	Nearly extirp. in Vt. (Godin 1977)		Wolves almost extirp. from S. Mich. (Baker 1983); Erie Canal (1828) and beginning of trans continental railroads (Flader 1983)
1840-49	Extirp. from Wisc.; declining in Minn., Mich., and S. Ontario (Cringan 1969)		Almost extirp. in New England (Mattfeld 1985; Taylor 1956)	1848, California Gold Rush; many farms abandoned in east
1850-59			Extending into N. Scotia from N. Brunswick (Huot et al. 1985)	Period (to 1890) of rapid westward expansion - transcont. railroads, settlements, and logging of spruce-pine forests of northern US and Ontario.
1860-69	Extirp. in NH (Cringan 1969); almost extirp. Minn. (deVos and Peterson 1951)	Almost extirp. in Mich. L.P. (Baker 1983)	Almost extirp. in S. Wisc. (Taylor 1956); extirp. in Vt. (Hornaday 1913)	Expansion slowed by Civil War, 1861-65; 1862, Homestead Act passed; 1867 development of refrigeration railroad cars expand market for commercial hunting (McCabe and McCabe 1985), Canada becomes nation, beginning of rapid expansion in Ontario and west.

Table 2 (continued).

Date	Caribou	Moose	White-tailed Deer	Other
1870-80		Almost extirp. Mich. U.P. (Baker 1983)	Successfully reintro. to Vt. (Hornaday 1913); (1875-86) peak of pop. in L.P. Mich. (Baker 1983); beginning of severe decline in New England (Trefethen 1961)	Expansive logging of white pine in Mich. U.P.; severe decline in lumber market, peak of land clearing - logging and agr. - in Maine (Smith 1972)
1881-89			Late 1880's, est. total pop. in U.S. at 300,000 (McCabe and McCabe 1985)	1887, record severe winter in Maine (Smith 1972); 1885-89 extensive forest fires decimate large portions of Maine/N.B. forest (Smith 1972)
1890-1900	Almost extirp. in Maine (Palmer 1938); reintro. in N.H. - all died "for lack of suitable food" (Godin 1977); "very abundant along N. Shore Lake Superior; uncommon or extirp. in SE Ontario (DeVos and Peterson 1951)	In New England, only in extreme n. Vt., N.H., and Maine; introduced to Lab. (Dodds 1974)	Reintro. to N. Scotia (Banfield 1974); range extended to northcentral Ontario (Pimlott et al. 1969); nadir of decline in eastern U.S.; almost extirp. in S. Mich. (Baker 1983), Minn. (Taylor 1956); extirp. in Penn. (Schmidt 1978); first season since Vt. reintro. (Hornaday 1913)	Cutting of second-growth timber for pulp began in New England; passage of federal Lacey Act, 1900, ended legal market hunting; 1897, NY passed law ending jacklighting and hunting with hounds
1910-19	Extirp. from mainland Mich. and N. Scotia, declining in Ontario (Cringan 1969); extirp. from Maine (Hornaday 1913)	Extirp. in Wisc., invading previous and new range in N.B. (Hornaday 1913); abundant in northcentral Ontario (Pimlott et al. 1969)	Extirp. in Delaware, Ohio (Hornaday 1913); abundant in northcentral Ontario (Pimlott et al. 1969)	Wolves abundant in northcentral Ontario, poisoning program in Algonquin Park began (Pimlott et al. 1969); auto. extends access to game by hunters - outlawed for hunting by several states (Hornaday 1913); public pressure forces increased protection for wildlife from hunting and forests from fire (Flader 1983, Irland 1982)

Table 2 (continued).

Date	Caribou	Moose	White-tailed Deer	Other
1920-30	Extirp. on Isle Royale (Baker 1983) and Cape Breton I., N.S. (Dauphine 1975); extirp. in Minn. (Cringan 1969)		Reintro. in New England exceeding habitat (Schmidt 1978); almost extirp. N. Wisc. (Taylor 1956); abundant in southern portions of St. Lawrence and Northern Hardwoods Forests (Mattfeld 1985); increasing in Lake States due to fire suppression and wildlife law enforcement (Blouch 1985)	
1931-40		Increased in northcentral US (Hazard 1982)	Severe winters and overbrowsed range result in die-offs in northcentral US (Hazard 1982) and Ontario (Pimlott et al. 1969)	

Table 3. Forest types of New England-southeastern Canada and the Lake States-Ontario region* (ref. Fig 1)

Forest Type	Dominant Tree Species	Comments
Boreal	White spruce in better-drained sites; black spruce or tamarack in bog sites; balsam fir in some poorly-drained sites; paper birch and aspen on well-drained sites as fire successional.	Appears as intrusions into Lake States-Acadian Forest at higher elevations; primary habitat for woodland caribou, and for moose in disturbed areas (fires, blow-down, etc.). Virtually unused by white-tailed deer (even today).
Great Lakes-St. Lawrence	White pine on rocky uplands or as oil-field successional on sandy soils; red pine, eastern hemlock, yellow birch, American beech, sugar maple, northern red oak on moderate sites; white cedar or balsam fir in swamp areas; aspen and poplar are fire successional in northern portions; basswood and oak more prominent in southern portions.	Transition between Northern Hardwoods forest and Boreal forest. Original southern limit of caribou distribution in New England-Lake States; probably the most heavily impacted forest type during settlement; moose winter in balsam fir thickets; deer winter in white cedar thickets.
Acadian	Similar to Great Lakes-St. Lawrence forest, except red spruce dominant; white cedar rare except in New Brunswick.	Mostly confined to southeast Maritime Provinces and eastern Maine.
Northern Hardwoods	American beech, yellow birch, northern red oak, sugar and red maple on well-drained sites in northern portion; ash and cherry in southern portions.	Occurs as major association within the Great Lakes-Acadian Forest types (where climate and soils suitable), and as major forest type in transition between coniferous forest zone and Southern Hardwoods (oak-hickory-ash) forest of deciduous forest zone. This forest type advanced northward as result of settlement. Prior to colonization, deer present in low density but scattered throughout this forest type; moose present in areas within coniferous thickets. Caribou probably present only as occasional immigrants or where Northern Hardwood forest appears as intrusion into Great Lakes-Acadian forest.

* From Blouch (1985), Cringan (1969), Flader (1983), Huot (1985), and Rowe (1972).

by the Indian groups based on semipermanent agricultural settlements were almost entirely confined to the Northern Hardwoods forest. The Cree, northern Ojibwa, and Assiniboine groups of the northern portions of the Lake States and Ontario relied heavily on a diet of caribou and moose. Caribou remained important to these groups into the mid 1800's (Flader 1983); therefore, we assume that caribou were plentiful then.

Between 1600-1800, caribou habitat remained essentially unaffected by human use of the landscape. The amount of white-tailed deer habitat in the Northern Hardwoods Forest probably also remained unchanged not only because the primary white-tailed range was still in the Southern Hardwoods Forest, but also because losses attributable to urbanization during white colonization by Europeans were offset by abandonment of farmsteads, or by new clearing in the mature forest (McCabe and McCabe 1985).

In contrast to the somewhat neutral effects of white settlement on wildlife habitat, the effects on wildlife populations were drastic. The effects on white-tailed deer were especially severe, probably because most of the settlement by 1800 was in original white-tailed deer range (McCabe and McCabe 1985). However, moose populations were also affected (Dodds 1974). Both deer and moose were intensively hunted for subsistence (hides and meat) during the early settlement days. Far more important, however, was the rise of market hunting to provide hides for the European tanneries. This trade increased substantially in the American colonies during the last half of the 18th century, but was abruptly halted not only by the Revolutionary War and War of 1812, but also by the scarcity of deer in accessible areas (McCabe and McCabe 1985). As a result, by 1800 the white-tailed deer population had been reduced from the pre-Columbian estimate of 23-34 million animals to 12-14 million (McCabe and McCabe 1985). Moose were also eliminated from their original southern range in Massachusetts, southern Vermont, New Hampshire, and New York (i.e., throughout the northern hardwoods and transition forest region of New England) (Godin 1977). Moose were much reduced in southeastern Canada near the early Maritime Provinces settlements and the few settlements of the St. Lawrence Valley (Banfield 1974, Dodd 1974). Very little information is available about caribou during this period, except that they had disappeared from New York by 1800 (Cringan 1969).

1800-1865. This period was characterized by a rapid expansion of settlement westward and northward in the US, and westward (up the St. Lawrence Valley primarily) in Canada. Although the direct impacts of settlement on eastern woodland caribou populations were likely minor during the early part of the period, a course was set in motion that would affect caribou later in the century. This included a land management policy that emphasized clearing of mature forest to expand agriculture and settlement, elimination of large predators (especially wolves and cougar) which would compete with settlers for game or which would endanger livestock, waves of immigrants from Europe seeking better economic or political conditions, the re-opening of trade relations with European markets following the American Revolution and War of 1812, the expansion of transportation systems (especially railroads, and the Erie Canal), the California Gold Rush, the passage of the Homestead Act in 1862, and the abandonment of marginal farms established in the colonial times (Flader 1983, Irland 1982, McCabe and McCabe 1985, Taylor 1956). These events resulted in the virtual elimination of predators in New England

by 1820, except for northern Maine and extreme northern New York (Goodwin 1935, Mattfeld 1985, McCabe and McCabe 1985); the abandonment of much farmland around the colonial population centers; establishment of new agricultural areas in the Ohio, upper Mississippi, upper St. Lawrence, and Lake Ontario valleys (Flader 1983, McCabe and McCabe 1985); and expansion of lumbering inland in Maine and New Brunswick (Irland 1982, Smith 1972) and, a few decades later, into the Lake States Forest of northern Minnesota, Michigan, and Wisconsin (Blouch 1985, Flader 1982).

Although we found no direct references to effects on woodland caribou during this period of expansion, many of the activities associated with changes in the landscape occurred on historic caribou range. Lumbering was one of these activities. Although the expansion of lumbering was mostly westward, there was also an increase in lumbering in Maine and northern Vermont and New Hampshire. During the 1840's and 1850's northern New England became the top lumber-producing region in the country. In terms of lumber production, by the time of the Civil War this region was eclipsed by the northern Lake States (Smith 1972).

Because both the Lake States and New England were also the primary eastern woodland caribou range in the US at the time, it is important to understand the effects of logging on mature coniferous forest there. Logging technology in Maine remained basically the same until the 20th century and in the Lake States until the 1880's, although the cutting areas and products sought after changed (Flader 1982, Smith 1972). Areas were cut that were within several days travel of the major rivers. Logging spread inland from coastal or Great Lakes ports near the mouths of the major rivers suitable for log drives. Logs were cut and transported to these rivers during winter and subsequently moved downstream on massive river log drives at spring breakup. In spite of these seemingly primitive methods, an annual average of 30-200 million board feet of white pine and spruce were shipped through Bangor, Maine between 1830-1865 (Smith 1972, p. 12). The impact of early-day logging on forest soils and undergrowth was minimal, and conifer species re-grew in many old cuts and were recut within decades.

In contrast to logging, however, the effects of fire were severe. In northern Maine large areas were not cleared for potential farmsteads because most of the land was in large timber company holdings. Thus, deliberate burning of large areas did not occur as it had in southern Maine and the remainder of New England and in the Lake States where logging was viewed merely as a method of gaining revenue from forests during their development into farmland. However, accidental fires did burn large areas of northern Maine. In one fire alone 20,800 km^2 (800 mi^2) of mature coniferous forest were burned (Smith 1972, p. 337). As a result of the combination of logging and subsequent uncontrolled fires, large areas of the region were essentially denuded of any forest cover for long periods of time, and became virtually unuseable by caribou, white-tailed deer, or moose. In areas of the Lake States-St. Lawrence Forest which were cleared but not severely burned, white-tailed deer populations fluctuated in response to the combined effects of increased deer habitat (especially abandoned farmland), and periodically severe winters (Mattfeld 1985, Huot et al. 1985). However, the overall trend was toward conditions more favorable for deer than for moose and caribou. The factors limiting deer populations then, as it is now, was the combination of snow depth and winter temperature and the availability of

suitable winter habitat ("yards")--primarily thickets of white cedar mixed with other conifers (Huot et al. 1985 Hazard 1982). In areas where balsam fir, a major winter food of moose, was abundant and where infection of moose with meningeal worm (Parelaphostrongylus tenuis) was absent, moose were able to survive better than white-tailed deer (Baker 1983, Taylor 1956).

In summary, by the end of the Civil War, the status of deer, moose, and caribou in the northern Lake States-Ontario and New England-southeast Canada was:

(1) Caribou: essentially extirpated in the southern margins of their range (i.e., Wisconsin, southern portions of Michigan's Upper Peninsula, Vermont, New Hampshire), but apparently still fairly abundant in the northern portions of Minnesota, Michigan, and Maine (Baker 1983, Cringan 1969, deVos and Peterson 1951), and in Ontario (Flader 1983);

(2) Moose: extirpated in most of New England, with the exception of northern Maine, and rare in the transition between Southern Hardwood Forest and Northern Hardwood Forest in Michigan (Baker 1983, Godin 1977);

(3) White-tailed deer: almost eliminated from settled portions of New England and the Lake States, but expanding into new areas being settled (primarily southern Lake States and further west) and into areas of abandoned farmland (Mattfeld 1985, McCabe and McCabe 1985). Populations numbered 12-13 million--slightly higher than in 1800 (McCabe and McCabe 1985).

1866-1900. Although the pace of human expansion was rapid during the first half of the 19th century, the pace was even more dramatic after the Civil War in the US, and following the establishment of Canada as a sovereign nation in 1867. The Homestead Act in 1862 lured a large number of settlers from marginal farms in the eastern US to new areas of the American West. Similarly, in Canada during the middle part of the 19th century and especially after the North won the Civil War, Britain encouraged westward expansion to offset the American expansion. However, Canada developed a slightly different land use policy than that in the US. Whereas the US policy was to clear the forest for the immediate revenue and to provide agricultural land regardless of its suitability for farming, the Canadian policy was to grant timber rights on its land, but to retain the land in public control until such time that it could be reliably shown that the land was suitable for agriculture. As a result, in the last part of the 19th century, Canada developed its land (especially Ontario) more slowly than did the US and adopted a sustained yield forest management policy earlier than the US (Flader 1983). More of Ontario remained in forest longer than did similar areas of the Lake States. Therefore, habitat conditions remained more favorable for caribou and less favorable for white-tailed deer longer in Ontario than in the Lake States.

Although the basic methods used by the lumbering industry remained similar between the late 1800's and earlier in the century, regional differences developed in the type of transportation used to move logs from the woods to market. Although river log drives remained the basic method for shipping logs from the woods in both areas (Flader 1983, Smith 1972), small logging

railroads were used more into the northern Lake States than in Maine. In the Lake States railroads not only brought logs and charcoal for Michigan and Minnesota smelters out of the woods, but also provided access to settlers in new areas. In Maine local railroads ran from logging camps to the nearest major river and did not provide a ready means of access by the public to new areas. The intercontinental railroads, however, did significantly affect Maine indirectly by providing ready access between eastern urban markets and the Lake States and the Pacific Coast old-growth fir and pine. This competition from western areas resulted in a depression in the Maine lumbering market in the 1870's and further contributed to the abandonment of marginal farms. These events lead the way toward the control of vast areas of northern Maine by large companies which could acquire public land and abandoned farms cheaply. As a result, by the 1890's much of northern Maine had become industrial forest, and was managed for wood products on a sustained-yield basis (Flader 1983, Smith 1972). This was also the area that remained as the major caribou range in the eastern US in the late 1800's (Godin 1977).

Although market hunting had been common before the Civil War and had figured in the decline in a number of species in the east (Dodds 1974, Godin 1977, Hornaday 1913, McCabe and McCabe 1985, Schmidt 1978, Trefethen 1961) and upper midwest (Baker 1983, Hazard 1982), the heyday of the market hunters was between 1870-1900 (McCabe and McCabe 1985, Trefethen 1961). Most hunting (for the market as well as personal use) was of white-tailed deer (McCabe and McCabe 1985), and to some degree of moose (Dodds 1974). Market hunting was concentrated on white-tailed deer because deer were relatively accessible in the newly settled areas, and especially accessible to major railroads. In the late 1860's railroads developed refrigerated railroad cars to ship meat (mostly venison) from these newly-settled areas to large midwestern and eastern markets where venison was considered an important meat source (in 1888, 100,000 deer carcasses were shipped from Michigan alone [Blouch 1985]). There does not appear to be much evidence to support the notion that market hunting of caribou was a significant cause of the decline in northern Maine. The caribou range in northern Maine was still relatively inaccessible.

Although market hunting has been commonly blamed for the declines and local extirpations of several big game species, in reality most of the animals killed were for personal consumption (Baker 1983, McCabe and McCabe 1985, Schmidt 1978). As Schmidt (1978, p. 268) aptly summarized:

> Although market hunting accounted for the kill of an incredible number of big game animals, and its effects on many big game populations undoubtedly were harmful, it is generally agreed that market hunting was not the greatest cause for the decline of many big game populations. Of greater influence was the kill of big game for direct consumption by increasing numbers of miners, farmers, loggers and others who settled the continent.

As was the case with market hunting, most of the heavy harvest occurred along the leading edge of settlement, where alternative resources (e.g., seafood, beef) were not as available.

The effects of overharvest were especially pronounced on white-tailed deer, which declined severely in areas such as Michigan's Lower Peninsula, and southern Minnesota and New England, in spite of habitat changes that should have been (and historically had been) favorable to deer (Baker 1983, Hazard 1982, Blouch 1985). Moose likewise had been eliminated from central Minnesota and Michigan's Lower Peninsula, although this decline occurred several decades earlier than that of white-tailed deer (Baker 1983, Hazard 1982), and likely also involved habitat changes, such as increased clearing and burning, that did not necessarily favor moose over deer (Baker 1983, Hazard 1982). Caribou were considered fairly abundant but declining in most of Minnesota in 1865 (deVos and Peterson 1951) and in northern Michigan along Lake Superior in the 1850's (Baker 1983); abundant on Michigan's Isle Royale until extirpation there in 1925 (Baker 1983); and were considered very abundant along the north shore of Lake Superior in Ontario in 1897 (de Vos and Peterson 1951) and the south shore of Lake Superior in Minnesota until the 1920's (Cole 1982).

In northern New England, moose, which had been eliminated from southern portions prior to the Civil War, declined rapidly so that by 1900 they were present only in extreme northern Maine (Dodds 1974, Godin 1977). Caribou populations in Maine declined rapidly between 1885-1900 as the following reports of caribou from the Maine Commissioners of Inland Fisheries and Game imply (Godin 1977):

> 1886: "The reports to use are of plenty and in all sections ... of all our big game animals, the caribou is most capable of taking care of itself."
>
> 1889-90: "We think moose and caribou have made an increase."
>
> 1894: 50 animals were reported [in 1895] as taken in 1894
>
> 1895: 105 animals reported as taken
>
> 1896: "The caribou is fast disappearing and will very soon be practically extinct."
>
> [The 1896 harvest was reported to be 239 caribou; however, other records indicate that in 1895-96 one railroad line alone shipped approximately 130 caribou each year, but that after that time the number of caribou declined due to "eastward movement of animals once more" and to the year-round open season]
>
> 1900: The season was closed until 1905.
>
> 1905: "There is no indication that the caribou are returning or ever will return."
>
> 1906: "There are no indications of any caribou in the State."

New Brunswick, which would likely be the area receiving the "eastward movement" of caribou after 1896 (if such movement occurred) was itself extensively cleared in the latter half of the 19th century, and its caribou declined prior to 1915 (Cringan 1969).

It is tempting to speculate that two events in the late 1800's could have affected the survival of caribou populations in New England. One event was the record-severe winter in 1887, and the other was the development of the pulpwood industry.

The severe winter of 1887 could have indirectly affected caribou by depressing white-tailed deer populations in New England; therefore, reducing the transmittal of meningeal disease from deer to caribou. As an indication of the severity of that winter it is useful to note that there was seven feet of snow on the ground in March, causing a shutdown of logging, and widespread starvation of logging livestock (Smith 1972). Although there is no documentation of white-tailed deer declines in the area, it can be inferred that widespread mortality of deer occurred. Deer in the same area have experienced widespread starvation on numerous occasions in more recent times under much less severe conditions (Mattfeld 1985). Caribou would have had a slight advantage in survival over white-tailed deer due to the former's greater mobility and ability to feed on arboreal lichens that would not have been covered by deep snow. The decline in white-tailed deer would have meant less opportunity for transmittal of meningeal disease from deer to caribou. Meningeal disease is the infection of the brain of the host by a roundworm (Parelaphostrongylus tenuis). Deer are carriers of this worm but do not appear to be much affected, while other hosts (e.g., moose, caribou) are often fatally inflicted. Meningeal disease, as such, was not confirmed to be present in Maine deer until the 1930's (Dodds 1974); however, Hornaday (1913, p. 83) reported that caribou bands were dying of a "mysterious disease" in Quebec, Maine, and New Brunswick. By the 1960's, 85% of Maine's deer herd was considered infected by meningeal worm (Godin 1977). Meningeal disease was considered responsible for the failure of caribou reintroductions in Maine in 1963 (ibid.) and in other areas of the Lake States and New England (Dauphine 1975).

The second factor that could have affected caribou in Maine in the late 1800's was the development of the pulpwood industry (Smith 1972). Following the depression in the Maine lumbering industry in the 1870's, the large land and lumber companies bought many farms abandoned by part-time loggers, and consolidated their holdings in large industrial forests that became major pulpwood producers by 1900 (Irland 1982, Smith 1972). Because pulp could be made from a variety of tree sizes and species, these companies began clear-cutting large areas rather than continuing the custom of high-grading the best trees. As a result, large even-aged timber stands replaced the mosaic pattern of cut-over or natural forest stands. Because of the relatively short rotation period that characterizes forest management for pulpwood, arboreal lichen abundance is severely depressed (Cringan 1969). Utilization of arboreal lichens is one characteristic that gives caribou a competitive advantage over other ungulates where they share the same range.

4.2 PACIFIC NORTHWEST AND WESTERN CANADA

Small herds of mountain caribou are scattered throughout the northern Rocky Mountains from the Selkirk Mountains in extreme northern Idaho and Washington, to northern British Columbia and Yukon Territories (Bergerud 1980b, Stevenson and Hatler 1985). Most of these herds have declined since the turn of the century (Edwards 1954). We have selected as examples four herds that are influenced by different controlling mechanisms. The Selkirk

Herd inhabits the Selkirk Mountains of extreme northern Washington-Idaho and southern British Columbia. The Wells Gray Herd inhabits Wells Gray Park in the Cariboo Mountains of British Columbia. The Raven Lake Herd inhabits central British Columbia around the Yellowhead Highway-Prince George area. The Spatsizi Herd is located in the Spatsizi Provincial Park in northern British Columbia.

Selkirk Herd. The Selkirk herd numbered "hundreds" of animals in the early 20th century, and roamed from the North Fork of the Flathead River in Montana, as far west as the Pend Oreille River in Washington, and as far south as the St. Joe River of Idaho (Carlton 1982). Currently the herd numbers only 20-30 animals, and is confined to a very small area of the Selkirk Mountains along the US-Canada border near Kootenay Pass (Van Zwoll 1983). Seasonal movements are primarily minor altitudinal migrations from the preferred winter range in the Engelmann spruce-subalpine fir forest to the higher elevation summer range in alpine tundra, or to the ecotone between the two. The upper hemlock-cedar forest is also occasionally important winter range during years of exceedingly deep snowfall when caribou must leave the spruce-fir forest and move to lower-elevation areas (Freddy and Erickson 1975).

The decline of the Selkirk Herd in the early 20th century has been attributed to overhunting, and to range deterioration due to logging and forest fires that destroy arboreal lichens (the main winter forage supply) (Carlton 1982, Freddy and Erickson 1975). Bergerud (1983) considers that forage is currently not limiting the growth of the Selkirk caribou herd; however, he does not specifically address reasons for the historic decline. Bergerud (1983) believes that the declines of British Columbia herds since the 1940's have been due to increased predation rather than to habitat destruction. Increased predation has been indirectly caused by habitat changes (e.g., logging, increased fire) that favored increases in mule deer (Odocoileus hemionus), white-tailed deer, and moose. Increases in these prey species in turn favored increases in predators (primarily wolves). Although mountain caribou are a less important prey species of wolves than are moose and deer, mountain caribou populations are more vulnerable to predation because they are composed of scattered, small herds. Even a small amount of caribou mortality due to wolf predation can have proportionately large effects on these small herds (Bergerud 1983).

The available literature sheds little light on the decline of the Selkirk Herd between the turn of the century and the 1960's. In 1963, the Trans-Canada Highway was constructed through the herd's range and across its migration corridors, especially through the Kootenay Pass area. The construction of this major highway resulted in a proliferation of logging roads further into Selkirk Herd range, and caused an additional source of mortality due to collision with vehicles (Freddy and Erickson 1975, Johnson and Miller 1979). In 1964, at least one group of 24 animals was observed; however, mortality due to collision with vehicles and poaching accounted for at least 10 deaths that same year (Freddy and Erickson 1975). In 1972, the minimum population was 35 animals. Calf production from 1972 to 1979 averaged 5 calves/year; however, at least 3 calves during the period were killed by automobiles (Johnson and Miller 1979). By the early 1800's, the herd was estimated to number in the 20-30 animals (van Zwoll 1983). Mortality due to poaching and collisions with vehicles, disruption of

movements due to physical (e.g., snowberms) and "psychological" barriers (e.g., cleared rights-of-way), and habitat destruction caused by continued large-scale logging in important mountain caribou habitat (such as the spruce-fir forest) are all considered serious threats to this remnant herd (Carlton 1982, Freddy and Erickson 1975, van Zwoll 1983). Although predation may have been a factor in the herd's decline historically (e.g., Bergerud 1983), it is not keeping the herd at its current low level.

Wells Gray Herd. The Wells Gray Herd inhabits the foothills of the Clearwater River drainage of the Cariboo Mountains of Wells Gray Park in east-central British Columbia (Edwards 1954). Unlike caribou of the Selkirk Herd, those of the Wells Gray Herd undertake a pronounced altitudinal migration from alpine meadows and adjacent subalpine forests in the summer, to the valley bottom forests of mature cedar-hemlock (balsam fir) an elevational change of over 1,220 m (4,000 ft) (ibid.). Neither Bergerud (1983) nor Edwards (1954) provide detailed population numbers during the period of the decline; however, Bergerud (1983) notes that although a large fire occurred in 1926, the herd did not decline until 1935 and furthermore that the herd increased again in the 1950's and 1960's during a period of intensive wolf control in British Columbia. Edwards (1954) attributed the original decline to the 1926 fire, which was so intense that it essentially denuded 518 km^2 (200 mi^2) of forested land. Most of the burned area was at lower elevations, and comprised 60-70% of caribou winter range. Fires subsequently reburned parts of the original burn and an additional 466 km^2 (180 mi^2), so that by the 1950's much of the original caribou range of the Clearwater River drainage was in seral successional stages rather than mature forest. Both Edwards and Bergerud noted the dramatic increase in moose and mule deer after the fires. Edwards cites the increase in these species as evidence of a dramatic change in the successional stage of vegetation, from mature forest to seral stage. These vegetation changes would have resulted in a decrease in forage and cover available for caribou. On the other hand, Bergerud cited evidence that increased predation, rather than a decrease in forage abundance, was responsible for the decline: (1) caribou numbers remained unchanged for at least 9 years following the fire, whereas moose and deer increased rapidly; (2) caribou numbers in the 1950's and 1960's increased during wolf control efforts between the late 1940's and 1950's, and in spite of the fact that the forest destroyed during the fires of 1926 and later had not produced arboreal lichens; and (3) the caribou herd has continued to increase (as of 1977) while wolf populations have remained low. However, survey data of Ritcey (cited in Stevenson and Hatler 1985) indicate that the herd declined in the mid 1970's and continued to decline, although at a lesser rate, to 1982. The conclusion of Stevenson and Hatler (1985) is that the evidence is not conclusive that the herd increased or declined in the 1970's.

Raven Lake Herd. Most of the available information regarding this small herd of 250-300 caribou (as of 1977) is from Bloomfield (1979). This herd inhabits the area between the northwest Cariboo Mountains and the Fraser Plateau, east-southeast of Prince George, BC, along the Yellowhead Highway. As is the case with the Wells Gray Herd, Raven Lake Herd animals undergo a pronounced seasonal altitudinal migration between alpine meadows and low elevation cedar-hemlock forest.

This herd likely numbered about 1,500 animals historically. Evidence suggests that the decline in numbers occurred primarily in the 1960's. Prior to and during this period, construction of the Yellowhead Highway and numerous associated logging roads dramatically increased access to caribou range for hunters. Continuation of liberal hunting regulations and an increase in commercial guiding (encouraged by the provincial government) resulted in overharvest by the late 1960's. At the same time that the increased access was occurring (and partly as a result), logging operations changed from small, seasonal operations to large scale, highly mechanized and centralized industrial processes with all-weather service roads. Large scale clear-cutting became common practice. Much of this logging was originally concentrated in the accessible lowland forest, but has since expanded to the spruce-fir forest zone. As a result of the effects of initial and continuing overharvest coupled with increasing habitat destruction and interruption of migration corridors, many small caribou bands have been extirpated and total numbers have declined. Predators have not been numerous; the caribou decline has occurred during a period of predator control. Fires are also not considered to be a significant cause of the decline.

Although Bloomfield (1979) provided considerable data about habitat utilization by these caribou, and about hunting and development activities in the region, he was unable to directly attribute the decline in the Raven Lake Herd to human development activity. Bergerud et al. (1984) have challenged Bloomfield's conclusion that habitat destruction and/or disruption of movements have contributed to the decline. Bergerud et al. (1984) conclude that overhunting alone has caused the decline. Although they agree with Bloomfield (1979) that overhunting was facilitated by the increased access provided by the Yellowhead Highway and associated logging road network, Bergerud et al. (1984) believe that a recovery from the initial decline has been prevented because of predation by a moderate number of wolves (ibid, figure 7). Bloomfield (1979) states that wolf numbers have remained low in the area. Until this discrepancy can be resolved it is unlikely that firm conclusions can be made about the demise of the Raven Lake Herd except that it was initiated by overharvest that in turn was facilitated by road construction.

Spatsizi Herd. Bergerud (1983) has summarized much of the information regarding the Spatsizi Herd which inhabits the Spatsizi Provincial Park of northern British Columbia, along the headwaters of the Stikine River. Although Bergerud (1983) did not provide estimates of the herd's size in the 1950's and 1960's, he did compare the percentage of calves in the herd. Wolf control in the area began in the mid 1950's and continued to 1963. Calves comprised an average of 11% of the herd in the early 1950's, and 28% of the herd in the early 1960's (ibid.). By 1973, calves comprised only 5% of the herd (Bergerud et al. 1984). Between 1977 and 1982 the herd dropped from 2,500 to 1,300 caribou (ibid.). Because no development activity has occurred in the park and apparently there is little or no harvest, the decline in numbers of this caribou herd is likely due to predation, primarily by wolves and brown bears.

4.3 KENAI PENINSULA, ALASKA

Caribou were common, but not abundant, on the Kenai Peninsula in the late 1800's. Skoog (1968) considered the Kenai Peninsula to be marginal caribou habitat, and an "overflow area" that received influxes from the Nelchina Herd when it was large and expanding. By 1912 caribou were extirpated on the peninsula (ibid.). With the advent of mining in the 1890's, numerous man-caused fires burned large areas of the peninsula and changed the vegetation from mature boreal forest to seral shrub and decidous overstory. Moose populations reached high numbers by 1913 (Davis and Franzmann 1979), suggesting that there were major habitat changes several years prior to that time.

The extirpation of caribou on the Kenai Peninsula has long been considered an example of habitat destruction, especially fire, being responsible for the demise of a caribou herd (e.g., Bangs et al. 1982, Buckley 1958, Dufresne 1946, Leopold and Darling 1953). However, that theory has been recently challenged (Davis and Franzmann 1979). Although the decline of the Kenai Peninsula caribou herd occurred at the same time as the increase in fires, Davis and Franzmann (1979) conclude that overhunting, and not destruction of habitat by fire, was responsible for the decline. There are ample historical records indicating that market and personal use hunting were making serious inroads into the population (ibid.).

Because the period of extensive fires occurred at the same time as the period of overharvest the timing of the caribou decline does not provide evidence supporting one theory for the decline over another. There are no concrete data from that period to uniquivocally reject one theory for the decline over another. However, data gathered from the two groups of caribou that were reintroduced on the Kenai Peninsula in 1965-66 indicate that there was considerable suitable habitat in the Kenai Mountains that was not burned historically and that has been used intensively by one of the reintroduced groups (ibid.). In the Kenai Lowlands, the area used by the other reintroduced group, caribou have used sedge meadows and adjacent black spruce muskeg instead of the unburned mature spruce forest that is also available (ibid.). It is unlikely that reintroduced caribou differ substantially in their use of habitat from use of habitat by caribou in the late 1800's; there is ample habitat remaining to have supported continued caribou existence on the Kenai Peninsula. The most likely explanation is that overharvest, and not fire, was responsible for the decline of the original Kenai Peninsula caribou herd.

4.4 SOVIET UNION

We have obtained most of the information regarding caribou and domesticated reindeer information in the Soviet Union from Wild Reindeer of the Soviet Union, the proceedings of a symposium on caribou held in Dudinka, in the Taimyr, in 1974 (Syroechovskii 1984b). The purpose of this symposium was to discuss the potential exploitation of caribou, and conflicts between caribou and domestic reindeer husbandry in the Soviet Union. There was a surprising diversity of opinion by the attendees. Opinions ranged from those who favored outright protection from hunting and protection of habitat in huge faunal preserves, to those who encouraged government-supported extermination of local caribou herds in order to reduce competition with domestic reindeer

herds. Although Soviet Rangifer biologists were scheduled to attend the 1983 International Reindeer/Caribou Symposium in Finland, they were unable to do so (D. Klein, pers. comm.). Thus, this reference continues to be the best single source of information available in English regarding Rangifer in the USSR. A brief update of caribou population status in the Soviet Union was reported by Klein and Kuzyakin (1982).

Several precautionary comments are necessary regarding interpretation of the information discussed below. First, there is not a large body of available background literature regarding Soviet reindeer biology with which we could compare the conclusions reached in Wild Reindeer of the Soviet Union. Many of the references that were cited in the symposium are in reports in Russian that have not been reprinted in English. Nevertheless, the range of opinion expressed by the symposium participants, and the sometimes pointed discussion regarding some of the conclusions reached in the previous supporting literature, suggest that most of the information presented in the symposium proceedings was generally regarded as accurate in 1974. For example, Syroechovskii (1984a) pointed out that [as of 1974] caribou populations had not become sufficiently numerous that "rational exploitation" should overshadow the problem of restoration of extirpated or decreased populations; therefore, he advocated strong antipoaching measures, and most importantly, that the state should protect caribou habitat as much as it protects other natural resources. On the other hand, Geller and Vostryakov (1984) recommended shooting caribou in areas of domestic reindeer husbandry, and developing methods for physical isolation (e.g., barrier fences) between caribou and domestic reindeer.

Second, it is obvious that Soviet biologists, much like their North American and Fennoscandian counterparts, were influenced by the prevailing philosophy of the period regarding the necessity of terrestrial and arboreal lichens to Rangifer survival. If there is one major criticism of this symposium, it is that the theory regarding the necessity of lichens appears to have been accepted uncritically by many biologists whose presentations are reported below. Nevertheless, several Soviet biologists (e.g., Shtil'mark, Grigor'ev and Leont'ev, and Syroechovskii) provide examples in which lichens are neither required nor utilized by caribou. This is another example of the wide range of opinion expressed at this symposium. Third, there is the obvious possibility that the information discussed below is outdated. Much of the original research that contributed to conclusions presented at the Taimyr symposium is now 10-15 years old. New data and reinterpretations of old data could well have occurred.

The approach in the following discussion is to provide a general summary of the historical changes in Rangifer populations, followed by a selection of examples of major changes in distribution and abundance including extirpations. Unless otherwise stated, much of the historical information is from Syroechkovskii (1984b).

Because in the Soviet Union and Fennoscandia the history and fate of caribou populations have been tied to the development of the domesticated reindeer industry, we will discuss the history of the reindeer industry as well as that of caribou. Historically, there was an estimated 5 million caribou in the Soviet Union; this figure is considered a reasonable estimate for the recent pre-historic population as well. Domestication of reindeer began

prior to the 10th century A.D. by primitive tribes in the Altai-Sayan highlands; these tribes migrated to the tundra of northwest Siberia, where they founded a new center of reindeer husbandry. From this center, reindeer husbandry spread throughout the Soviet Union and Northern Europe. Up to the 17th and 18th century, husbandry remained fairly primitive--small herds of domesticated reindeer were kept for transport and personal consumption by small, nomadic hunter groups which also relied on caribou for sustenance. By the 18th century, the total number of domesticated reindeer in the Soviet Union and Europe was only one million animals. In much of the Soviet Union and Europe in the late 18th century the system of small, nomadic herders changed in favor of larger, more organized husbandry. However, in isolated areas of Siberia the nomadic lifestyle remained until after World War II. As reindeer husbandry expanded in the late 18th century, some observers already claimed that caribou in northwestern Siberia were declining because of the development of the reindeer industry, and because of large forest fires associated with increasing settlement (Skrobov 1984, p. 90).

By the late 19th century, caribou were said to number "in the millions;" however, they were declining rapidly due to shooting by "foreigners" during industrial development, and due to competition with the developing largescale reindeer husbandry. During this period it was the policy to exterminate caribou in areas where domestic reindeer husbandry was developing. Although competition for forage between caribou and domestic reindeer was also blamed for the decline of caribou, opinion is divided on whether competition was a factor or not. Several authors (e.g., Shtilmark 1984, Syroechovskii 1984a, Geller and Vostryakov 1984) point out that caribou usually are found in the same areas as domestic reindeer only during brief periods during migration, and that the food habits of each are sufficiently diverse that direct competition is unusual. Other authors (e.g., Andreev 1984, p. 62) state that such forage competition is common and reduces pasturage available for domestic reindeer. Other potential interactions, such as disease transmission between wild and domestic reindeer are not believed to be important in the decline of caribou. The major effect on caribou of increased domestic reindeer husbandry appeared to be the direct extermination of the former in order to supposedly decrease the impact of caribou on domestic reindeer.

By the early 20th century, caribou had vanished from much of the European USSR and in the Ural Mountains (Shtilmark 1984, p. 95). By the 1920's and 1930's, caribou had declined drastically in parts of the Soviet Union. Skrobov (1984, p. 91) discusses several examples. In Soviet Karelia the distribution of caribou receded rapidly northward in the face of increasing agricultural development in the south, where caribou became almost extirpated. In the Arkhangels'k district, montane caribou were extirpated in areas of agricultural development, areas of expanding reindeer husbandry, areas where forest fires had increased during settlement, and areas where predator populations had been high (ibid). The direct effects of extermination of caribou by reindeer herders, and habitat destruction due to industrial and agricultural expansion are considered to be responsible for the decline of caribou in Yakutia and the Kola Peninsula in the first half of the 20th century (ibid).

Caribou distribution in the Soviet Union since the 1930's has become discontinuous, consisting of small isolated herds of forest or montane

reindeer located in relatively inaccessible areas of the more developed portions of the country, or of several large populations of tundra reindeer (such as the Taimyr population) that comprise the major portion of the USSR caribou population (Klein and Kuzyakin 1982). Between 1930 and 1950, the Soviet caribou population continued to decline, to an estimated 300,000-350,000 animals. [Ed. note: Although no specific reasons were given for this decline, one can assume that the scarcity of food in the Soviet Union during World War II may have resulted in increased hunting pressure for the sustenance of residents in the areas in which caribou ranged. In many areas of the country, domestic reindeer herding was disrupted or eliminated during the war; in the absence of heavy hunting pressure, this should have resulted in a caribou increase rather than decline.]

In the 1950's, caribou began to increase. Although the exact reasons for the increase are unknown, several reasons have been suspected. One reason was the abandonment of numerous, scattered and isolated small settlements and their subsequent resettlement into large industrial centers. This consolidation of settlements created large areas remote from the combined pressures of hunting and habitat destruction. Caribou increased in these remote areas (Syroechovskii 1984a, p. 16). Another reason was the general trend toward protection of Arctic fauna (Skrobov 1984, p. 94), and specifically, initiation of controls on land use (e.g., agriculture, logging) and hunting in areas reserved as caribou habitat. The increase in caribou populations continued through the 1960's in areas where predator control was undertaken and illegal hunting was curtailed restricted, e.g., the Taimyr Peninsula (Syroechovskii 1984a, p. 24).

Population estimates (table 4) and recent distribution (figure 2) for the major Soviet caribou herds are reported as of 1972 (Syroechovskii 1984a, table 1) and 1980 (Klein and Kuzyakin 1982, figure 1). The modern distribution of caribou in the Soviet Union corresponds with areas remote from human activities, and where reindeer husbandry has been absent. Numerous examples of human activities resulting in regional changes of caribou distribution and abundance are available. A sampling of these is presented below:

(1) Soviet Karelia. In the late 1800's, wild forest reindeer (ref. table 1) covered the majority of what is now the Karelian ASSR (figure 2) and were common as far south as Leningrad (Pullianen 1980b). By the early 1900's, wild forest reindeer distribution was restricted to small, scattered populations in northern Karelia (Danilov and Markovsky 1983). This change in distribution, accompanied by a sharp decline in numbers, was due to the combined effects of direct elimination of individuals due to indiscriminate shooting (Danilov and Markovsky 1983) accompanied by habitat loss associated with expanding agriculture (Skrobov 1984) in the southern part of its range; and to direct extermination of groups near domestic reindeer range in the northern part of its range (Pullainen 1980b, Danilov and Markovsky 1983). The situation was further exacerbated by overhunting in the 1920's-1930's, at the end of which time wild forest reindeer were thought to be on the brink of extirpation in Karelia (Danilov and Markovsky 1983).

Table 4. Population estimates of caribou in selected regions of the USSR, 1972 and 1980.

REGION	1972[1)]	1980[2)]
Taimyr	350,000	460,000
Yakutia	160,000[3)]	240,000
Kola Peninsula	35,000[4)]	12,000
Irkutsk[5)]	13,000	70,000
Arkhangel'sk	10,000	9,000
Khabarovskii[5)]	10,000	3,000
Sakhalin Island[6)]	2,000	15,000
Karelia	2,000	7,000[7)]
Others	28,000	84,000
TOTAL	620,000	900,000

1) Unless otherwise noted, from Syroechovskii (1984b), Table 1
2) Unless otherwise noted, from Klein and Kuzyakin (1982, Figure 1)
3) Egorov and Popov (1984) estimate 195,000
4) Considered an overestimate by Klein and Kuzyakin (1982, Figure 1) - more likely estimate is 20,000
5) Verbal description from Syroechovskii (1984b) does not completely overlap mapped information of Klein and Kuzyakin (1982) - estimates may not be comparable
6) 1972 estimate from Zagorodski and Reimers (1984); 1980 estimate includes feral reindeer which no longer can be differentiated from caribou (Klein and Kuzyakin 1982)
7) Estimate in 1981, from Danilov and Markovsky (1983). Klein and Kuzyakin (1982, Figure 1) report 11,000 - this figure may include feral reindeer, however, because Pullainen (1980b) reports that consideral hybridization has occurred since World War II

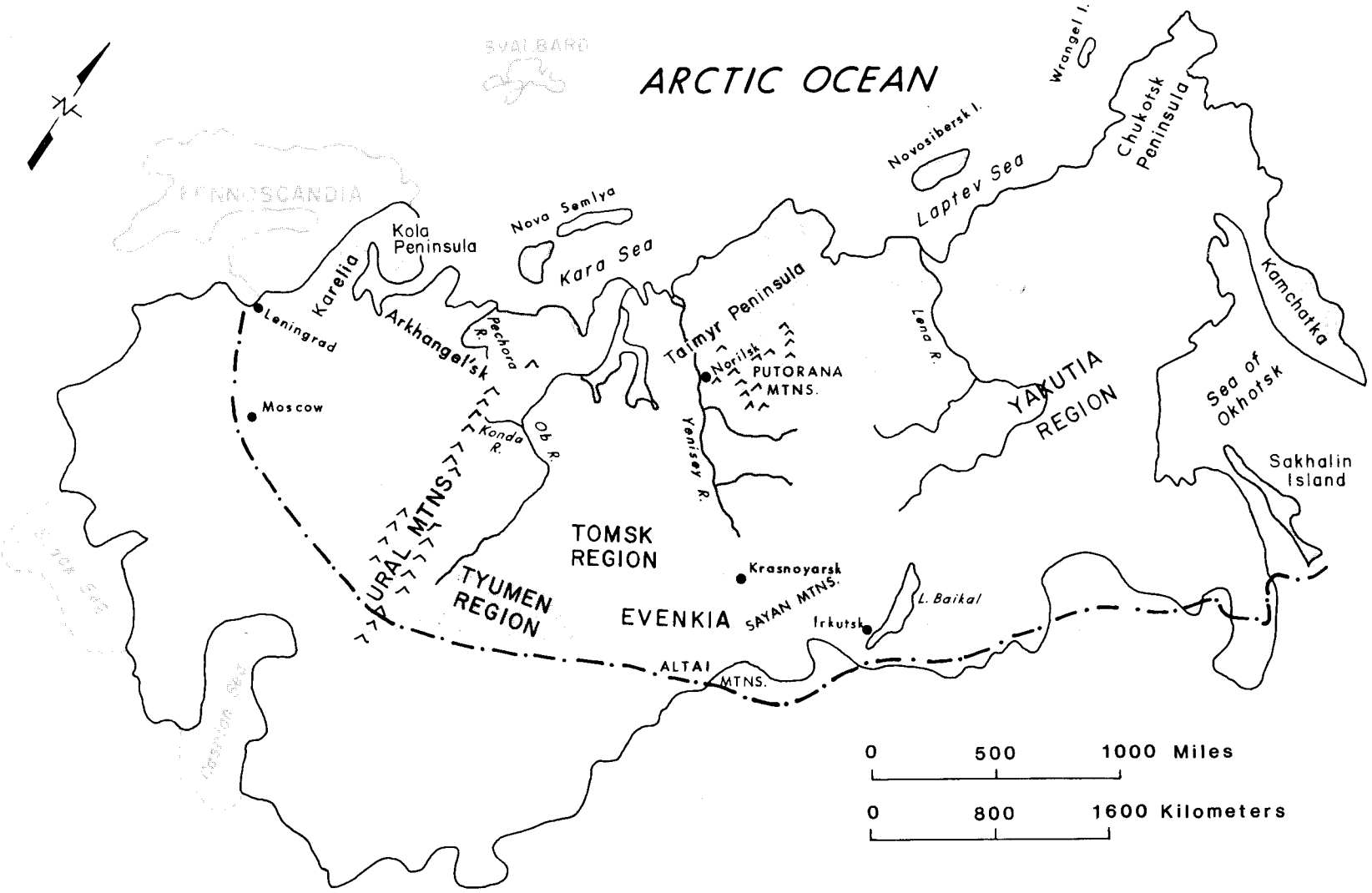


Figure 2. Wild reindeer distribution in the Soviet Union as of 1980.

—·— SOUTHERN LIMIT OF DISTRIBUTION CA. 1900 (Petrovskii 1984)

DISTRIBUTION AS OF 1980 (Klein & Kuzyakin 1982, Syroechovskii 1984)

During World War II, reindeer herding in several areas near the front (e.g., Karelia, Kola Peninsula) was disrupted to the point that it never recovered as a major industry, and many of the domestic reindeer herds turned feral (Pullainen 1980b, Semonov-Tyan-Shanskii 1984). Many of the domesticated reindeer in Karelia were derived from wild forest reindeer stock; therefore, the resultant hybrids are almost pure forest reindeer (Pullainen 1980b). Because of the restrictions on hunting and cessation of direct shooting of wild reindeer by reindeer herders, and possibly due to the infusion of domestic reindeer turned feral, the Karelian population as of 1981 was estimated (table 4) to be 7,000 animals by Danilov and Markovsky (1983), or 11,000 animals according to Klein and Kuzyakin (1982). As the caribou population in Karelia has increased, the distribution has expanded to nearly that of the late 1800's, although the areas of lowest abundance correspond to the most intensively settled portions of Karelia (Danilov and Markovsky 1983; figure 1 in Pullainen 1980b).

The population may be approaching the maximum for the available winter habitat, according to Danilov and Markovsky (1983) who argue that intensive logging in the forest-lichen areas has reduced the available winter range.

(2) Kola Peninsula. By the late 19th century, caribou were almost eliminated from the Kola Peninsula (figure 2) because of deliberate extermination by reindeer herders (Semenov-Tyan-Shanskii 1984, p. 163). In the 1920's, the population consisted of a few hundred animals in two main groups. A western group inhabited tundra areas west of Murmansk, and an eastern group inhabited forest tundra of the upper Pana and Varzuga rivers. Increased enforcement of the prohibition on hunting, the creation of the Lapland Reserve (established to protect caribou and their habitat), the change by the local human population from dependence on hunting and fishing to a cash economy (Zakharov 1984, p. 167), and the destruction of the domestic reindeer industry during World War II resulted in both the eastern and western Kola Peninsula caribou groups expanding considerably after the war. As of 1974, the Kola Peninsula supported the third largest population of caribou in the USSR. However, in spite of the dramatic increase in caribou numbers the distribution of caribou remained as two groups, separated by a strip of urbanized area along the Murmansk-Kandalaksha railroad which bisects the Kola Peninsula, and thus restricts range expansion by both groups. In 1974, concern was expressed for the condition of the range of both groups. The winter range in mountain tundra areas appeared to be overused and the physical condition of many animals appeared to be deteriorating (Semenov-Tyan-Shanskii 1984). Klein and Kuzyakin (1982) reported that of all the Soviet caribou herds for which they had data, only the Kola Peninsula herd appeared to have declined since the mid-1970's. The decline was due to mortality caused by "adverse winter snow conditions," and to excessive harvest (ibid.). There has been no mention of the extent to which the effects of the overused range, observed in 1974, played a role in the decline.

(3) Sakhalin Island. In the 18th century caribou were distributed throughout Sakhalin Island (figure 2), and numbered up to 10,000 animals [however, this estimate is considered high]. In the early 20th

century caribou were found in marshy landscapes of the southern part of the island and in upland areas, especially larch and spruce-fir forests, and river valleys. Caribou vanished from southern Sakhalin in the 1920's-1930's following massive habitat changes as a result of human activities such as construction of defense installations, logging, widespread bamboo planting, and commercial hunting (Zagorodoskii and Reimers 1984). In 1974, the population numbered 1,500-1,700 animals and was located mostly in more remote areas of the northern part of the island (figure 2). Even in these remote areas, the habitat available to caribou was decreasing due to competition for forage between caribou and domestic reindeer, and because deforestation had been destroying an estimated average of 1% of the habitat each year for the past 20 years (ibid). The decline of the Sakhalin Island herd is most likely due to overharvest because there are no predators of caribou on the island, and the estimated annual harvest of 300 animals (20% of the population) (ibid.) appears to have been excessive. By 1981 the Sakhalin Island herd had increased to 15,000 animals; however, this number is misleading because it includes both wild and domesticated (now feral) reindeer (Klein and Kuzyakin 1982). Klein and Kuzyakin (1982) reported that reindeer on Sakhalin Island numbered 15,000 animals in 1981; they attributed this increase to the mixing of wild and domestic reindeer so that they were no longer distinguishable.

(4) Konda River Basin. Historical records of caribou abundance are rather generalized for this area, which is located just east of the Ural Mountains (figure 2). Records from the 1960's suggest a population of 4,500-14,000 for the Tyumen Region, of which the Konda River basin forms only a part (Syroechovskii 1984a, table 1). The current estimate for numbers of caribou in the Konda River basin is 8,000-9,000 (Shtil'mark and Azarov 1984, p. 182). [Note that the actual number counted was only 221, p. 182] This increase has been attributed to the establishment of the Konda-Sos'va reserve between 1920-1951, during which time hunting was restricted and habitat was protected (Shtil'mark 1984). However, the Kondo-Sos'va reserve was eliminated in 1951, and massive development projects began at the same time that commercial hunting was dying out (Shtil'mark and Azarov 1984, p. 181) [This conclusion appears to be in conflict with Shtil'mark's earlier statement, p. 97, regarding restrictions on hunting associated with reserves]. Construction of the Ivdel-Ob railroad opened vast areas of the upper Konda River basin to industrial expansion. Between 1960-1970, logging eliminated over 500,000 ha (200 mi^2) of pine-lichen forest (the winter habitat preferred by caribou) along the railroad alone (Shtil'mark 1984, p. 96). Nine large lumber mills, petroleum development, resin-gathering operations, and man-caused forest fires seriously reduced caribou habitat, and especially winter habitat consisting of pine-lichen forests (Shtil'mark and Azarov 1984, p. 182). These habitat changes have resulted in caribou of the Konda River basin concentrating in remnant areas of good habitat, especially in the Arantur Lakes area (ibid.). These areas are destined to become sanctuaries; however, in Soviet sanctuaries hunting is restricted whereas habitat is not. In spite of the severe habitat changes that have occurred in the Konda River basin, this caribou herd has increased or remained stable, assuming the initial and current population estimates are accurate.

Taimyr Region. The largest population of wild tundra reindeer in the Soviet Union, and a smaller herd of wild forest reindeer, are located in the Taimyr region of central Siberia (figure 2). The distribution of the Taimyr population corresponds to areas where human activiites and settlement are, for the most part, minimal (Yakushkin et al. 1984). The wild tundra reindeer group, which numbered over 400,000 animals in 1978, consists of a large western group that ranges from the tundra of the Taimyr Peninsula-Yenisey River area in summer to taiga of the Krasnoyarsk-Evenkia region in winter (Klein and Kuzyakin 1982). A portion of this western group apparently also now includes several tens of thousands of caribou that were fairly restricted in movements in taiga areas in the 1970's, and are considered by Geller and Borzhanov (1984) to be wild forest reindeer. An eastern group of wild tundra reindeer, consisting of some 30,000 individuals in 1978, remains on tundra range year-round on the Taimyr Peninsula (figure 2). In the 1940's, the distribution of caribou in the Taimyr region was almost the reverse. The majority of the population was located in the eastern portion of the Taimyr region, and migrated to the eastern portion of the Putorana Mountains, or into Yakutia, while the western portion summered on the Taimyr Peninsula and wintered north of Norilsk (e.g., remained on tundra range the entire year). In the late 1940's or 1950's, this movement pattern changed, although the causes for the change were not given. Skrobov (1984) implies that the construction of the mining and smelting complex at Norilsk may have been responsible for some of the change. Prior to the construction of the complex, caribou wintered in the Norilsk area; now however they migrate through to taiga ranges farther south (*ibid*).

In the 1930's, the Taimyr caribou population numbered 400,000-450,000 animals (Yakushkin et al. 1984)--i.e., similar to that of the 1978 population estimate. In the 1940's, the herd declined rapidly, and although the reasons for this decline were unknown, it was attributed to the "phenomenon of self-regulation of population" (ibid). In the past few decades, the population has grown steadily from 110,000 animals in 1959; 252,000 in 1967; to 460,000 in 1978 (Klein and Kuzyakin 1982 and table 4). In the early 1980's the population declined somewhat, due to commercial hunting which, by virtue of its location along northern river crossings during fall migration, took an excessively high number of females (D.R. Klein, pers. comm., 1984). In 1985, the Taimyr herd numbered 800,000 animals; however, this estimate may include animals that had been absorbed from nearby herds also (Lazmakhanin pers. comm., 1985).

Causes for the increase in the Taimyr population over the past few decades are not known; however, several explanations have been offered. One explanation is that due to the remote nature of the area, and relative scarcity of settlements, reindeer herding and/or intensive agriculture have not become as established as in other areas; hence the excessive harvest or direct extermination of caribou that characterized other regions of the Soviet Union has had little effect on the Taimyr population (Klein and Kuzyakin 1982; Yakushkin et al. 1984). In addition, wolf control was conducted in the Taimyr region, although the reported effects of this control are contradictory. Syroechovskii (1984a) reports that wolf control has been sucessful in removing the

"considerable pressure of predators ... since a large number of Taimyr wolves have been shot." Klein and Kuzyakin (1982) report that wolf control was conducted primarily around domestic reindeer herds, and "has not been considered effective in limiting wolf numbers in the range of the Taimyr herd" although wolf populations were low at the time. A further explanation for the increase in the Taimyr region caribou population is that the remoteness of the region and the severity of the climate have discouraged human developments in the region. As a result, habitat destruction caused by urbanization, intensive agriculture and forestry, and overgrazing of range by domestic reindeer, is relatively minor in both the winter and summer ranges of Taimyr region compared to many other regions of the Soviet Union (Klein and Kuzyakin 1982, Syroechovskii 1984a).

It is ironic that in spite of the remoteness of the region, and the general thriftiness (e.g., high calf survival, good individual condition) of the Taimyr caribou population, two of the most widely repeated specific examples of the effects of human industrial development on caribou occurred there. In one example, caribou migrating in the Yenisey River area (figure 2) during fall, were prevented from crossing the river near Ust'port by open water, ice floes, and pressure ridges caused by ice-breakers used to extend an open-water channel from Dudinka to the Kara Sea. This barrier resulted not only in many animals drowning, but also in localized range destruction due to overuse and trampling by animals unable to continue on their migration to winter range (Klein and Kuzyakin 1982, Yakushkin et al. 1984).

A second example of the effects of development is the interruption of the caribou migration in 1968-69 caused by construction of the gasline complex from the Messoyahka gas fields on the west side of the Yenisey River, to the the Norilsk mining and smelting center on the east side (Jakimchuk 1980, Klein and Kuzyakin 1982, Skrobov 1984, Syroechovskii 1984a). This example is discussed in detail in Volume II; however, a brief summary is included here. In 1968, a gasline was constructed from Messoyahka for approximately 193 km (120 mi) to the east in order to supply the mining center of Norilsk. A railroad paralleled the pipeline between Dudinka, a port on the Yenisey River, and Norilsk. The gasline was laid virtually on the ground, and became a physical barrier to caribou movements. As a result, caribou were halted during their northward (spring) migration in 1968, although most were able to eventually cross the pipeline at ravines or other natural crossing areas. In 1969, a second gasline was built, parallel and less than 1 km (0.5 mi) away from the first, thus exacerbating the problems caused by the first pipeline. Localized range destruction, direct mortality of animals from collisions with railroad locomotives and to a minor amount of poaching, and starvation of calves was reported. Although retrofitting of the pipeline with crossing structures was attempted, results were unsatisfactory. The solution was to construct over 80 km (50 mi) of lead fence in order to divert caribou from the Norilsk-Dudinka area, and force them around the entire gasline complex. As a result, a large area of potential winter range was lost. In spite of these examples, Klein (1984, pers. comm.) noted that his Soviet contacts have attributed no population-wide effects on the Taimyr region's caribou to the gasline.

Upper Pechora River. Sokol'skii (1984) reported on the status of a small herd of caribou that occupies the upper Pechora River region near the Ural Mountains (figure 2). The area between the Ilych and Pechora Rivers (which contains important winter habitat consisting of pine-lichen forest) was established as a sanctuary in 1930. By the 1940's the number of caribou using the sanctuary numbered 1,000. In 1951, a large number of the caribou that had used the sanctuary moved out. By the end of the 1960's, the number of caribou in the entire region (i.e., the sanctuary and surrounding area) was only 250-300. A corresponding decrease in the extent of migrations occurred, after which the herd became fairly sedentary in a remote pine-lichen forest area that is outside the sanctuary. The author expressed concern for the fate of this herd because of the increase in the region of the forest products and wood chemical industry which was destroying valuable pine-lichen forests. However, the author attributed the decline in numbers and cessation of migration to overuse of winter range by domestic reindeer, and infers that poaching and predation also figured in the decline (ibid).

Unfortunately, the recent status of this herd has not been reported. Klein and Kuzyakin (1982) report that most populations in the USSR have increased in the past decade, and in their distribution map (ibid, figure 1), they indicate a population numbering 2,700 in an area that may include the upper Pechora River region; however, the map scale is inadequate to accurately determine to which herd the estimate refers.

Conclusions. These examples point out the gamut of changes in caribou populations that have accompanied development and land use changes in the Soviet Union. The current distribution of caribou in the Soviet Union reflects the history of land use and development, especially of the domestic reindeer industry. Caribou are currently distributed in areas where domestic reindeer and other developments are absent or low in density compared to other areas of the USSR. Unlike the situation in North America, distribution and abundance of caribou in the Soviet Union has been greatly affected by the past policy of deliberate extermination of caribou in areas where caribou and domesticated reindeer overlapped. An additional consideration that further complicates understanding the effects of human developments, is that much of the European portion of the USSR was the scene of major fighting in World War II. The effects of habitat destruction on such a massive scale, and of harvest of caribou for sustenance of the human population during the war have not been explicitly reported by Soviet researchers; however, one effect that has been favorable to the recovery of caribou populations was the destruction of the reindeer industry in Karelia and much of the Kola Peninsula. The destruction of the reindeer industry is considered one reason for the increase in caribou of these regions (e.g., Danilov and Markovsky 1983, Semenov-Tyan-Shanskii 1984).

Especially earlier in this century, caribou were viewed strictly as an exploitable resource for commercial or subsistence use, and their management (or the lack of it) resulted in severe overharvest. Prior to the 1950's, the overharvest was due to subsistence or semisubsistence hunting, often by small, nomadic groups of natives. Following World War II, these nomadic groups were consolidated into urban centers, thus freeing large areas of the more remote portions of the Soviet Union (e.g., Yakutia, Taimyr) from overharvest. Official recognition of the national value of caribou also increased in the post-war years, and constraints on hunting in general, and

the establishment of reserves and sanctuaries, primarily in tundra regions that were not used by domestic reindeer husbandry, assisted in protecting caribou and their habitat. In general, Soviet caribou herds increased between the end of World War II and 1980; the increase was especially noticeable in the wild tundra reindeer herds of Taimyr and Yakutia, although at least some of the increase could have been due to the increase in accuracy of the population estimates. However, taiga caribou herds, which are more scattered and whose distribution has been more affected by human development (agriculture and forestry, as well as reindeer husbandry) have also increased. Specific examples from the Soviet Union of caribou habitat destruction, and displacement of caribou by human land use and development activities, and local declines in abundance that are attributed to each, are discussed in section 4.0. However, there are no examples from the available Soviet literature that specifically document extirpations, or major (i.e., on a regional scope) changes in distribution that are solely the result of habitat changes resulting from human land use or development activities. This is not to say that habitat changes have not been a factor in causing such changes, rather that as Skrobov (1984) states "in practice these types of human influence [i.e., habitat destruction and overhunting] are coincidental; persecution of reindeer [caribou] coincides with depletion of habitats." The evidence is irrefutable that the current distribution of caribou in the Soviet Union is considerably less extensive than that of even one hundred years ago (figure 3), and that this shrinking distribution can for the most part be attributable to the effects of human activities, including hunting and land uses.

4.5 FENNOSCANDIA

The history of caribou in Fennoscandia is similar to that of many other regions--caribou populations were historically reduced or extirpated from much of their historic range by overhunting (deliberate or inadvertent), but in the period since the original decline, human land uses and developments have increased so that historic ranges will no longer support caribou at the same numbers or throughout the same geographic area. The modern distribution of caribou in Fennoscandia is much different than the prehistoric and historic distribution.

Although somewhat controversial the prevailing theory of prehistoric distribution of wild reindeer in Fennoscandia is that after the latest glaciation wild mountain reindeer invaded from the south, and wild forest reindeer invaded from the northeast (Sjenneberg and Slagsvold 1979). As recently as several hundred years ago both varieties of reindeer were found in some areas of Fennoscandia although each inhabited different ecological niches. Wild forest reindeer were also found as far south as Poland in the 16th century (Sulkava 1980).

By the end of the 19th century wild mountain reindeer were extirpated in Fennoscandia except for a few small herds in alpine and subalpine areas of southern Norway. Wild forest reindeer survived later than wild mountain reindeer in most of Fennoscandia. Pullainen and Siivonen (1980) mention that wild mountain reindeer in northern Finland were shot out before wild forest reindeer. Reimers et al. (1980) report that in Norway the rapidly increasing reindeer industry combined with extensive hunting decreased the caribou population there, so that by the beginning of the 20th century, wild

mountain reindeer were restricted to small herds in alpine and subalpine areas of southern Norway. In Sweden both varieties of reindeer were exterminated by the 1880's (Nordkvist 1980), although wild forest reindeer disappeared in the late 1700's (Sulkava 1980), possibly because forest reindeer inhabited areas less remote from human settlement. Wild forest reindeer remained in Finnish Lapland until the 1920's by which time they were extirpated (ibid.). In the 1950's scattered reports of wild forest reindeer in Finland suggested that individuals from the adjacent region of Karelia, USSR, had reinvaded Finland (Sulkava 1980, Pullainen 1980). By 1980, the Finnish population of wild forest reindeer numbered 500 animals and was thought to be stable or increasing (Sulkava 1980). This population together with the scattered herds of wild mountain reindeer in southern Norway constitute the only caribou remaining in Fennoscandia.

As was the case in the Soviet Union, the development of domestic reindeer husbandry as an industry played an important role in the decline of caribou herds in Fennoscandia. Most of northern Fennoscandia became dedicated to domestic reindeer husbandry, and caribou were deliberately exterminated to remove competition with domestic reindeer. However, human land uses and developments have increased so that historic ranges will no longer support domestic reindeer at the same numbers or throughout the same geographic area as they had in the past. In Sweden, Nordkvist (1980) has summarized the effects of development on domestic reindeer husbandry: "The rapid urbanization of the northern inland is a threat primarily to the winter pastures, whether it means actual reduction of grazing areas or reduced accessibility. Modern forestry plays an important role in this respect. Hydro-electric power plants, mines, new roads with heavy traffic deep into the mountain region, and expanding tourism are other phenomena exerting a heavy pressure on this ... industry ..."

Many of the wild mountain reindeer herds of southern Norway have interbred with domestic reindeer to the point that phenotypically they are similar (Reimers et al. 1980). The North Ottadalen herd (figure 3) is an example. However, the herds of the Dovrefjell region (e.g., Snohetta, Knutsho, Rondane North, and Rondane South - figure 3) have remained almost pure wild mountain reindeer (Gaare 1985, pers. comm.).

Although domestic reindeer husbandry and hunting of wild reindeer (usually in combination) played an important role in historic declines and changes in distribution of caribou in Fennoscandia, other land uses and developments have also contributed. Gaare (1968) notes that in Norway wild mountain reindeer are divided into individual herds whose distribution is confined to subalpine and alpine plateaus by natural and artificial features. Reimers et al. (1980) report that in Norway, "...borders between areas [of caribou distribution] are partly natural (deep valleys, steep mountains, glaciers, lakes, etc.) and partly formed by human construction (railroads, highways) and human settlement" (see figure 3). In the Dovrefjell region, for example, there was historically one large herd, the Rondane herd. Probably because of overhunting earlier in this century the herd was reduced to several smaller subgroups which have become four herds that are separated by hydropower projects, highways, and settlements (Gaare 1985, pers. comm., figure 3). Because these herds no longer have access to the entire Dovrefjell region, several individual herds inhabit areas that no longer contain adequate seasonal ranges (ibid.). In the Snohetta area of Norway

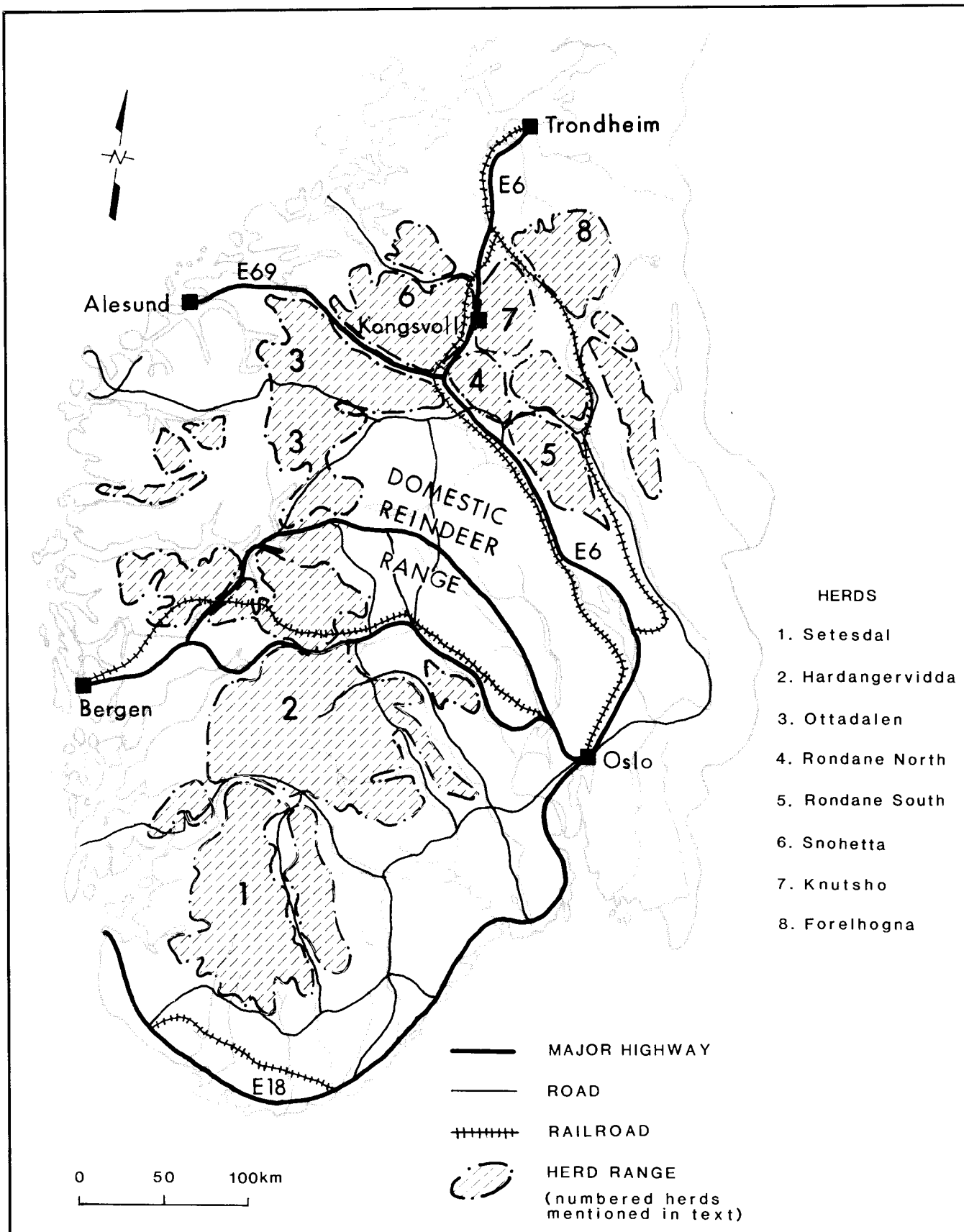


Figure 3. Wild reindeer distribution in Norway (derived from Gaare 1985, Skogland and Molmen 1980).

(figure 3 and 4), construction of a railroad, major highway and numerous smaller roads, a hydro project, and settlements have influenced the numbers and geographic distribution of caribou there (Skogland and Molmen 1980). This case is regarded by some researchers (e.g., Klein 1971) as a classic case of disruption of movements by development, and subsequent reduction in population size. Bergerud et al. (1984), Jakimchuk (1980), Skogland (1985), and Skogland and Molmen (1980) have summarized the available information about the history of the Snohetta herd (figure 4). Unless otherwise stated, the following summary is from Skogland and Molmen (1980). Archaeological and biological investigations have indicated that wild reindeer have inhabited the Snohetta region at least periodically since 1100 A.D. Due to the increased use and efficiency of firearms, hunters in the late 19th century reduced wild reindeer to the point that in 1920-25 it was believed that the Snohetta herd numbered only a few hundred individuals. Bergerud et al. (1984) mention that in 1900, the herd numbered 1,000, and that 250 of them were on the Knutsho range and the remainder on the Snohetta range (figure 4). Traditional migration patterns were to winter in the Rondane and Knutsho areas in the eastern portion of the Dovrefjell region, and to migrate westward to the Snohetta area to calving and summer ranges. However, these migrations ceased when the herd was at extremely low numbers in the 1920's, and the herd remained year-round on the Snohetta range. The literature is unclear about whether or not there were two separate herds, or only one herd entirely on the Snohetta range. In 1921, construction of a railroad across the Dovrefjell began, and continued to the 1930's. During the railroad construction period, no animals crossed from the Snohetta to the Knutsho area. The herd gradually increased [in the 1930's, presumably] so that a controlled hunting program was in place. During World War II, Nazi occupation forces prohibited hunting and the herd increased to 10,000 animals by the 1950's (figure 6 in Skogland and Molmen 1980). Between 1946-53, several large hydroelectric projects flooded much of the calving areas in the Snohetta region, and a series of roads and transmission lines crossed several of the Snohetta calving areas which had been in use even during the early 1900's when the Snohetta herd was at low numbers (figure 4). Reindeer use of some of these calving areas ceased when the areas were inundated but other areas were abandoned because of the increased disturbance to the animals that was caused by activity along roads and by other developments such as powerlines (Skogland and Molmen 1980). During this period (1950's) a road, paralleling the railroad, was constructed across Dovrefjell. By the middle of the 1950's, the Snohetta group numbered 15,000 animals. Marked destruction of lichen range in the Snohetta area was documented. The destruction occurred because not only had animals remained year-round on what had previously been only summer range, but also because the herd had outgrown the available forage even if it had used the Snohetta area only during summer.

During the severe winter of 1956, approximately 200-600 animals moved across the highway and railroad to the eastern (Knutsho) side of Dovrefjell, probably as a result of starvation on the western (Snohetta) side (Jakimchuk 1980). A reduction hunt was initiated in 1960; however, in 1965 winter starvation on the Snohetta range was still high in spite of the fact that the Snohetta group had been reduced to 1,500 animals (figure 6 in Skogland and Molmen 1980), and that approximately one-third of the group had migrated to Knutsho in winter. During the 1960's the road was upgraded, and in the 1970's became a major travel route (E. Gaare 1985, pers. comm.). In 1972,

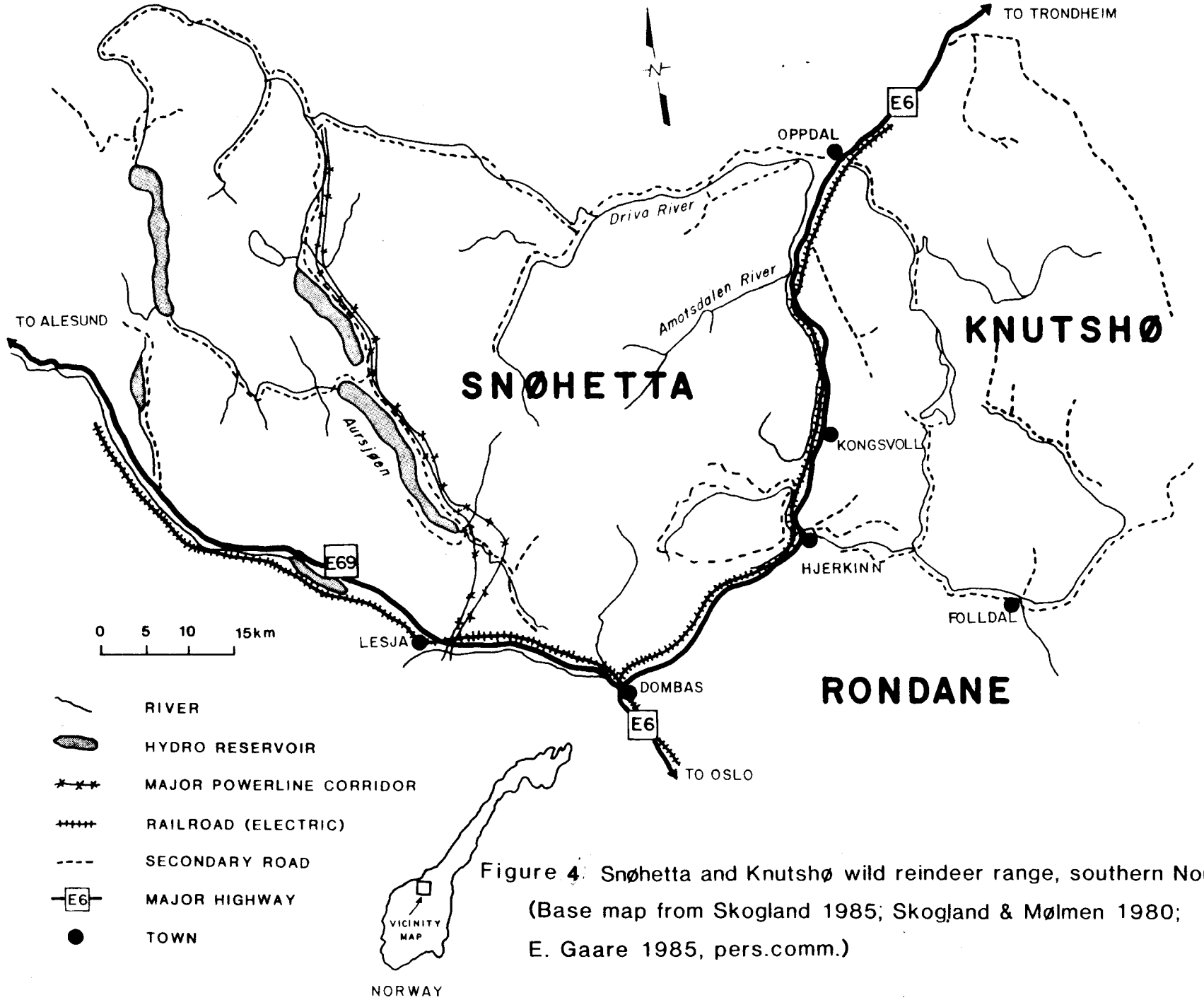


Figure 4. Snøhetta and Knutshø wild reindeer range, southern Norway. (Base map from Skogland 1985; Skogland & Mølmen 1980; E. Gaare 1985, pers.comm.)

high water in the Driva River along the road/railroad corridor prevented parturient cows on the Knutsho range from migrating to calving areas on the Snohetta range (Jakimuchuk 1980). Since then Knutsho animals have remained on their range to calve. Apparently, a portion of the Snohetta group also now migrates to Knutsho during the winter, crossing the highway at night when traffic is less (E. Gaare 1985, pers. comm.). The situation as of the early 1980's was that a portion of the Dovrefjell reindeer remained year-round in the Snohetta area, a portion summered in the Snohetta and wintered in the Knutsho region, and a portion remained year-round in the Knutsho (Skogland and Molmen 1980). However, for the past 3 winters the entire Snohetta herd has remained year-round on the Snohetta side of the transportation corridor (E. Gaare 1985, pers. comm.).

Skogland and Molmen (1980) conclude that: (1) hydroelectric development in the west and the transportation corridor on the east have acted as "semibarriers" to movements between seasonal habitats; (2) reindeer have been able to adjust to structures associated with the development (e.g., roads, snowfences, and a railroad), however the associated human activity has caused avoidance of many areas as well as disruption of traditional migration routes; and (3) overgrazing and destruction of lichen winter ranges has been caused by the restriction of migration. However, Bergerud et al. (1984, p. 15) argued that "the halt in migration was probably a result of a contraction of the range because the herd's numbers were low." Although Bergerud et al. (1984) may be correct that the construction of the Dovrefjell railroad may not have been directly responsible for the cessation of migration in the 1920's, they do not address the observation that migration to Knutsho did not begin again until the Snohetta group had experienced widespread starvation and a severe winter. Topographic barriers to movements are few along the historical migration routes, and it seems likely that reindeer would not remain in the same area until starvation forced them to move elsewhere unless some other feature of their environment, such as a transportation corridor, were restricting their movements. Furthermore, Bergerud et al. (1984) do not address the fact that use of the traditional calving areas in the western portion of Snohetta had virtually ceased by all but a few bulls after the road and powerline corridors and the hydro reservoirs had been constructed. The evidence points to human developments as being responsible for the herd's decline.

However, the Snohetta case is not an isolated example. The Hardangervidda Herd's range is bounded by natural topographic features such as the Hardanger Glacier on the west, but also by artificial features such as several roads, a railroad, and a major highway. This herd has adequate summer range but inadequate winter range (Skogland 1983). Another example, the Setesdal Herd (figure 3), currently has sufficient summer and winter range but a railroad has been an occasional barrier to movements to winter range and a proposed hydro project is viewed with concern because it will likely block movements to winter range (Gaare 1985, pers. comm.). Gaare (1985, pers. comm.) points out that because of the loss of wild mountain reindeer range and disruption of historical migration routes as a result of human development, Norway has been forced into intensive management, primarily by selective hunting, in order to maintain wild mountain reindeer herds within the shrinking carrying capacity of their range. This management has been only partially successful.

5.0 IMPACTS LITERATURE REVIEW

In the following section, we summarize the impacts to Rangifer or to Rangifer habitat that are caused by human land uses or types of development and that have been discussed in the published literature. This section is organized according to the different types of land use or development (e.g., Agriculture, Forestry). The discussion of the impacts of each type of land use or development is brief because more extensive discussion is provided in the appended annotations.

5.1 AGRICULTURE (EXCLUDING REINDEER HERDING)

References to the general impacts of agriculture on Rangifer are most common in the Soviet literature; however, with a few exceptions, these are very general. For example, Nagretski (1984) reported that the Bulunsk Herd (in the lower Lena River valley) has declined precipitously since the 1920's and attributed this decline to "intensive industrial and agricultural development in the North." Syroechovskii (1984b) noted that in the Tomsk Region, "...agricultural development of the taiga has led to a substantial reduction of [caribou] pastures, and poaching occurs." Skrobov (1984) reported that increased agricultural development that accompanied the construction of the Krasnoyarsk-Irkutsk railroad caused a discontinuous distribution of caribou in that region. Skrobov (1984) also noted that "...the causes of extinction of wild reindeer in a number of areas of Arkhangel'sk region to be agricultural expansion [emphasis added], development of reindeer husbandry, forest fires, and destruction by predators."

Specific impacts of agriculture which have been discussed include competition for feed between caribou and cattle in the Soviet Union, and the death of reindeer in Sweden caused by aerial spraying of herbicides. Syroechovskii (1984a) noted that in Tersk, USSR, approximately 1,000-1,200 ha/yr (2,500-3,000 acres/yr) of caribou lichen pasture were lost to domestic cattle that use it as a winter feed. Klein (1971) noted that domestic reindeer in Sweden were poisoned by 2,4-D and 2,4,5-T herbicides that were sprayed over a forested area. These compounds, which had been used in agriculture and forestry, were subsequently banned for such application.

For impacts of agriculture that are related to the effects of reindeer grazing, see section 5.5.

5.2 AIR TRANSPORT

In the following section, the discussion of the impacts caused by air transport focuses on active (e.g., chasing) and passive (e.g., unintentional) harassment caused by aircraft activity. There are few references to other types of impacts of air transport except an unsubstantiated statement by Dufresne (1946) that accelerated road and air field development was tending to restrict Alaskan caribou migrations. Conversely, one of the two recently reintroduced Kenai Peninsula caribou herds resides near the largest airport on the Kenai Peninsula apparently enjoying the benefit of an area where human activity keeps most predators away (Davis and Franzmann 1979).

For the purposes of this report "harassment" is defined at a specific human activity that results in an overt change of an animal's behavior such that the behavior in response to harassment would be considered more bioenergetically "expensive" to the animal or that could result in injury to the animal. Such behavioral changes could range from cessation of feeding to increased locomotion (e.g., from walking to running). The animal probably perceives the source of harassment (e.g., an airplane) as a potential predator or pest (e.g., warble fly). However, it is possible that the caribou is merely reacting to a sudden, novel stimulus.

The following discussion is restricted to that of overt behavioral responses because these have been most commonly monitored. This should not imply that physiological responses (for example, elevated heart rate or change in blood chemistry) do not occur, nor that these are not significant. The overt behavioral responses of caribou to overflying aircraft have ranged from a minor change in ongoing behavior, such as simply orienting toward the stimulus, to strong escape reactions such as panicked running. Conflicting conclusions about the importance of these responses to the animal's habitat utilization and survival have been reached. Harassment by aircraft can cause caribou injury or death resulting from panicked running, especially when the animals are in large, insect-harassed groups (Calef et al. 1976, Roseneau and Curatolo 1976); increased energy expenditure as a result of escape responses and disruption of grazing (Calef et al. 1976); increased calf abandonment due to disruption of the cow-calf bond immediately after calving (Bergerud 1985, pers. comm.; Lent 1966); and long-term abandonment of range (Calef et al. 1976). Bergerud (1978), Bergerud et al. (1984), and Valkenburg and Davis (1985) acknowledge that caribou can react strongly to certain types of disturbance; however, they maintain that caribou can habituate to these types of disturbance. Furthermore, they believe that there is no empirical evidence that links harassment with demographic consequences or range abandonment by North American caribou (ibid.). In spite of the seemingly conflicting point of view of the latter investigators they conclude that unnecessary harassment, especially on the calving grounds, should be avoided (e.g., Bergerud 1978).

Because the responses of Rangifer are thought to differ depending on whether the disturbing agent is a fixed-wing or helicopter aircraft, the following discussion is divided into three sections--fixed-wing aircraft, helicopter aircraft, and conclusions from both.

5.2.1 Fixed-wing aircraft

Numerous investigations, summarized in Calef et al. (1976), Davis and Valkenburg (1979), and Valkenburg and Davis (1985) have reported the overt behavioral reactions of caribou to harassment by fixed-wing aircraft. In these three studies, categories of caribou responses are directly comparable with each other and with those of Klein (1973, summarized in Calef et al. 1976). The results summarized in Calef et al. (1976) and Davis and Valkenburg (1979) are not directly comparable with those of McCourt et al. (1974) because the latter used three response categories rather than five, and because altitude categories were not similar. All of these studies have been conducted in conjunction with other activities (e.g., aerial reconnaissance, population census, radio tracking) and were not specifically designed to test the effects of aerial harassment. In addition,

observations of caribou responses were made from the survey aircraft rather than by observers on the ground who could have independently and closely monitored the animals' responses. Nevertheless, results are in general agreement that numerous external variables are involved in the caribou's response. Some variables appear to be more important than others. In addition to aircraft height, variables which have been identified include: season of the year, caribou group size, group composition (especially the presence of calves), habitat type, and ongoing activity (e.g., resting, feeding, walking) (Calef et al. 1976, Davis and Valkenburg 1979, McCourt et al. 1974). An additional variable is the individual animal's previous experience with aircraft (Valkenburg and Davis 1985). The following discussion summarizes the relationship found among different variables that may affect the response of caribou to aircraft.

Season: Most of the observations of the responses of caribou to aircraft have been made during the calving and post-calving seasons; this can be attributed in part to the emphasis that most management agencies place on such activities as aerial censuses, composition counts, and reconnaissance during that period. Calef et al. (1976) observed that during the calving and post-calving period caribou frequently exhibited panic and escape responses to aircraft flying at altitudes of up to 150 m (500 ft) above ground level (AGL). Although McCourt et al. (1974) concluded that, in general, no major seasonal differences in reactivity of Porcupine Herd caribou to disturbance by aircraft were observed, inspection of their Table 41 reveals that during summer movements, aircraft at 91-182 m (301-600 ft) AGL caused 87.5% of the caribou to respond with intensities ranging from mere interuption of behavior (e.g., cease feeding to trotting away) to panicked running (50% of observations). Cooper (1981) noted that during early summer, cows and calves were more reactive than bulls and other nonparturient animals. Anecdotal observations from Darby (1978) and Calef et al. (1976) during mosquito season suggest that large aggregations during mosquito season are extremely reactive ("galloping wildly" - Darby) to aircraft several thousand feet overhead. It should be noted that these extremes were caused by aircraft circling at these high altitudes, though single passes at much lower altitudes evoked similar responses. Anderson (pers. comm. 1984) has observed that while he was conducting aerial surveys of the Western Arctic Herd at post-calving, many caribou remained bedded down during the overflights, during which the aircraft remained at 500 m (1,500 ft) AGL. The difference between the observations reported by Calef et al. (1976) and NWT Wildlife Service (1979) and that of Anderson (pers. comm. 1984) can possibly be explained by the intensity of mosquito harassment at the time of the flights. Post-calving aggregations enduring mosquito harassment have been observed to be very responsive to aircraft (pers. obs., RTS, on Western Arctic Herd).

Calef et al. (1976) also found that caribou were very reactive to aircraft during early winter (November). However, results were not directly comparable with those of McCourt et al. (1974), Davis and Valkenburg (1979), or Valkenburg and Davis (1985).

Based primarily on the seasonal changes in caribou response observed by Calef et al. (1976), it appears that the overt responsiveness of caribou to fixed-wing aircraft varies with season, and that especially during the calving and post-calving period, altitudinal restrictions of 660 m (2,000

ft) AGL should result in only minor overt reaction by caribou to single passes.

Group Size: McCourt et al. (1974) found that flights at altitudes of less than 91 m (300 ft) AGL evoked more intense and frequent responses by larger groups compared to smaller groups. With the exception of the incident during insect harassment mentioned above, Calef et al. (1976) found no correlation between caribou response and group size. Data of Davis and Valkenburg (1979, table 2-5) was not conclusive but suggested that larger groups may be more reactive.

Group Composition: Calef et al. (1976) and Davis and Valkenburg (1985) both reported that calves were more responsive to aircraft than other age classes; however, neither presented evidence that this responsiveness necessarily resulted in a similar response by the entire group. Davis and Valkenburg (1985) and Valkenburg and Davis (1985) noted that calves in the Delta Caribou Herd were much less responsive than those of the Western Arctic Herd.

Previous experience: An additional factor that complicates a comparison of results from different investigations is that although McCourt et al. (1974) and Calef et al. (1976) investigated the Porcupine Herd, Davis and Valkenburg (1979) and Valkenburg and Davis (1985) investigated the Western Arctic Herd and Delta Herd respectively. Anecdotal information suggests that animals from different herds, which have had different experiences with aircraft, may react differently to aerial harassment. Darby (in NWT Wildlife Service 1979) felt that Kaminuriak Herd animals responded more readily and more severely to aircraft harassment than did animals of the Beverely Herd. Likewise Valkenburg and Davis (1985) reported that Western Arctic Herd caribou were much more reactive to aircraft than were Delta Herd caribou. They related this observation to the history of aircraft use over the Delta Herd range, and to differences in the timing and amount of hunting by aircraft and snowmobile that the two herds were subjected to. Caribou of the Delta Herd have been subjected to a considerable amount of military and civilian aircraft activity for the past 40 years; most of this has been relatively benign because it has not been associated with hunting. Conversely, the Western Arctic Herd has not been subjected to much aircraft activity of any type; these animals react more strongly to aircraft possibly because it is a comparatively novel stimulus, and/or possibly because they associate the aircraft with being hunted from a snowmobile (ibid.).

A confounding factor is that herds may occupy different habitats (i.e., tundra vs. forest); therefore, inter-herd differences in response to aircraft could be due to adaptations to a particular habitat type rather than necessarily to differences in previous experience with aircraft. However, this is unlikely to be important with respect to the Delta and Western Arctic herds because each of these spends at least part of the year in forested habitat.

In almost all studies, aircraft maintaining flight altitudes of 660 m (2,000 ft) AGL caused little or no disturbance to caribou during any season, and flight altitudes above 300 m (1,000 ft) AGL caused few strong responses by caribou.

5.2.2 Helicopter Aircraft

McCourt et al. (1974), Calef et al. (1976), and Davis and Valkenburg (1979) reported on the overt behavior of caribou to fixed-wing and helicopter aircraft. These investigators reached conflicting conclusions about caribou responses to helicopters and fixed-wing aircraft. McCourt et al. (1974) found that during March-April caribou responded more severely to a helicopter than to fixed-wing aircraft at altitudes under 91 m (300 ft) AGL, but did not respond differently to either type at altitudes above 91 m (300 ft) AGL. Calef et al. (1976) on the other hand, found that during calving, helicopters are not more disturbing than fixed-wing aircraft. However, Calef et al. (1976) pointed out that the most severe reactions they witnessed at any time were to aircraft chasing caribou and that this form of active harassment is only possible with a helicopter.

The only systematic and experimental studies of the effects of helicopter aircraft on overt behavior of caribou were conducted by Miller and Gunn (1979, 1980) on Peary caribou on Prince of Wales Island, N.W.T., and by Gunn et al. (1985) on the Beverly Herd, N.W.T.

In the Prince of Wales Island study, helicopter (Bell 206) flights (including "normal" overflights, cargo slinging, and circling) and landings were conducted at fixed altitudes, intervals, and seasons over Peary caribou. Individual and group responses were noted by observers in the aircraft and on the ground. The following conclusions from that study are pertinent:

(1) Cow/calf groups are the most responsive to helicopter overflights, principally due to the reaction of the calf (i.e., running to its mother) to unfamiliar stimuli perceived as threatening. Adult bulls were the least reactive sex/age class.

(2) Peary caribou in large (greater than 20 individuals) groups tended to be more responsive than individuals in small groups especially if calves were present.

(3) Caribou were more responsive to overflights below 200 m (600 ft) AGL between 24 June-15 July, and to flights above 200 m (600 ft) AGL between 15 July-7 August, than at other times of the year. It should be noted in this context that insect harassment of Peary caribou is minimal (Miller 1982); therefore, the responsiveness of Peary caribou is probably unrelated to the intensity of insect harassment.

(4) Terrain, wind direction, and position of the aircraft with respect to the sun were additional factors that affected the caribou's response. Reactions were most severe in terrain which caribou appeared to consider a "barrier" (e.g., cliffs).

(5) Responses of caribou to helicopter landings, and to humans moving around the helicopter after landing, were significantly stronger than to overflights or cargo slinging.

In the Beverly Herd study, pre- and post-disturbance observations were made of the behavioral responses of cows and calves in post-calving aggregations to a helicopter overflight at 300 m (1,000 ft) AGL, followed by landing at

distances from 300-2,200 m (1,000-7,000 ft). The results indicated that there was no statistical difference in the pre- and post-disturbance activity patterns of cows and calves; however, the sample size was very small because most caribou groups moved out of the observation area before the total cycle of observations could be completed. The authors interpreted this movement as a response to the helicopter--in many instances the animals were 1-3 km (0.6-1.8 mi) away before observations were halted.

5.2.3 Conclusions

In all the studies discussed above, and in numerous others reviewed but not discussed here, no injury, debilitation or death of caribou as a result of overflights was observed. However, several investigators commented on the potential, especially during large calving/post-calving aggregations, for such effects to occur. Zhigunov (reported in Klein 1973) reported that harassment of reindeer in the Soviet Union during extremely cold weather resulted in pulmonary edema; however, no documentation was provided. Investigators also recognized that numerous physiological responses as well as subtle overt responses (e.g., change in activity) could have occurred, but these were not observable.

It is also important to note that the significance of aerial harassment on caribou is still under discussion. Several investigators consider that in most situations caribou can habituate to aircraft as long as the animals do not associate aircraft with a negative stimulus (e.g., hunting) (Valkenburg and Davis 1985), and that caribou can withstand periodic severe disturbance without adverse effects on their productivity (Bergerud et al. 1984). These investigators do not condone harassment nor do they believe that harassment is unimportant in all cases; however, they provide examples (such as the Delta Herd in Alaska and several Newfoundland herds) in which caribou have been subjected to extreme levels of aircraft harassment with no apparent effect on the herd.

Investigators are in general agreement that aircraft (helicopter and fixed-wing) overflights which maintain altitudes of 600 m (2,000 ft) AGL above caribou during calving, postcalving, and winter, and 300 m (1,000 ft) AGL during other seasons, are unlikely to result in significant impact. However, in some instances this may be overly conservative (e.g., the Delta Herd [Valkenburg and Davis 1985]) and unwarranted. In order to increase the precision of this recommendation, one should take into account the individual herd's previous history of the type and amount of contact with aircraft (e.g., low-level small aircraft as opposed to high-altitude jet traffic), terrain, and possibly the herd's history of contact with ground traffic (e.g., hunters on snowmobiles) (Valkenburg and Davis 1985).

5.3 HUMAN-CAUSED FIRE

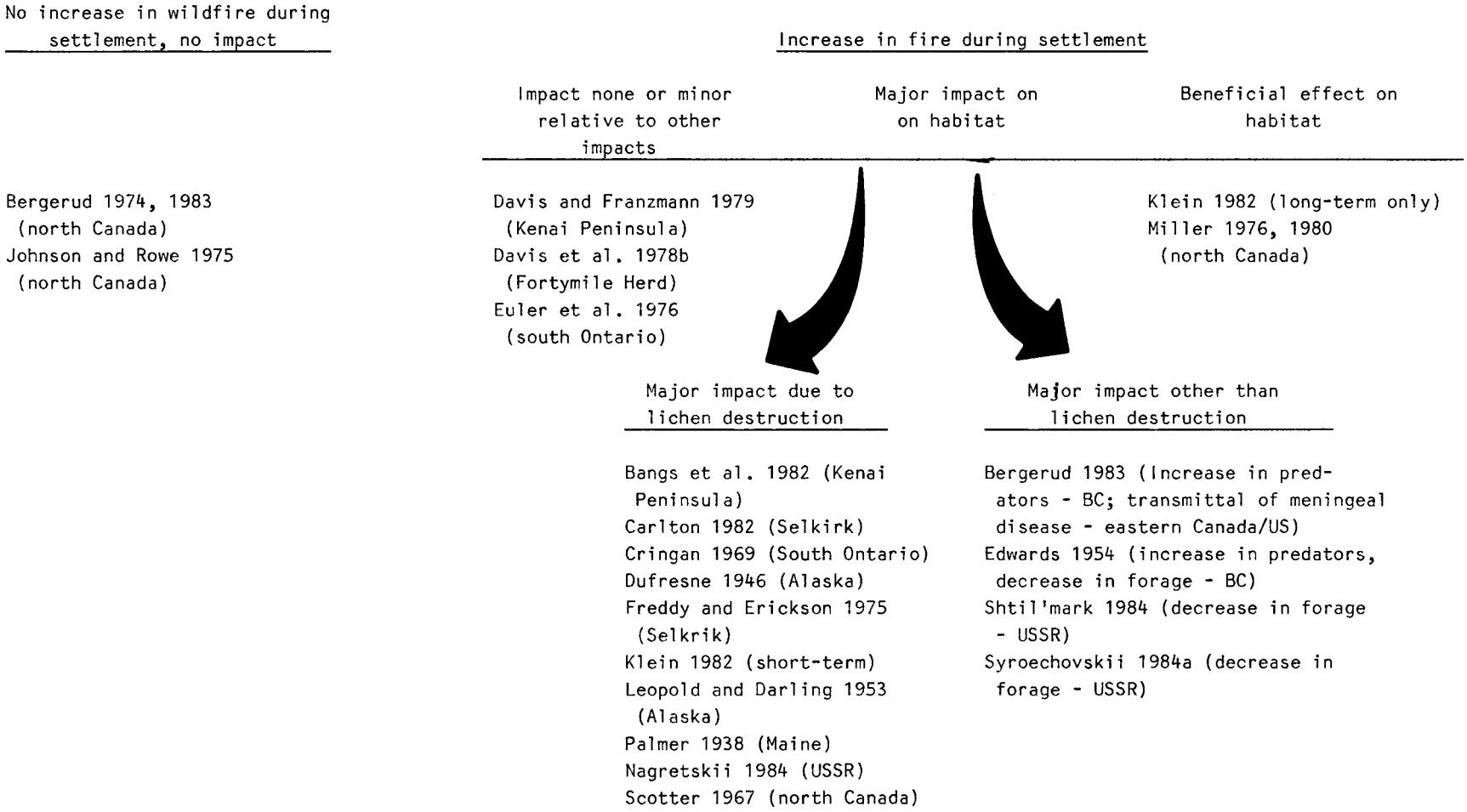
The interpretation of the effects of man-caused wildfire on caribou has probably generated more controversy than that of any other human land use or developments. This controversy is a crystallization of the differences between the "Forage" and "Predation" theories of caribou population regulation. On the other hand, some biologists argue that the incidence of fire did not increase during the period of human settlement. Other biologists argue that even if fire had increased during settlement, because

caribou population's are not regulated by the availability of forage, populations would not have been affected. On the other hand, some authors argue that because most caribou are seasonally dependent on lichens, the general declines of North American and Soviet caribou populations during the period of settlement were due in large part to destruction of lichen habitat by fire. There are other points of view including the conclusion that fire is ultimately beneficial to caribou populations due to increased forage abundance or diversity in response to fire, or that the indirect effect of fire (e.g., increase in predators, or transmittal of disease from other ungulates that invade after a fire), and not destruction of forage per se, is the major impact. These opinions are summarized in figure 5.

Johnson and Rowe (1975), Miller (1976, 1980) and Bergerud (1974, 1983) have reviewed data on the occurrence of fire following settlement in northern Canada, and concluded that (a) fire has not increased significantly since the beginning of settlement (i.e., early part of this century to present); (b) there has been no correlation between the decline of caribou in northern Canada during the period of settlement and increased fires, not only because of "a" but also because caribou are not dependent on lichens (terrestrial or arboreal); and (c) wildfire may actually be beneficial to caribou by providing heterogeneity in vegetation patterns, including opening certain types of climax forest so that growth conditions for terrestrial lichens become more favorable (Bergerud 1971a), and by allowing caribou more options for foraging among diverse vascular plant communities (Miller 1980). Klein (1982) noted that certain types of burns (i.e., very low intensity burns) may actually enhance terrestrial lichen growth. Miller (1980) reported that in the North American Boreal Forest terrestrial lichens reach abundance sufficient to attract caribou approximately 40 years after a fire, and that periodic fire or cropping by caribou is necessary to maintain the maximum abundance of terrestrial lichens. In Newfoundland, fire and logging opened closed black spruce forests and, depending on conditions for succession to lichen woodland, may have enhanced lichen production (Bergerud 1971a). In northern Sweden, controlled burns to reestablish a seedbed in clear-cut forests resulted in a brief increase in vascular forage plants for domestic reindeer, but these plants were only available at a time of year when alternative food sources were readily available (Eriksson 1975).

Numerous authors have agreed that the incidence of wildfire in various parts of North America and the Soviet Union has increased during and following the period of settlement (figure 5); however, their assessment of the effects of fire on caribou has differed. Davis et al. (1978b) and Davis and Franzmann (1979), for example, agree that wildfire has increased significantly due to human settlement in the Fortymile and Kenai Peninsula areas of Alaska (over 75% of the Fortymile Herd's range has burned over the past 75 years) but the increased incidence of fire was not responsible for the decline of the Fortymile Herd or the extirpation of the Kenai Peninsula Herd in the early 1900's. Bergerud (1971a, b) reported that in Newfoundland the incidence of fire increased following settlement, but that because caribou did not winter in areas affected by fire or logging the decline of Newfoundland caribou in the early 1900's was independent of these effects. Shtil'mark (1984) and Syroechovskii (1984a) conclude that in numerous regions of the Soviet Union wildfire was partially responsible for the decline of caribou. Although they believe that habitat destruction due to fire caused the declines, they do not explicitly relate this to destruction of lichen habitat. Skrobov

Figure 5. Opinions regarding the impacts of wildfire on caribou (refer to text).



(1984) noted that increased wildfires following development have continued--in the years from 1967-70 over 8.5 million ha (32,000 mi^2) of caribou taiga range in Evenkia had burned. Bergerud (1983) discussed the observation that in British Columbia, mountain caribou in the Wells Gray Park area declined following a region-wide fire in 1926 that denuded most of the lower Clearwater River valley. He attributed the decline to the indirect effect of increased predators following an irruption of mule and white-tailed deer and moose in the burned area (ibid.). In contrast, Edwards (1954) attributed the decline primarily to the destruction of lower-elevation forests that the herd utilized as winter range. In another example of an indirect effect of wildfire on caribou, Bergerud (1983) concludes that the decline of eastern woodland caribou in New England and eastern Canada was not due to the reduction of forage abundance associated with the clearing and burning of climax coniferous forest, but rather was due to the expansion of white-tailed deer into primary caribou range and transmittal of meningeal worm to caribou. In the cases discussed above, wildfire was shown to have increased following settlement, but the role which fire played in caribou declines was variable. Wildfire played no role in some caribou declines. In other cases fire did play a role; and in some cases (e.g., USSR) the role was habitat destruction (but not necessarily lichen habitat), but in other cases the role was indirect.

Another group of researchers (e.g., Bangs et al. 1982; Carlton 1982; Dufresne 1946; Leopold and Darling 1953; Nagretskii 1984; Scotter 1967, 1972; Skrobov 1984) believe that wildfire has resulted in decreased caribou abundance, and that this decrease has been due in large part to the destruction of lichen habitat. Klein (1982) argues that although wildfire may increase forage abundance over the long term by providing heterogeneity of vegetation types within the mature coniferous forest, and thereby in some cases providing conditions suitable for terrestrial lichen growth, the short-term effects of fire (i.e., destruction of forage for several years, rendering of the area impassable due to blowdowns and fire-felled trees) may occur for a period of time sufficient to eliminate caribou use for several generations. Individual characteristics of the fire (e.g., size, intensity of burn), availability of suitable alternative resources while the burned area matures, and ability of the particular herd to migrate to these alternative areas are all factors that should be evaluated in determining whether a fire is beneficial or detrimental (Klein 1982, Miller 1980). Fire-induced changes in habitat that may be beneficial to caribou in the Boreal Forest may not be beneficial to small, isolated herds of eastern woodland caribou in the Lake States-Acadian Forest (figure 1 and table 3) or small mountain caribou herds in the British Columbia Rocky Mountains. Arboreal lichens are an important component of the winter diet of these caribou, and may be necessary for their survival in deep snow years (Bergerud 1971a, Bloomfield 1979, Carlton 1982, Cringan 1969, Stevenson and Hatler 1985). Arboreal lichens do not become sufficiently abundant to support caribou until at least 40-60 years after a fire or logging destroys the stand; however, once the stand reaches climax forest, periodic blowdowns and senenscence of mature trees keeps a supply of arboreal lichens on fallen trees available (Cringan 1969). In those areas where a stable climax coniferous forest maintains the availability of arboreal lichens as a food source during winters of deep snow, the effects of fire are likely more detrimental than beneficial.

In summary, although the incidence of fire has increased following settlement in southern Canada/New England, western Canada, Alaska, and the Soviet Union, fire has not apparently increased in northern Canada. In some cases wildfire may be beneficial to caribou in terms of providing heterogeneity of forage sources (predominately vascular plants) and under certain conditions even to increase the abundance of terrestrial lichens. In cases where fire has had a detrimental effect on caribou, the detrimental effect has not necessarily been forage destruction--indirect effects such as increased predation or parasitism have also been thought to be as or more important than forage loss. Individual characteristics of each fire (especially the size and intensity of the burn), the food habits and habitat of the particular herd that may be affected (especially whether the herd is a small, isolated one that uses arboreal lichens to a high degree), and whether one is discussing long term as opposed to short term impacts, are all considerations in evaluating the impact of fire on caribou. Although large, uncontrolled fires are much less common today in North America and Fennoscandia with the advent of fire control technology, prescribed burning as a forest management tool remains a potential impact if the same considerations mentioned above are not included in fire planning. For example, in the lichen woodland domestic reindeer range of northern Sweden, controlled burning following logging has been banned because environmental conditions after the fire eliminated regrowth of lichens for many years (Eriksson 1975). Presumably, the vast uncontrolled wildfires that characterized human settlement at the turn of the century in North America are a thing of the past. Future fire management can be tailored to specific situations in which caribou habitat can be enhanced or as much as possible a natural fire regime can be maintained.

5.4 FORESTRY

Forestry, as used in this section, includes the activities of logging (including land clearing) and silvicultural practices such as stand management, seedbed preparation and fertilizer or herbicide treatment. Many of the impacts associated with logging have been discussed in a previous section (4.0) concerning regional changes in populations and distribution in North America and the USSR. Impacts similar to those occurring as a result of logging have been discussed in section 5.3, Human-caused Fire. Impacts of forestry include those which indirectly affect the individual, such as habitat changes (e.g., loss of forage, microclimatic changes that inhibit production of forage useful to caribou, perpetuation of a less desirable stage of succession), and those that directly affect the animal (e.g., poisoning by herbicides/fertilizers, harvest of animals, or interference with movements due to physical or behavioral barriers).

5.4.1 Habitat Changes

Historical impacts of logging on caribou habitat in the USSR and North America have been discussed in section 4.0 and will only be summarized here. By the early 1900's land clearing had dramatically reduced climax coniferous forest in the eastern US and southeastern Canada and is thought to be partially responsible for caribou population declines there because of decreased arboreal lichen abundance. Early logging techniques, prior to increased mechanization in the late 1800's, were relatively benign in terms of destruction of forest soils and vegetation other than that in the

immediate vicinity of logging operations. Most of the logging prior to the pulpwood boom in the late 1800's consisted of selective cutting of individual trees, or of stands of trees. This type of logging resulted in the immediate loss of forage abundance in those cases in which a particular caribou herd relied on terrestrial and especially arboreal lichens as a major winter forage source. If natural succession would have been allowed to occur for the most part conditions would have remained acceptable for lichen regrowth and return to pre-logging abundance. However, most of the area ended up in perpetual "disclimax" because the logged areas became farmland, or because deliberate or accidental fires tended to ravage the cutover area. The result was a change in large areas of the northeastern US and southern Canada from coniferous to deciduous forest. The pulpwood industry has continued the trend toward management of forests for short periods between harvest such that climax forest will never be reached. Arboreal lichen production in this short-rotation management scheme is much less than in mature coniferous forest.

In addition to microclimatic changes extensive fires and logging created regional climatic changes. In the northern Great Lake states the average seasonal temperature in the early 1900's fluctuated several degrees each direction due to the loss of forest cover (Flader 1982).

Although logging often creates microclimatic changes such as lower humidity and higher ground temperatures that can be inimical to terrestrial lichen regrowth, in some cases clearing of the overstory can create microclimatic conditions that are favorable for terrestrial lichen growth (e.g., Stevenson and Hatler 1985). Bergerud (1971a) in Newfoundland and Eriksson (1975) in Sweden have noted that in such forest types as bog woodlands, which are too mesic for terrestrial lichen growth, clearing can initiate the production of terrestrial lichens and thus render this forest type more useful to caribou.

Logging has been considered at least partially responsible for historical declines in the Selkirk and Raven Lake herds of British Columbia (Bloomfield 1979, Carlton 1982, van Zwoll 1983). Logging is eliminating much of the subalpine fir-Engelmann spruce forest which provides arboreal lichens used by mountain caribou for winter forage when snow conditions eliminate access to other forage plants. The elimination of this forest type has increased with the advent of large scale, consolidated clearcutting operations (Bloomfield 1979, Stevenson and Hatler 1985). Clearcutting of lodgepole pine and lodgepole pine/black spruce forest in western Alberta has eliminated terrestrial lichen caribou winter range there, and resulted in several small herds of mountain and woodland caribou becoming isolated (Edmonds and Bloomfield 1984).

Similarly, large scale caribou habitat loss occurred as a result of logging in the Soviet Union. The impacts of logging were especially noticeable in the pine-lichen forests of the Konda River (figure 2) which have been logged extensively for lumber as well as resins and other wood chemicals (Shtil'mark and Azarov 1984). A similar situation was reported by Sokol'skii (1984) for the upper Pechora River region, where the wood products industry has developed around a major caribou sanctuary. Other examples of widespread lichen habitat destruction are described by Shtil'mark (1984), Syroechovskii (1984a), and Zagorodoski and Reimers (1984).

Seedbed preparation as a silvicultural tool is an artificial means of duplicating conditions that may occur naturally following logging or forest fires. Two of these techniques, prescribed burns and mechanical scarification, have been responsible in Sweden and Alberta for destruction of terrestrial lichen forage and for continuation of the cut area in stages of succession that did not favor domestic reindeer (Edmonds and Bloomfield 1984, Erikkson 1975). Another method involved in seedbed preparation is to windrow slash, either in preparation for burning or in order to increase insolation of the area as an aid in tree seedling survival. Slash windrows have, in some situations, created microclimatic conditions conducive to the survival of terrestrial lichens (Eriksson 1975); however, in more instances, slash has created a physical barrier to domestic reindeer movement through the clearcut (Eriksson 1975).

With the advent of modern forestry and the "managed" forest, two aspects of silviculture are especially deleterious to caribou. One such aspect is that stands of forest are commonly clearcut on a rotational basis to ensure that timber will be available for future use. This results in second-growth, even-aged stands which are in perpetual "disclimax" with little opportunity for arboreal, and in some cases, terrestrial lichens, to become re-established in sufficient abundance and for a sufficient period of time to provide forage for caribou (Bloomfield 1979, Cringan 1969, Eriksson 1975, Freddy 1979, Freddy and Erickson 1975, Stevenson and Hatler 1985). The continued replacement of climax forests that provide important arboreal lichen habitat to some caribou populations, especially mountain caribou in the Soviet Union and North America, with subclimax, second-growth stands prevents the significant growth and abundance of arboreal lichens, especially. This is considered a major impact on mountain caribou populations (ibid.) and one that changes in silvicultural practices, short of diminishing the annual timber harvest, may not be able to mitigate (Stevenson and Hatler 1985). In addition to providing suitable conditions for arboreal lichen production, old-growth forest on mountain caribou range intercepts snow and allows caribou greater mobility during the winter when deep snow would otherwise preclude the animals from moving between and on seasonal ranges (Stevenson and Hatler 1985). Such changes have also resulted in pine and pine/spruce forests of western Alberta (Edmonds and Bloomfield 1984).

A second aspect of modern silviculture is the management of forests by changing the composition of the forest from natural species to a more commercially desirable species. In Sweden, the natural climax spruce forest is being replaced by the more commercially important pines (Eriksson 1985). Because pines have fewer lower branches, there is less substrate available upon which arboreal lichens can be established (ibid.). As a result, forage lichen availability on these managed forests has declined, and domestic reindeer range has been reduced (ibid.).

5.4.2 Direct Effects on Individuals

A significant effect of modern logging operations is the road access that is constructed to logging sites. This increased access in turn has resulted in increased harvest. The increased harvest has been considered responsible for initiating declines in caribou herds in the British Columbia Rocky Mountains (e.g., Raven Lake Herd, Bloomfield 1979; Selkirk Herd, Carlton

1982, Freddy 1979, van Zwoll 1982); in the Soviet Union, where increased access and harvest occurred concurrently with habitat destruction (Shtil'mark 1984, Syroechovskii 1984a); and western Alberta (Edmonds and Bloomfield 1984).

Logging has also been responsible for creating conditions conducive to increased predation. Bergerud (1983) concluded that logging in British Columbia not only created access for hunters but also created easier access for wolves to reach mountain caribou habitat by following logging roads. A more widespread impact is the habitat change brought about by reducing logged areas to seral stages of succession, which in turn resulted in an increase in deer and moose numbers. The increase in these prey species facilitated the increase in wolves. Although caribou are not the primary prey species of wolves, for these small, isolated mountain caribou populations, the loss of even a small number of caribou to wolves has a proportionally high effect on the caribou population (ibid.). A similar situation occurred in southern Ontario where wolves increased following logging, and the increased wolf predation was at least partially responsible for the decline of several small woodland caribou herds (Darby and Duquette 1985).

In the New England-southeastern Canada region, the faunal changes that accompanied land clearing and logging resulted in white-tailed deer expanding into eastern woodland caribou range, and the subsequent transmittal of the fatal meningeal disease to caribou (ibid.).

Logging operations also create physical and behavioral barriers to caribou movement through the area (Eriksson 1975, ibid.). Windrows of logging slash create physical barriers to passage (Bloomfield 1979). The extensive open areas created by clearcutting are avoided by mountain (ibid.) and woodland caribou (Darby and Duquette 1985), and in parts of the Rocky Mountains these areas contain such deep snow that they became impassable in winter (Bloomfield 1979, Carlton 1982, Freddy 1979, Stevenson and Hatler 1985, van Zwoll 1982).

Snow conditions in clearcut areas are also modified such that even if sufficient terrestrial forage is present, caribou would be unable to use it. In Swedish pine-lichen forest, clearcuts often contain shallower snow due to wind; as a result periodic thaws create icy layers in the shallow snow through which domestic reindeer cannot crater (Eriksson 1975).

Chemical application to forests has resulted in poisoning of individual caribou, and decreases in palatability of preferred lichen range such that cratering was adversely affected. Klein (1971) reported that after numerous domestic reindeer had been poisoned inadvertently by aerial application of herbicides (2,4-D and 2,4,5-T) such use in Sweden was banned. Forest fertilizers such as urea and ammonium nitrate have been tested under field and enclosed conditions; effects have varied from diarrhea and bloat (Rajala and Westerling 1980) to cessation of feeding following treatment of forage (Erikkson 1975, Nordkvist and Erne 1983). In most situations, the effects of ammonium nitrate are less severe than those of urea, for which toxic poisoning has been documented. In areas where ammonium nitrate has been applied the effects were minimal if reindeer were not allowed onto the range until after the ammonium nitrate had been dissolved by rain (Nordkvist and

Erne 1983). Eriksson (1975) found that domestic reindeer cratered significantly less in lichen forest that had been treated with urea than in untreated control areas.

5.5 GROUND TRANSPORT

Ground transport includes linear transportation systems (e.g., roads, railroads, pipelines) and off-road travel by vehicles or "pedestrians." Linear transport systems have been a major component of most human developments and land uses, and have been partially discussed in other sections of this report. The effects of transport systems such as railroads in opening vast areas of the Soviet Union to human developments and land uses were discussed in section 4.4. Similarly, general effects of transport systems in Fennoscandia were discussed in section 4.5. The impact of the Norilsk-Messoyhaka gas pipeline in the Soviet Union was summarized in section 4.4, and it and other examples of impacts of ground transport systems that are relevant to oil and gas development and the Central Arctic Herd are discussed in Volume II.

The two aspects of ground transport, linear facilities and off-road travel, can have direct impacts (i.e., acting on the animals themselves) and indirect impacts (i.e., acting on the habitat either by changing it or by disrupting its use by the animals; or by creating conditions that disrupt the relationship of caribou with other species--e.g., increased access to predators or hunters). Discussion specific to these types of impacts is presented below.

5.5.1 Linear Transport Systems

Direct impacts to caribou caused by linear transport systems include collisions with vehicles, and the creation of physical or behavioral barriers to movement. Barriers to movement, in turn, result in disruption of access to habitat and increased harvest or predation.

Collisions with automobiles along a major highway through the range of the Selkirk Herd has been a major mortality factor over the past decade in that small, remnant mountain caribou herd (Carlton 1982, Freddy 1979, Freddy and Erickson 1975, Johnson and Miller 1979, Johnson and Todd 1977, van Zwoll 1983). The Trans-Canada Highway bisects the range of the herd, and during migration animals frequently encounter traffic on the road. In addition, animals are attracted to the road to lick salt applied as a melting agent. In another area of British Columbia, collision with a Canadian National Railway train killed 17 woodland caribou out of a herd estimated to contain 35 to 100 animals (Stevenson and Hatler 1985). Collision mortality is a small but increasingly important source of mortality for the small woodland and mountain caribou herds in western Alberta (Edmonds and Bloomfield 1984). In Finland, collisions account for mortality to at least 2% of the total domestic reindeer population there each year (Koskela and Niemenen 1983). Collisions often occur when domestic reindeer are attracted to snowfree areas along railroads and highways during winter, and to highways during summer when hot air rising from the pavement reduces insect harassment (ibid.). Klein (1971) reported examples of collisions along railroads and roads in other areas of Fennoscandia.

Physical barriers to movement include steep road cuts, berms, and slash piles along logging roads and main highways (Bloomfield 1979, 1980; Carlton 1982; Klein 1971; van Zwoll 1983); snowberms (Klein 1971, van Zwoll 1983); snowfences to protect highways and railroads (Klein 1971, Skogland and Molmen 1980); and pipelines laid on or near the ground (Villmo 1975).

Behavioral barriers to movement often are the result of caribou reactions to a novel stimulus, or disturbance associated with types of passive harassment such as traffic or viewing, or active harassment such as hunting. In Sweden, domestic reindeer were observed to balk at crossing under powerlines, thus disrupting herding (Villmo 1975). The novel stimulus of a large opening in the forest, the "hum" of the powerlines, and change in snow conditions were thought to be responsible for the animals' reaction (ibid.). In some cases the reaction persisted up to 10 years after the line was constructed (ibid.). Wild mountain reindeer in Norway were observed to avoid crossing powerlines except where the line was the least visible (Gaare 1985, pers. comm.).

Other causes for behavioral barriers have often appeared to be caribou associating the facility with some form of harassment such as traffic or hunting. Caribou herds in Newfoundland are distributed in areas away from high-use road systems and settlements, and the "centers of habitation" (cf. Skoog 1968) and especially calving areas are located at maximum distances from such developments (Mercer et al. 1985). On the Avalon Peninsula, caribou have recently re-invaded historic summer range; in doing so they have begun to cross a gravel road with an average of 15 vehicles/hr during daylight hours (ibid.). However, these caribou remain 3-4 km (2 mi) from the road systems and towns, thereby reducing their effective summer range 182 km^2 (70 mi^2) available to only 21 km^2 (8 mi^2) that is used (ibid.). Northcott (1985) and Hill (1985) noted that caribou summer use of the area influenced by construction of the Upper Salmon Hydroelectric Development declined during construction, but recovered somewhat after construction. Most caribou were observed to approach trafficked access roads, reverse direction, and move 1.5 km (1 mi) from the area. Those animals that did cross the roads did so when the roads were closed to traffic, or at night when traffic was sporadic (Northcott 1985). In all cases, caribou appeared to react to the construction activity rather than to the facilities.

In Newfoundland, woodland caribou were much easier to approach from a highway after hunting had been closed there for a number of years (Bergerud 1980b). Dufresne (1946) and Georgeson (1904) reported that in the early part of this century in Alaska caribou were "becoming scarce along the trails," presumably because caribou were associating with being hunted, and were avoiding the trail network used by early day travelers.

Bergerud (1978) and Bergerud et al. (1984) state that the most important impacts of linear transport systems are to provide conduits for increased predation and/or hunting, and to prevent caribou from having access to adequate space in which to evade predators. In their view the most important component of caribou habitat is "space" rather than "forage." Bergerud et al. (1984) believe that misinterpretation of caribou behavior in response to encounters with roads and other linear facilities has created the misperception that many linear developments have impacted caribou by interfering with their access to forage. Bergerud et al. (1984) and

Jakimchuk (1980) cite several examples in which caribou movements have been disrupted by linear facilities, and in these same instances no effect on the population was measured. This argument will be examined in detail in Volume II.

5.5.2 Pedestrian and ORV Traffic

In addition to impacts on caribou movements caused by linear facilities, impacts caused by pedestrian and off-road vehicle (ORV) traffic have also been documented. Several authors noted the effects of snowmobile use upon caribou. Muller-Wille (1975) reported that the increased use of snowmachines by Lapp domestic reindeer herders has resulted in domestic reindeer, which are normally much more sedate than caribou, becoming more easily frightened and prone to stampeding. Valkenburg and Davis (1985) attributed differences in response to aircraft by caribou of the Western Arctic and Delta herds to the more common use of snowmachines for hunting by residents in the range of the former. Stevenson and Hatler (1985) note that harassment by snowmobiles has resulted in fragmentation of bands of mountain caribou in the Telkwa range, and elsewhere in central British Columbia snowmobile active and passive (e.g., unintentional) harassment of mountain caribou is becoming a serious management problem. Increased snowmachine access is considered to be an important impact of logging on small mountain and woodland caribou herds in western Alberta, not only because of the potential for harassment and poaching of caribou, but also because snowmobile trails can provide easier movements through deep snow by predators (Edmonds and Bloomfield 1984).

Dean and Tracy (1979) found that although bus and auto traffic along the Denali National Park road caused some disturbance to caribou, the effects were dramatically exacerbated when passengers disembarked from the vehicle; this herd has been hunted only lightly or not at all for a number of years. Skogland and Molmen (1980) conclude that in the Dovrefjell region of Norway, pedestrians (e.g., hikers, hunters, skiiers) cause more disturbance to caribou than do linear facilities. Although direct impacts to populations have not been identified from active and passive harassment due to pedestrian or ORV use, impacts on habitat use have been documented. Sokolskii (1984) noted that cratering for lichens in winter by a caribou herd disturbed by humans on foot was one half that of an undisturbed herd. Reimers (1980) determined that the absence of insect and human harassment allowed caribou on Svalbard to forage sufficiently during summer to survive the severe winter--if Svalbard caribou were subjected to the same level of insect and especially human harassment as were animals of mainland Norway herds (e.g., Hardangervidda), the former would likely not be able to survive (see discussion in section 3.2). These observations strongly suggest that the effects of linear facilities and/or off-road traffic may have important consequences to foraging success of some caribou herds, and that these effects on foraging success can ultimately result in declines of some populations.

5.6 HYDROPOWER

Much of the documentation concerning hydropower impacts on Rangifer is from Scandinavia, where numerous hydropower reservoirs and associated electrical transmission systems have been constructed in wild and domestic reindeer

range (Klein 1971, Villmo 1975) and from eastern Canada (e.g., Northcott 1985).

A major impact in Fennoscandia was the flooding of productive summer and winter range (Klein 1971). Barriers to migration that were created by flooding river valleys (e.g., Skogland and Molmen 1980) to create impoundments, and variations in flow from the impoundments in winter resulted in the formation of intermittent ice "shelves" sloping toward the reservoir (ibid.). Reindeer crossing these shelves slid into the reservoir and drowned because they were unable to climb back out, or were injured in falls on the ice. This same series of events occurred in areas downstream from the reservoir where fluctuations in water levels occurred (ibid.). A spectacular example of mortality caused by water fluctuations downstream of a reservoir received widespread public attention. In September 1984, an estimated 10,000 caribou of the George River Herd drowned while attempting to cross the flood-swollen Caniapiscau River. Although Hydro-Quebec attributed the flood level to natural causes, subsequent review of the event lends strong credence to claims that the river was abnormally high because Hydro-Quebec had released water from a new reservoir (Williams 1985).

In British Columbia rafting of floating debris in the reservoir behind Kenney Dam created a barrier to moose and caribou movements across the reservoir, but also minimized use of the reservoir for boat access by caribou hunters to caribou range (Stevenson and Hatler 1985).

Secondary impacts in Fennoscandia and in North America resulted from the human activity along roads linking the projects with settlements, and from behavioral barriers caused by the clearing and noise and visual stimuli associated with electrical transmission lines (ibid.). These impacts are discussed in Section 5.5, Ground Transport.

Many of these same impacts are anticipated for the proposed Watana-Devils Canyon dam in the range of the Nelchina Herd in Alaska (Pitcher 1982, 1983, 1984). The impacts of this hydro reservoir may be especially serious to pregnant cows that currently use a traditional migration route through the proposed impoundment area (Pitcher 1983). Additional anticipated impacts include the rafting of debris (e.g., floating timber) for several years after the reservoir is filled that could pose a barrier to caribou swimming across the impoundment, and mortality or injury to caribou due to collision with vehicles along access roads to the dam (Pitcher 1984).

5.7 NUCLEAR TESTING

The discussion in the literature regarding the impacts of nuclear testing on Rangifer is limited, and pertains only to the absorption by lichens and other foreage plants of radionuclides which have resulted from atmospheric nuclear testing in the 1950's and 1960's. The cycling of these radionuclides through the food chain (i.e., lichen to caribou to man or wolf) has been documented in Alaska (Holleman 1977, Klein 1971) and Finnish Lapland (Jaakola 1975). The accumulation and decay of fallout radionuclides has been used in both of these studies as a method for determining predator-prey food habits.

No deleterious affects on Rangifer were documented in the two studies mentioned previously; however, Skrobov (1984) made the general statement, unsubstantiated by corroborating data, that one cause for the decline of caribou in the Soviet Union included "... destruction of animals and their food resources by radioactive fallout."

5.8 REINDEER HUSBANDRY

Several authors in the literature note conflicts between caribou and domestic reindeer grazing operations and report on various facets of the problem. Although the basic components are similar in the two areas from which these conflicts have been reported (i.e., the northern USSR in Europe and Asia; and Alaska in North America), impacts to caribou have differed substantially due to differences in public policy. Impacts to caribou documented in the literature fall into several broad categories of conflict, including; intentional attempts at extermination, disease transmission, competition for forage, mixing of genetic stocks, and human influences related to reindeer grazing. In addition to the above effects upon either caribou alone or upon caribou and domestic reindeer interchangeably, some factors (e.g., predators accompanying caribou into domestic reindeer ranges) cause impacts to domestic reindeer only.

The most direct effect upon caribou from domestic reindeer grazing has been their direct extermination by herders seeking to eliminate competition for range and to prevent the incorporation of domestic reindeer into passing caribou herds. As is discussed in section 4.4 above, the literature refers to changes in distribution, numbers, and even the extirpation of some caribou populations in the USSR as national policy encouraged the expansion of the reindeer industry as a way to exploit range resources. In recounting the history of wild forest reindeer in Karelia, Danilov and Markovsky (1983) show how the wild animals were eliminated from areas important for domestic grazing, and then rebounded in numbers and reoccuppied range only as domestic grazing operations ceased. Intentional "control" activities have made caribou so rare in some areas of the USSR that they are now completely protected in such areas (Klein and Kuzyakin 1982). Other authors referring to this effect of the Soviet reindeer industry include Skrobov (1984), Sokol'skii (1984), Egorov and Popov (1984), and Vershinin et al. (1984). In recent years new views have begun to affect the management of Rangifer in the USSR (e.g., Syroechovskii 1984b), since value is now placed upon preserving caribou populations. This, combined with the abandonment of many domestic reindeer herding operations (due either to collectivization or the realization that domestic reindeer are less efficient than caribou in zones of sparse range resources or where seasonal ranges are widely separated), has resulted in the recent resurgence of some caribou herds. While Soviet management often still emphasizes maximum resource exploitation, there is a new realization emerging that perhaps caribou are the most "rational" means to that goal (Syroechkovskii 1984a), at least in some regions.

There is also the assertion in the literature that other human activities associated with domestic reindeer herding can also have an effect upon caribou. Hunting, poaching, construction of transportation corridors, and the mere presence of human habitation are cited as activities linked to herding (as well as other industries) which have affected mortality rates and/or range occupancy by caribou (Skrobov 1984, Vershinin 1984).

Unfortunately, these rather general summaries fail to deal specifically or quantitatively with such impacts.

In North America, government policies have not been directed towards "cleansing" areas of caribou in order to allow unhindered reindeer grazing. Rather, both the domestic and wild forms of Rangifer have had to exist in the face of competition from the other. This has led to an inverse relationship between caribou and domestic reindeer abundance (i.e., when caribou populations are small, then domestic reindeer herds can become large, but when caribou numbers expand, domestic reindeer operations fail). In the absence of the direct control activities characteristic of past Soviet management, caribou in Alaska and Canada are seemingly more affected by intraspecific competition with domestic reindeer (which also occurs in the USSR where caribou and domestic reindeer are present together--ref. Yakushkin et al. 1984). Competition for forage, disease transmission, genetic mixing, and predator relationships are all mentioned as factors in how caribou and reindeer interact (Adams and Robus 1981, Klein 1980a).

A commonly held belief is that overgrazing by domestic reindeer can displace caribou from ranges (Skrobov 1984, Murie 1935, Sokol'skii 1984, Metel'skii 1984) and further, that caribou can be prevented from reoccupying ranges even after domestic reindeer have abandoned the area if grazing pressure has been severe enough (Dufresne 1946, Leopold and Darling 1953). Implicit in the above relationship is the assumption that Rangifer can deplete range resources through grazing and/or trampling, which has been documented for feral reindeer in insular conditions (Klein 1968) and is alleged by several authors to have occurred in portions of Alaska and the Soviet Union where domestic reindeer herding has occurred (Dufresne 1946, Leopold and Darling 1953, Sokol'skii 1984, Zvezdkin 1984). Another assumption used in supporting the idea that domestic reindeer grazing pressure can displace caribou is that complete, or at least significant dietary overlap exists between caribou and domestic reindeer herds (Klein and Kuzyakin 1982, Zagordoskii and Reimers 1984). Some evidence exists that this is not necessarily the case. Syroechkovskii (1984a) mentions that domestic reindeer have a lichen-dominated diet, whereas caribou have a higher proportion of graminoids and heaths in their food. In contrast, experience in Alaska has shown that on winter range domestic reindeer can be held in an area and forced to eat less palatable species in addition to lichen, whereas caribou tend to be constantly on the move, taking palatable food from an expansive area (David O. Scott, Jr., pers. comm. to M.H. Robus). These observations may reflect the availability of food, rather than active selection. At any rate, there is some reason to believe that heavy grazing may not absolutely exclude either caribou or reindeer from an area, although carrying capacity may certainly be reduced.

A further complication in estimating the impacts of reindeer grazing upon caribou is that in most cases, other events also occur which may obscure the effects of range depletion. For example, Skoog (1968) believed that the absence of caribou from the Seward Peninsula (Alaska) during most of this century was due to natural changes in herd size and distribution, rather than as a response to heavy grazing by reindeer. He points out that the caribou (part of what is now called the Western Arctic Herd) had vacated the Seward Peninsula prior to the introduction of reindeer (indeed, the resulting perception of a shortage of meat led to the introduction of

reindeer). Since then, the Western Arctic Herd has used several different areas of its potential winter range, including the eastern end of the Seward Peninsula in many years (pers. obs. M.H. Robus). To date, large scale reoccupancy of the Seward Peninsula by caribou has not taken place, despite low reindeer stocking rates, adequate forage, and an expanding caribou population. Similarly, although many of the Soviet authors cite range depletion as an impact to caribou, one wonders if the policy of exterminating caribou mentioned above does not overshadow range depletion as a reason for the displacement of caribou from areas grazed by domestic reindeer.

Despite the inability to isolate range depletion as a factor which definitely displaces caribou from reindeer ranges, it is mentioned by so many authors from both eastern and western hemispheres that it should be taken into account when considering intraspecific conflicts between domestic reindeer and caribou. Certainly, if severe reindeer grazing pressure destroys a range's capacity to support Rangifer, then this factor could affect the distribution of caribou in subsequent years.

Perhaps the most puzzling aspect of the widely-held notion that caribou are "displaced" by reindeer grazing is its disagreement with the observed nature of reindeer-caribou interactions. One of the most commonly accepted rules of Rangifer behavior is that when domestic and wild animals meet, the domestic reindeer tend to turn wild and are "captured" by the caribou herd. On the other hand, caribou do not generally mix in and become part of reindeer herds, and are not repelled from an area just because reindeer are present. Therefore, it is likely that the term "displacement" conveys the wrong meaning when discussing the impacts of domestic reindeer grazing upon caribou. It is likely that the initial displacement of caribou from ranges is due to factors other than reindeer grazing pressure, such as direct extermination, increases in hunting, or disturbance from human activities. However, as mentioned above, it is conceivable that severe grazing pressure could prevent reoccupancy of an area by caribou, even after abandonment by domestic grazers.

Another potential impact is related to the "capture" of domestic reindeer by caribou which has been noted so often. Some authors (Dufresne 1946, Murie 1935) mention a concern about interbreeding and the addition of genetic material from domestic reindeer to the gene pool of the caribou, fearing that the quality of caribou would decrease due to the effect of introducing "inferior" (i.e., domestic) animals. In his paper reviewing conflicts between wild and domestic Rangifer, Klein (1980a), discounts these genetic effects primarily on the basis of asynchronous breeding, the inability of reindeer to tolerate the rigors of life in the wild, the small proportion of introduced reindeer in relation to total caribou numbers, and the smaller size and weaker migratory urge of the domestic animals. Skoog (1968) also believed that the ratio of "captured" domestic reindeer to caribou was small, and further, thought most of the intraspecific differences were recessive and would not significantly alter the genetics of caribou even if interbreeding took place. Other concerns related to "capture" are 1) the herder's desire to protect domestic herds, leading to the attempts at direct extermination mentioned above; and 2) the loss of domestic reindeer to caribou herds which is not in itself an impact to caribou.

The chance for disease transmission is also mentioned as a conflict between caribou and domestic reindeer (Klein 1980a, Skrobov 1984). Depending on the levels of infection in the respective herds, disease can be passed in either direction between wild and domestic Rangifer. Due to high densities, control of scavengers, and short migrations, domestic herds are often more highly diseased than their wild counterparts, although under intense, therapeutic management the opposite could be true. In some cases, the timing of contact between herds minimizes the chance for disease transmission. For instance, in northwest Alaska, domestic and wild herds are usually far apart at the times when chances for disease transmittal are greatest (i.e., calving, summer, breeding).

Other conflicts between caribou and domestic reindeer (e.g., predation, land use designations) have their impact primarily upon the domestic animals, and will not be discussed here.

5.9 WATER TRANSPORT

The only documentation of the impact of water transport on caribou pertains to icebreaking activity along the Yenisey River, in the Taimyr region USSR, in order to prolong the shipping season for the port of Dudinka (Klein and Kuzyakin 1982; Geller and Borzhanov 1984). The open water and jumbled ice floes produced by ice breaker operations resulted in direct mortality of numerous Taimyr caribou as they encountered the river during fall migration to winter range in southern Taimyr region. Several thousands of additional caribou were prevented from reaching their normal winter range, and were forced to winter in areas considered less suitable (ibid). Starvation of animals, especially calves, was noted that winter in winter range along the Yenisey River (Geller and Borzhanov 1984); however, it was unclear whether the authors were attributing this directly to the disruption of migration that had been created by the ice breaking activities.

Recently, concern has been expressed that the transport of liquified natural gas by ice-breaking tankers among the islands of the Canadian Arctic Archipelago may result in barriers to inter-island movements by the endangered Peary caribou of the Queen Elizabeth Islands (Gunn and Miller 1983). Such inter-island movements are thought to be important for maintaining the Peary caribou population. Not only are seasonal ranges located on different islands, but also such movements may result in the natural restocking of islands which have been depleted of caribou because of winter starvation or overharvest (Miller et al. 1977).

In western British Columbia a "bubble system" was devised to keep a river open for log rafting and booming during the winter (Stevenson and Hatler 1985). Because this open water was thought to be a potential barrier to caribou movements, a fence was constructed along the river to divert caribou from the area (ibid.).

6.0 DISCUSSION

There appears to be no dispute in the literature that in the Northern Hemisphere, caribou distribution and numbers have declined from their historic levels, and that the declines have accelerated over the past century as human settlement and accompanying development have expanded

numerically and geographically. Numerous examples of extirpated or declining herds from North America and Eurasia attest to this fact. Unfortunately, agreement about the specific human activities (e.g., hunting, logging, ground transport) that have caused the declines has not been as forthcoming. This lack of consensus has been due in part to the scarcity of objective information during the period of historic settlement; and in part because there is no clear agreement among modern caribou researchers about the relative roles of various influences on caribou population dynamics. This lack of consensus is especially noticeable in discussions about the relative importance of forage quality, quantity, and availability, and caribou-forage interactions, as compared to the effects of hunting, predation, and/or disease (ref. Section 3.0).

Many of the impacts of land uses and developments which have been discussed earlier in this report have included those that have had immediately noticeable consequences on individual animals (e.g., direct mortality due to predation or hunting that has been caused or aided by the type of development). There appears to be considerable agreement about these types of impacts. For example, Cringan (1969) and Bloomfield (1979) conclude that the initial cause for the declines of eastern woodland caribou and mountain caribou, respectively, were due to overharvest, but they also conclude that the reason for the herds not increasing once controls on harvest were implemented was that the habitat had been severely altered, also as a consequence of human land use. This type of synthesis also appears often in the Soviet impact literature. Declines were often initially caused because of deliberate extermination by reindeer herders; once the herds had declined, recovery by the population and/or expansion to its original range was slowed or eliminated because of habitat destruction (e.g., Syroechovskii 1984a, Skrobov 1984).

In some cases, direct impacts have been exactly that--collision with vehicles, including trains, has figured in mortality of domestic reindeer in Sweden (Nordkvist 1980), caribou in Taimyr (Klein and Kuzyakin 1982), and mountain caribou in British Columbia (Carlton 1982, Stevenson and Hatler 1985). In most cases, this type of mortality is a small increment to the total mortality affecting a population. Nevertheless, in the case of the Selkirk Herd and other small herds of mountain caribou, even a small number of deaths due to collision with highway vehicles or trains has been a major mortality factor in this extremely small population. Additional impacts have included habitat changes that indirectly affected caribou herds by increasing the number of predators, or by introduction of disease (i.e., meningeal worm from deer to eastern woodland caribou). In most caribou herds of northern Canada and of Alaska, predation and subsistence and/or sport hunting have been more important than land use or developments in regulating populations (e.g., Bergerud 1983, Bunnell et al. 1975, Porcupine Herd; Calef 1980, Northwest Territories; Davis 1980, Alaska; Davis et al. 1983, Delta Herd; Juniper 1980 and Meredith 1983, George River Herd; Simmons et al. 1979, Kaminuriak Herd).

In some instances, land use regulations implemented to protect caribou habitat during mineral exploration and development activities may be preventing impacts. Examples of such controls include the Caribou Protection Measures implemented by the Canadian federal government for protection of the Beverly and Kaminuriak herds (Clement 1982; Cooper 1981;

Darby 1978, 1980). Such controls emphasize protection of calving areas and protection of river crossings. Some provisions of these measures include protection of calving areas from human harassment, a recommendation by Bergerud et al. (1984). Interestingly, the Soviets emphasize protection of winter range, and seldom mention impacts to calving grounds (Syroechovskii 1984b).

Because many of the impacts of various land use activities have been discussed in the literature with the a priori assumption that caribou are forage-limited, it follows that one's assessment of a habitat alteration as an "impact" is as dependent on one's philosophical viewpoint as it is on any real effect of the activity on individual caribou or the population. For example, all the effects of such activities as logging, agriculture, or domestic reindeer husbandry, that relate directly to a reduction of available forage, or to interruptions of access to forage habitat, become moot if one assumes that forage is not a factor in regulating mainland caribou until populations reach densities that have not been heretofore reported in the literature. We know from the St. Matthew Island case (Klein 1968) that in the absence of the capability to disperse to new areas, North American caribou do not appear to have any inherent ability to regulate their populations in the face of decreasing forage. However forage-related sources of calf mortality have been identified for domestic reindeer (Baskin 1983) and caribou (Geller and Borzhanov 1984) in the Soviet Union, and for wild mountain reindeer in Norway (Reimers 1983, Skogland 1985). Skogland (1983, 1985) has analyzed data from wild mountain reindeer herds in Norway and established the relationship between forage quality/quantity and calf production and survival--according to him, both are directly related to winter range quality. Reimers (1983) believes that summer range quality is equally important. Although no similar linkage has been established between forage quality/quantity and calf production/survival in North American caribou, this and other information suggests that such a linkage may exist. It is possible that such a relationship would not become apparent in North America until caribou herds are confined to such small areas that hunting and predation can no longer mask the effect of decreased forage. Until that point is reached, however, there is sufficient information to suggest that we should be concerned with protection of caribou forage habitat and access to that habitat, and that land management options should include caribou habitat protection measures. Because hunting is a form of harassment, irrespective of its immediately fatal consequences, that can exacerbate other forms of harassment, it creates its own type of impact. In summary, it seems that no single theory has adequately addressed all caribou management situations. Caribou managers must be aware of the strengths and weaknesses of the different theories in order to be able to address and resolve complicated management issues. It is clear, however, that both population management, in the sense of harvest and predation regulation and maintenance of habitat (and access to habitat) should be reflected in caribou management programs.

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8.0 ANNOTATED BIBLIOGRAPHY OF SELECTED REFERENCES IMPACTS OF HUMAN LAND USE AND DEVELOPMENTS ON CARIBOU

The attached bibliography includes annotated references concerning the impacts on Rangifer of human land use and development activities, excluding those of oil and gas exploration and development. A second volume, Technical Report 86-3, is devoted to the topic of impacts of oil and gas exploration and development on caribou of Alaska's Central Arctic Herd. The subject bibliography includes direct references to impacts information, as well as additional references that are deemed appropriate for a thorough understanding of the impacts references. Therefore, the references annotated here should not be viewed as a complete compilation of all literature references to Rangifer, nor of all references to impacts to Rangifer. However, these annotations do represent a significant portion of this literature.

The organization of each annotation consists of a summary of the original author's(s') conclusions and observations, either paraphrased or as a direct quote. Comments by the reviewer are enclosed in brackets [ ], and if the comments are more than a few words, are often preceded by "Reviewer's note" ([Rev. note:...]).

Adams, L.G., and M.H. Robus. 1981. Caribou and domestic reindeer grazing on public lands in Alaska: introduction to a unique management problem. Pages 319-328 in Transactions of the 46th North American Wildlife and Natural Resources Conference. Wildl. Mgt. Inst., Washington, D.C.

This review paper examines the impacts and conflicts that are facing land managers because of a desire to increase domestic reindeer grazing on winter ranges that are also used by wild caribou. Increased reindeer grazing is proposed for the eastern Seward Peninsula, Alaska, an area that is currently used by the Western Arctic Caribou Herd as winter range. The authors provide a history of the Western Arctic Herd and a history of the domestic reindeer grazing industry in northwestern Alaska.

Relevant observations and conclusions include the following:

(1) The main area of conflict exists with the Hadley Allotment, a BLM grazing allotment held by a Native corporation on the eastern Seward Peninsula. Authorization to graze reindeer on the eastern section of this allotment during winter is currently withdrawn because of use of the area by 15,000-30,000 caribou of the Western Arctic Herd. To resolve the conflict, the land managers must make their decision in light of socioeconomic and ecological conflicts. Reindeer grazing can be allowed to increase, providing 1) additional income to Native residents of the area from the sale of meat, hides, and antlers, 2) a source of red meat, 3) a source of employment, and 4) grazing conflicts with wild caribou. Conversely, maintenance of a healthy Western Arctic Herd population is also important as it provides a subsistence meat source for many of the 10,000-15,000 people of northwestern Alaska, an economic asset to the Alaskan economy from sport hunting, and a resource of "national and international significance."

(2) The authors felt that interactions of the reindeer industry with wild caribou should be minimized and that before expanding onto caribou range, the reindeer industry managers should stock ranges already dedicated to reindeer grazing, and not used by caribou, to their potential.

(3) Conflicts mentioned between domestic reindeer and caribou included 1) loss of reindeer to caribou herds, 2) loss of reindeer from wolves that follow migrating caribou into reindeer ranges, 3) forage competition, and 4) transmission of diseases such as brucellosis.

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Bangs, E.E., T.H. Spraker, T.N. Bailey, and V.D. Berns. 1982. Effects of increased human populations on wildlife resources of the Kenai Peninsula, Alaska. Pages 605-616 in K. Sabol, ed. Transactions of the 4th North American Wildlife and Natural Resources Conference 1982. Wildl. Mgt. Inst., Washington, D.C. 722 pp.

This paper opens by quoting a letter written by Dall DeWeese in 1902 extolling the abundance of wildlife on the Kenai Peninsula and then contrasts that with statements made in papers by Culver (1923) and Palmer (1938) regarding the decimation of many wildlife populations there. The authors then synopsize the history of impacts and management that have occurred for key species in an effort to document the significance of expanding human populations with respect to wildlife.

The following pertinent information is included:

(1) Caribou were common but probably not abundant on the Kenai Peninsula in the 1800's. With the influx of gold miners in 1890, large man-caused fires converted vast areas of mature forest to early successional stages. The authors believe that with much of the climax vegetation on the peninsula converted to early seral stages, caribou numbers declined. Remaining pockets of animals were later eliminated by commercial and unregulated hunting. [Rev. note: The paper by Davis and Franzmann (1979) is the only reference given at the end of the passage containing the above; however, only the latter statement reflects the position of Davis and Franzmann. Although Davis and Franzmann did acknowledge that total range carrying capacity for caribou decreased with widespread burning, they did not link this with declines in populations and, in fact, stated that ample caribou range probably still existed subsequent to the big fires. It should be noted that Bangs et al. give no evidence of die-offs of caribou, although that period is well enough documented that these probably would be recorded had they actually occurred.]

(2) The article goes on to review the reintroduction of caribou to the Kenai Peninsula. Two small viable herds have become established, one in a limited alpine area of the Kenai Mountains, the other in lowlands near the city of Kenai. Both ranges are atypical, compared to other Alaskan habitats.

The Kenai Mountains herd showed good productivity until the range's carrying capacity was approached. According to the authors, productivity "declined sharply during the mid-70's as the herd reached carrying capacity." [Rev. note: This is an extremely interesting statement in light of the arguments presented by Bergerud (1983), in which he states that reproduction and survival in growing caribou populations remain relatively constant through the point of range overuse and that no density-dependent negative feedback seems to occur to slow productivity. One wonders if the term "productivity" is used loosely by Bangs et al. to mean "growth of the herd." It seems likely that the herd stopped growing because of hunting and predation mortality equalling (or exceeding) recruitment and that total numbers were within range-carrying capacity when this happened. It is impossible to make further conclusions because no evidence or references are presented. On the surface however, this is a paper that advocates range capacity being the proximate limiting factor for caribou over the hunting/predation theory.]

(3) The second herd occupies lowlands near the town of Kenai. Poor recruitment has plagued this herd, with domestic dogs being cited as

the major factor in calf mortality, even though wolves and black bears are also abundant. Human disturbance is also cited as a negative effect to this herd.

(4) The section of this paper devoted to caribou ends by restating that past habitat alteration limits caribou on the Kenai Peninsula [statement contrary to Davis and Franzmann (1979)]. Although overharvest problems are allegedly solved, "the slow successional rate of boreal forest ecosystems and non-consumptive human activity continue to affect caribou distribution."

[Rev. note: Portions of this article run counter to many modern works on caribou. Without better evidence for their conclusions, the authors' opinions should be regarded with caution. They seem to have disregarded published information from as far back as 1935 (Murie) that dispells the notion that caribou are necessarily dependent on climax forest.]

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Baskin, L.M. 1983. The causes of calf mortality. Acta Zool. Fennica 175:133-134.

This paper is a report of the causes of mortality for calves from a population of 189,700 female domestic reindeer in Kamchatka, USSR. The study was performed in order to estimate the causes of mortality within wild herds, in the belief that mortality factors would be similar for domestic and wild herds. The latitude and climate of Kamchatka is similar enough to Alaska to allow extrapolation, although it is not clear from the paper whether the animals studied were on forested or tundra ranges.

The following relevant information is presented:

(1) The largest factor contributing to lack of recruitment in the herd was barrenness (8.45% of females). Although the author discusses the role of bulls in provoking the oestrous cycle in cows, he felt that the observed rate of barrenness could not be improved through introducing more males, as the sex ratio was adequate for complete breeding. Also, because of the social hierarchy, additional bulls would likely not change the effective sex ratio anyway.

(2) Intrinsic factors, such as abortion, "monstrous" calves, and weak calves accounted for a total calf mortality of 3.747% (of total adult females), with abortion being by far the most important component of this (2.89%).

(3) External factors, including predation (0.356%), dogs (0.045%), disease (1.063%), and weather (0.355%) accounted for 1.819% of total females.

(4) Accidents and abandonment caused the deaths of .970% (total females).

(5) Mothers without milk caused 0.105% (of total females) calf mortality. The author believes that lack of a stable mother-calf bond makes it

impossible for the calf to follow its mother, causing interruption to lactation, in turn causing a cessation of maternal behavior. Many of the young lost to weather could probably be attributed to this problem.

[Rev. note: Losses from category (5) are included here in order to show that some additional weather or accident-oriented mortality occurs. Because no human activities are examined, the article is of limited use for this review.]

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Bergerud, A.T. 1974. Decline of caribou in North America following settlement. J. Wildl. Manage. 38(4):757-770.

This article examines four hypotheses that have been proposed in order to explain the general decline of caribou in North America in the late 1800's and early 1900's. The hypotheses are 1) numbers decreased because of a shortage of lichen supplies caused by the destruction of lichen pastures by fire and logging, 2) numbers decreased because of increased hunting mortality, augmented by increased wolf predation, 3) a combination of 1 and 2, and 4)) caribou declined in Alaska because of increased movement to marginal habitats under the stimulus of high densities.

The following pertinent information is presented:

(1) Discussing hypothesis 1 (range destruction), Bergerud notes that a long series of authors have reported this condition (usually attributed to fires or logging) as the factor causing caribou declines. He states that in order for this hypothesis to be valid, three component premises must stand: a) survival of caribou is dependent upon the abundance of lichens; b) settlement accelerated the frequency of fire and logging that destroyed climax lichen floras; c) man's impact in reducing habitat and forage caused the decline of herds. Even if a) and b) are true, c is not necessarily true, unless a causal relationship can be shown. However, if a) or b) are not true, then c) cannot stand.

Caribou and reindeer do poorly on diets of lichen only. Caribou actually appear more versatile in their feeding habits than other cervids in North America. Bergerud cites several studies in which caribou wintered successfully on ranges without abundant lichens [although most of these were from areas with less severe winters than in the Arctic].

There is no substantial evidence that fires increased in northern Canada with early settlement, according to the author. Recent modelling simulations forecast that the range of the Kaminuriak herd could, on the basis of forage supplies, support 2 million animals, even with the effects of the fires that others (especially Scotter) had noted.

A further weakness of hypothesis 1 is that no one has been able to show that a reduction in the absolute amount of forage available has caused changes in either the reproductive or mortality rates of caribou. In fact, relative abundance (i.e.. absolute abundance as modified by snow cover and other factors) can vary widely without affecting these population parameters. In only a few instances (usually range icing) has forage availability caused winter starvation. The author believes that caribou can adjust to changes in absolute forage abundance because of their mobility; therefore, the amount of damage caused by fires on extensive caribou winter ranges is not significant, even if an increase in fires could be demonstrated.

Because neither premise "a" (lichen required by caribou) nor "b" (range destruction leading to forage depletion) stand up under scrutiny, Bergerud discounts hypothesis 1 without examining for a causal relationship (i.e., premise "c") between man's activities leading to range destruction and a decline in caribou.

(2) Hypothesis 2 is based on the premise that hunting can cause caribou populations to decline, that increased predation can occur as the result of habitat changes and therefore augment hunting mortality, and that disease may also contribute to declines in some cases.

Bergerud states that caribou are more vulnerable to hunting than any other North American cervid, based on their use of open habitats, traditional migrations, lack of wariness, etc. He points out that Rangifer have a low reproductive rate and that in pristine situations there was a balance between gains and losses in populations. With the advent of efficient rifles, mortality exceeded recruitment, and herds began to decline. A high natural mortality rate, including a very high calf mortality rate, leaves little margin for new mortality beyond that caused by predators and weather.

Although the author discounts hypothesis 1, he believes habitat changes brought on by fire, logging, etc., could have caused an increase in wolf populations by creating favorable habitat for prey species other than caribou. The implication is that when these prey populations become established and after they decline as seral habitats regrow to climax caribou suffer the impacts of increased wolf densities. Observed caribou declines in the realm of a decade after fires had burned fits this premise; if a forage shortage had caused starvation or changes in reproductive rates, then a caribou decline would have occurred much sooner.

For support of this theory, Bergerud cites instances where caribou exist in high densities on islands years after having been eliminated in adjacent mainland areas (data from Cringan 1956 for Slate Island in Ontario). Apparently, the lack of predators was the primary variable between the island and mainland. The island had been burned and logged and had a low abundance of lichens (less than 5%). The continued abundance of caribou here seems to be a crucial test of the rival hypotheses of lichen destruction and mortality due to hunting and predation. When this population eventually crashed, apparently due to starvation, Bergerud maintains that rather than being caused by a

lichen shortage, it was really a typical overutilization problem often seen in insular populations lacking predation.

The author also speculates that with the invasion of other cervids into seral habitats caused by man's activities, new diseases could begin to affect caribou. Pneumostrongylus tenuis (meningeal worm) is mentioned as the most likely organism that could impact caribou.

To summarize, Bergerud's hypothesis 2 states that with settlement came increased hunting of caribou, which in some areas was augmented by increased wolf predation and possibly disease. This increase in mortality was enough to disrupt the close balance between reproduction and natural mortality in undisturbed populations and started a decline.

(3) Hypothesis 3, a combination of 1 and 2, is represented by the conclusions of some workers (esp. Cringan). Apparently Cringan (1956) believed that range conditions caused or continued a decline of caribou after hunting had initially driven a population into decline (Nova Scotia and New Brunswick). Apparently, Cringan based this partially upon the fact that the decline continued subsequent to the formation of law enforcement efforts in these areas. Bergerud feels that continued poaching could have maintained pressure on the caribou and that this was weak evidence that range quality had anything to do with it.

Although Cringan mentioned the destruction of closed-canopy forests in Nova Scotia and New Brunswick, he failed to consider the possibility that lichen productivity might actually be improved with the removal of overstory. Also, he is contradicted by results from other caribou populations that increased in eastern Canada in the midst of fires and logging.

(4) Hypothesis 4 is based upon Skoog (1968) and his theory that social pressures at high densities can stimulate emigration of caribou to marginal habitats. Bergerud interpreted this to mean that declines would then result from relative shortages of food caused by snow and ice on winter ranges. No evidence of large-scale die-offs is presented in Skoog's work, so Bergerud leaves this theory with the remark that it deserves further investigation but cannot be supported at present.

(5) Bergerud closes by saying that recent life history studies support his belief that hypothesis 2 is valid and that proponents of the range destruction theory need to state what will be accepted as disproof of their theories. He states that he will accept as disproof of his theory on predation demonstrated instances where calf survival does not decrease as predator (wolf) density increases. Further, he proposes the following crucial test between hypotheses 1 and 2:

Hypothesis 1: Caribou require lichens, a lack of which will cause a decline through increased starvation mortality and/or decreased reproduction. Hypothesis 2: caribou do not require lichens, if other foods are available, but natural predation can limit population growth.

Test condition: Introduce caribou to an island lacking predators and lichens but with adequate food supplies. Later, before forage overutilization occurs, introduce wolves.

Test implications: 1 (range) - Population should decrease prior to wolf introduction; 2 (predation) - Population should rise prior to wolf introduction, then decrease as wolf predation increases.

[Rev. note: The Bergerud et al. (1983) article on the Avalon Peninsula caribou herd came close to matching these test conditions. See annotation for that paper.]

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Bergerud, A.T. 1978. Caribou. Pages 83-101 in J.L. Schmidt and D.L. Gilbert, eds. Big game in North America. Harrisburg, PA: Stackpole Books. 494 pp.

This article is meant to be an all-around review and update of knowledge on the ecology, habitat, distribution, and management of North American caribou. The author maintains his position as stated in Bergerud (1974): i.e., caribou declines since the early 1900's have been caused by hunting and predation, with disease as a possible additional factor. The theories of others that destruction of range (especially by fire) limited caribou in the past are disputed and dispensed with.

Regarding impacts from development, Bergerud presents the following:

(1) Six of the seven Alaskan caribou herds that have declined since 1964 did so because of heavy hunting of adults (10-20% annual harvest) at the same time calf survival was poor because of predation. Calf survival increased dramatically in response to wolf control.

(2) Results from studies (prior to the paper) on the ability of caribou to navigate pipelines and roads have been inconclusive because of flawed study designs and/or logistic difficulties in conducting the studies.

(3) Bergerud believes caribou are very adaptable and that no evidence exists to show caribou abandoning ranges because of human activities; e.g., zones hunted along roads are still used.

(4) The author believes the adverse effects of harassment to be overstated and that this is an incremental change to existing levels of intrinsic harassment (e.g., insects). The exception to the above is in calving areas, where young can be trampled or lost and abandoned when herds bolt from sources of harassment.

(5) Bergerud feels that a subtle effect of man is the modification of caribou-predator interactions. He cites Banfield's (1974) observations on wolves ambushing caribou using seismic lines and predicts that a new road through a caribou wintering area in Canada will allow wolves to penetrate this area more frequently. Finally, the ultimate question is

whether adequate land areas are available for caribou to roam. He implies that this is for predator evasion and response to range conditions.

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Bergerud, A.T. 1980a. A review of the population dynamics of caribou and wild reindeer in North America. Pages 556-581 in E. Reimers, E. Gaare, and S. Skjenneberg, eds. Proceedings of the second international reindeer/caribou symposium, Røros, Norway. Direktoratet for vilt og ferskvannsfisk, Trondheim. 799 pp.

This paper, presented in 1979, attempts to synthesize a number of theories concerning North American caribou/reindeer population dynamics. Factors relating to birth and mortality rates, including the validity of methods used to study these factors, are considered and evaluated.

Relevant observations and conclusions include the following:

(1) Caribou commonly reach puberty at 29 months and have their first calf at 3 yr of age. Depending upon the nutritive value of their range, however, some animals may come into estrous as early as 17 months or not breed until 41 months of age.

(2) The average pregnancy rate for animals two and one-half years of age or older in eight herds studied was 82%. The average percentage of parous females in seven herds was 86%. In general, reproductive rate showed little variation between years or herds.

(3) In contrast to a consistent birth rate the mortality rate of caribou calves in many herds in North America was variable, exceeding 50% and frequently as high as 80-90%. Most of the mortality occurred in the first few months of life and was attributed to predation; although other factors such as weather, stillbirths, birth defects, drownings, and accidents accounted for mortalities as well.

(4) The annual adult mortality rate was estimated to vary from 7 to 13% (mean 10%) for herds where predators are common and 5-6% if predators are rare.

(5) In general, herds without predators showed rapid population growth approaching r_m (maximum potential growth), whereas populations coexisting with predators showed little or no growth and even declined if hunting was an additive factor.

(6) Predation was considered the chief limiting factor to population growth and sets the level of stocking commonly at one to two animals/mi^2 or less. Limits imposed by dispersion or food supplies occur at much higher densities.

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Bergerud, A.T. 1980b. Status of Rangifer in Canada. I. Woodland Caribou (Rangifer tarandus caribou). Pages 748-753 in E. Reimers, E. Gaare, and S. Skjenneberg, eds. Proceedings of the second international reindeer/caribou symposium, Røros, Norway. Direktoratet for vilt og ferskvannsfisk, Trondheim. 799 pp.

As of 1979, an estimated 260,000 woodland caribou (Rangifer tarandus caribou) were believed to exist in locations throughout Canada. The George River Herd, the largest herd in Canada, was estimated to comprise 70% of the total population. Herds decreased in British Columbia and increased in Newfoundland, while population trends for large herds in the Yukon and Northwest Territories could not be determined. Many other herds existed at low densities with stable population numbers. The author identifies 41 discrete herds of woodland caribou.

The reasons for declines in several herds vary, although the author cites overharvest, wolf and lynx predation, disease, and poaching as major contributing factors.

[No impact-related information was presented.]

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Bergerud, A.T. 1983. The natural population control of caribou. Pages 14-61 in F.L. Bunnell, D.S. Eastman, and J.M. Peek, eds. Symposium on natural regulation of wildlife populations, March 10, 1978. Proc. No. 14, Northwest Section, The Wildlife Soc., Forest, Wildlife and Range Experiment Station, Univ. Idaho, Moscow.

In this paper, Bergerud reviews hypotheses that address the natural control of caribou populations in the absence of direct action by man. For this reason, most of the paper is not pertinent to this review. As can be expected, based on his previous papers [see review of Bergerud 1974] he advocates the theory of limitation by predation and disease as apposed to the traditional range carrying capacity theory.

One item is pertinent to this review, because it is indirectly linked to man's activities. Since Bergerud's 1974 work, Dauphine (1975) had established that caribou cannot coexist with white-tailed deer because of transmission of the meningeal worm (Parelaphostrongylus tenuis). This strengthens Bergerud's previous supposition that disease contributed to caribou declines (acting in concert with hunting and increased predation) as man's activities penetrated northern regions. To the extent that white-tailed deer invaded caribou habitat because of vegetation changes attributable to man, impacts to caribou populations probably occurred.

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Bergerud, A.T., R.D. Jakimchuk, and D.R. Carruthers. 1984. The buffalo of the north: caribou (Rangifer tarandus) and human developments. Arctic 37(1):7-22.

In this review, the authors discuss the effects of various types of human developments (e.g., roads, pipelines), land use (e.g., logging), and other activities (e.g., hunting) on the demographics of seven North American caribou herds and the Snohetta wild reindeer herd in Norway. The reactions of caribou to disturbance from human and predator harassment and to linear features (natural as well as man-made) are also discussed. The effects of predation in sensitizing caribou to disturbance are also discussed.

Relevant observations and conclusions include the following:

(1) There is considerable uncertainty in the literature regarding the effects of human disturbance on large ungulates. This uncertainty is due to the extrapolation from observations on individuals or small groups to effects at the population level, to the great variation in the quality of the information available, and to the use of correlational reasoning rather than hypothesis testing.

(2) The effects of transportation corridors, primarily roads, on the Forty-mile, Nelchina, British Columbia, Central Arctic, Newfoundland and Kaminuriak herds were discussed. The authors concluded that the major impact of transportation corridors has been to increase access by hunters, resulting in many instances in overharvest. Demographic changes were the result, and these changes have been incorrectly attributed to the effect of the corridor itself rather than to the increase in hunting along the corridor. In other instances, major distributional changes have been incorrectly attributed to disturbance associated with transportation corridors when in fact the distributional changes were more likely the herd's natural response to changing abundance. The authors conclude that in none of the herds mentioned above have permanent declines occurred.

(3) The authors discuss the Snohetta Herd case history in some detail. They argue that although earlier authors had emphasized the observation that the disturbance and facilities associated with construction of a railroad were responsible for the cessation of migration between the Knutsho and Snohetta ranges, the actual reason was merely that the herd was naturally responding to lower population levels resulting from overhunting along the railroad and road corridor.

(4) The authors present cases in which severe aircraft or vehicle harassment occurred during caribou tagging studies in Newfoundland, Manitoba, and Alaska. Tagging operations were conducted during the immediate postconception period and during calving, yet calf production and survival were unaffected. The authors conclude from these and several other examples that although harassment is neither unimportant nor acceptable, caribou ... "can withstand periodic severe disturbance without adverse effects on productivity and survival."

(5) Caribou have been observed to parallel and deflect around natural features (e.g., rivers, lakes, mountains) just as they have been observed

to climb steep slopes. This behavior is attributed to caribou moving in response to "paths of least energetic resistance." Observations of paralleling or deflecting from man-made structures such as road berms and fences should not be construed as abnormal responses.

(6) Caribou reactions and sensitivity to disturbance should be evaluated in the context of Rangifer's co-evolution with wolves. There are several examples in which caribou, following habituation to humans, may have actually sought human-altered habitat (e.g., around settlements). Conversely, new roads, seismic lines, etc., may provide opportunities for wolves to enter caribou habitat that was previously unavailable to them.

(7) The major environmental variable that caribou need is space - space that will provide habitats where caribou have an advantage (such as mobility) over predators. Much as the buffalo, caribou have the problems of overharvest and need for space. Caribou populations must not be dissected into small discrete units so that they lose their ultimate adaptation - mobility to escape predators.

[Rev. note: This is an extremely thought-provoking article and deserves a critical review that is beyond the scope of this annotation - a more detailed review will be provided in the text of the report to which this bibliography is appended. Many of the examples the authors cite involve caribou populations that encounter linear developments, such as transportation corridors, during fall or spring migration. One questions whether responses to these corridors would be the same if they were placed in calving grounds or winter range, where caribou are relatively sedentary. At least one of the authors (Bergerud 1978, p. 100) has recommended that harassment by humans should be prevented near calving grounds.]

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Bergerud, A.T., M.J. Nolan, K. Curnew, and W.E. Mercer. 1983. Growth of the Avalon Peninsula, Newfoundland Caribou Herd. J. Wildl. Manage. 47(4):989-998.

This paper reports on conclusions reached from study of population data of a small caribou herd increasing in density with virtually no predation pressure [wolves and lynx had been intensively "controlled"]. The purpose of the paper is to examine whether caribou populations at high densities exhibit a logistic growth curve (i.e., a density-dependent reduction in increase) as argued by Haber and Walters (1980) or a constant rate of increase until densities exceed 4.0 caribou/km^2, as Bergerud (1983) had previously suggested.

The data suggests that Bergerud was correct. Birth rate and calf survival continued to be high and rate of increase remained relatively constant during an increase in density from 0.23 caribou/km^2 to 2.0/km^2. Unlike most wildlife populations, density-dependent negative feedback does not seem to operate to slow upward growth. In the absence of predation, the herd will

ultimately be limited by range resources and will crash because of overexploitation at the densities it has and will achieve.

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Bloomfield, M.I. 1979. The ecology and status of mountain caribou and caribou range in central British Columbia. MS Thesis, Univ. Alberta, Edmonton. xviii + 318 pp.

This thesis summarizes research on mountain caribou (Rangifer tarandus caribou) that was conducted in the Yellowhead Highway region of central British Columbia between September 1975 and December 1977. A combination of direct field research, literature review, and interviews with local residents was used to determine caribou food habits, seasonal habitat utilization, population status, and factors affecting historic and current population trends. Food habits and habitat utilization were determined by a few direct sightings of individual feeding caribou but primarily by analysis of fecal remains and visual analysis of feeding sites that were observed during aerial or ground surveys. Population status was determined from a few direct observations but primarily through interviews with area residents and track analysis. [Rev. note: Although ground surveys and 115 hours of helicopter surveys were conducted during the study period, only 134 direct observations of caribou were made.] Historical and current land use activities were determined by search of historical records as well as by interviews with local residents.

Relevant observations and conclusions include the following:

(1) The estimated population in the 6,000 mi^2 study area was 250-300 caribou. Very few calves or yearlings were observed by either the author or his cooperators during the study.

(2) Mountain caribou used a combination of forage plants at different times of the year; microclimatic differences due to elevation, slope, and aspect enabled the caribou to select different forage species. Other factors such as snow depth and density and insect abundance caused variations in "normal" patterns of use. Overall, forbs were the most selected forage type; however, during winter when snow depths increased, arboreal lichens were eaten primarily because of availability rather than preference. Dense, low-elevation forests were the preferred feeding sites during the deep snow of winter. In early spring, horsetail (Equistetum spp.) was highly preferred.

(3) Since the 1950's, the regional logging industry changed from small, seasonal, localized operations to large, centralized industrial complexes with all-weather roads. Large-scale clear-cutting became the conventional practice. Likewise, the highway and railway network expanded during the same period. Fire was not a principal factor in the study area, although between 1960 and 1969 over 68,000 acres of timberland burned, and some important caribou ranges were included. Both logging and wildfire have destroyed mountain caribou habitat, especially mature forests, which are the substrate for arboreal lichens

utilized by caribou during winter; however, logging has been the more destructive of the two. In addition, roads and railroads associated with logging and other types of development have not only destroyed habitat but also created physical barriers due to slash and debris piles and steep cutbanks and "psychological" barriers of large areas without forested cover. [Rev. note: The reactions of caribou in the study area to these activities were not directly observed; rather, the author related the effects noted in other studies, which may or may not have been relevant to the author's study area.]

(4) Using demographic characteristics of other mountain caribou herds and carrying-capacity estimates derived from habitat utilization observations in the current study, the author generated a statistical model that indicated that the historic population in the study area likely was ca. 1,500 individuals. The decline [Rev. note: assuming the historic estimate is correct] occurred primarily during the 1960's.

(5) The author argued that because of the rapid expansion of the road network concurrent with logging, increased access to caribou range resulted in an overharvest in the mid-to-late 1960's. Local extirpations of caribou bands occurred, according to the author's informants, at the same time that habitat modification was disrupting traditional caribou migration routes. The increase in commercial guiding and the continuation of either-sex hunting seasons exacerbated the decline in the late 1960's-early 1970's. The author concluded that the effect on the population in the study area was a decline in total numbers rather than a shrinkage of its general distribution. This was due primarily to the extirpation of localized bands of caribou and disruption of migration routes between bands. This situation likely will reduce the ability of the population to recover.

(6) Although no good information on wolf/mountain caribou interactions was available, the author points out that current [as of the late 1970's] wolf populations were low and that the caribou decline occurred during a period of extensive wolf control.

(7) The author's major conclusion was that mountain caribou in central British Columbia were in a severe decline due to the cumulative effects of overharvest (as a result of increased hunter access) and habitat modification as a result of industrial and recreational development.

(8) The author proposed numerous guidelines for logging, transportation system, and other types of development. [Rev. note: These guidelines all presume that the impacts the author identified as causing the caribou population decline were in fact correct. As such, they appear to be an excellent source as long as the reader realizes that the author's documentation of impacts was scanty.]

[Rev. note: The author presented a good argument for his major conclusion that overharvest and habitat modification were responsible for the decline in mountain caribou in his study area. He developed his argument for overharvest more extensively than the argument for habitat modification, probably because extrapolations from known aspects of caribou demographic characteristics are easier than determining changes in habitat utilization,

migration routes, etc., which rely on gathering extensive field data. It is important to remember that the author's conclusions were based on only 134 direct observations and extensively on interviews which are subject to interpretational bias not only by the interviewee but also by the interviewer. Nevertheless, this study is the best source of documentation available and appears to be as thoroughly done as could be expected, given the extremely low caribou density and difficult observation conditions. The major conclusions, however, should be regarded as tentative.]

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Bloomfield, M.I. 1980. The impact of development, settlement, and associated activities on mountain caribou in central British Columbia, Canada. Pages 705-715 in E. Reimers, E. Gaare, and S. Skjenneberg, eds. Proceeding of the second international reindeer/caribou symposium, Røros, Norway. Direktoratet for vilt og ferskvannsfisk, Trondheim. 799 pp.

This report summarizes portions of the author's thesis [cf. Bloomfield 1979], which focussed on the effects of land use activities and human harvest on mountain caribou. [Rev. note: Salient points of this article have already been discussed as part of the annotation for Bloomfield (1979). Because the author references his own work as the authority for statements made in this paper, the same caution applies to his conclusions here as to those in Bloomfield (1979).]

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Buckley, J.L. 1958. Effects of wildfire on Alaskan wildlife. Pages 123-126 in Proceedings of the Society of American Foresters. Salt Lake City, UT.

The author reviews the direct and indirect effects of fire upon Alaskan hydrology and vegetation and develops theories on impacts to wildlife.

The following relevant information is presented:

(1) Buckley says that in general wildlife benefits from the interspersion of vegetation types generated from fire patterns. He recognizes the naturalness of fire in the boreal forest.

(2) The author is concerned about the increase in the extent of fires since 1890 however, because of the reduction in climax habitat. [Rev. note: Although acreage burned from 1940-1957 is presented, no direct statement or evidence of an "increase" is presented until reference is made to an increase in the author's conclusions.]

(3) Buckley says that the caribou is the best example of a species dependent upon climax vegetation, and that the loss of climax vegetation would reduce an area's utility or at least attractiveness to

caribou. He hedges by saying that knowledge of caribou food habits is incomplete and that it is known that caribou can survive without lichens [hence his statement that caribou are dependent upon climax vegetation is a bit self-contradictory]. He bases his concern upon the apparent preference for lichens and the fact that lichens occur only in undisturbed areas, [a statement contradicted by later studies (although in different areas) - e.g., D. Miller 1976].

[Rev. note: The reader gets the impression that the author was speaking of his impressions of his experiences in Alaska rather than basing his statements upon studies. Note that no evidence is given that any impacts (e.g., population declines, die-offs) had actually occurred. Still, Buckley is much more moderate on fire and its effects upon caribou than many of his contemporaries (e.g., Leopold and Darling 1953).]

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Bunnell, F., D.C. Dauphine, R. Hilborn, D.R. Miller, F.L. Miller, E.H. McEwan, G.R. Parker, R. Peterman, G.W. Scotter, and C.J. Walters. 1975. Preliminary report on computer simulation of barren ground caribou management. Pages 189-193 in J.R. Luick, P.C. Lent, D.R. Klein, and R.G. White, eds. Proceedings of the first international reindeer/caribou symposium, Fairbanks, Alaska, 1972. Biol. Paper Univ. of Alaska, Special Rept. No. 1. Fairbanks. 551 pp.

This paper reports the results of a workshop of computer modellers and caribou biologists who tried to determine the effects varying various factors upon population size and growth. The Kaminuriak Herd was used as the basis for the model.

The following relevant material is presented:

(1) Food supply is not presently [in the early 1970's] a limiting factor for the Kaminuriak Herd. Even if no harvest took place, food supply wouldn't begin to limit the herd for at least 50 yr.

(2) At present harvest levels (5%) and calf mortality (60%) the herd will remain in a gradual decline.

(3) Increasing the rate of habitat burning by a factor of five would have only a minor effect upon the present population. Ten times the present burning rate would cause a decline in the population beginning in about 20 yr.

(4) Absolute food abundance is modified not only by natural snow conditions but by trampled, hardened snow, which makes food unavailable around feeding craters.

(5) Any increase from 60% calf mortality resulted in rapid population decline. Mortality of up to 80% has been seen in the field (Kelsall 1968), and entire calf crops could be lost in certain years. The model

predicts this would cause a decline from which the population would recover only slowly.

[Rev. note: The results of the modeling effort are interesting but have some obvious weak points. For example, the Canadians always seem to have assumed 5% hunting mortality. In a situation where the assumed mortality is causing a steady decline in this herd, uncertainty in the harvest figures should be of prime concern to managers. The model makes it clear, however, that no factor in the ecology of the Kaminuriak Herd was (in the early 1970's) more important than achieving a reduced mortality rate due to harvest.]

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Calef, G.W. 1980. Status of Rangifer in Canada II. Status of Rangifer in the Northwest Territories. Pages 754-759 in E. Reimers, E. Gaare and S. Skjenneberg, eds. Proceedings of the second international reindeer/caribou symposium, Røros, Norway. Direktoratet for vilt og ferskvannsfisk, Trondheim. 799 pp.

During the period of 1976-1979 all major herds of barren ground caribou were censused and an estimated 550,000 animals were believed to exist in Canada's Northwest Territories. The Porcupine, Bathhurst, and Beverly herds appeared to be stable, while the Kaminuriak and Baffin caribou herds were declining. The Bluenose, Wager Bay, and Melville Peninsula herds appeared to be increasing.

Peary's caribou, a separate subspecies that inhabits the Arctic Archipelago, was partially surveyed and herd numbers suggested an 89% population decline from the last comprehensive survey in 1961. Starvation and/or depressed reproduction caused by severe weather and icing conditions were believed to be responsible for this decline.

In general, heavily hunted herds (those in which 5% or more of the population is killed annually) were declining, while lightly hunted herds remained stable or were increasing. The author suggests increasing the reported hunter kill in censuses by 25-50% to account for incomplete or inaccurate reporting and for wounded or unretrieved animals.

Grizzly bears (Ursus arctos) were considered to be potentially important predators on the calving grounds of the Porcupine and Bluenose herds, although elsewhere wolves were the only significant predator of caribou throughout the Northwest Territories. No official programs to control predators existed in 1979, although it is reported that Native hunters were responsible for reducing over 1,000 wolves from the Bathhurst Herd's range during the winter of 1978-1979.

[No impact-related information was presented.]

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Calef, G.W., E.A. DeBock, and G.M. Lortie. 1976. The reaction of barren ground caribou to aircraft. Arctic 29(4):201-212.

The overt responses to aircraft of 736 groups of Porcupine Herd caribou in northern Alaska and Yukon Territories are discussed in this report. The responses of these groups, ranging from one to several thousand individuals, were divided into five classes: Class 1, Panic Response: Animals were completely out of control, stumbling into each other and into inanimate objects (e.g., willows); Class 2, Strong Escape: Animals trotted or ran, usually continuing after aircraft had passed; Class 3, Mild Escape: Animals diverted from aircraft, or original direction of travel, at a walk or a trot for a short distance; Class 4, Stationary: Animals stopped feeding, rose from resting position, or assumed alarm posture; Class 5, No Response: Animals showed no visible response. Data were gathered by the investigators between May 1972 and November 1973. The authors emphasized that although in some instances there was no overt response by caribou, other responses such as increased stress level, hormone imbalance, and/or metabolic changes could still be occurring. The authors mentioned that they were also not able to evaluate the cumulative effects of disturbance, such as abandonment of range.

Relevant observations and conclusions include the following:

(1) Reactions of caribou to overflights by fixed-wing and helicopter aircraft were similar; however, because helicopters can follow or haze caribou closely from the rear, this particular type of harassment results in the most severe panic reaction.

(2) The investigators observed strong seasonal differences in caribou reaction to aircraft. Caribou were most reactive during calving, post-calving, and early winter, and least reactive during spring and fall migration. On several occasions during the insect harassment period, large groups (10,000-60,000) could be "herded" by flying at altitudes of 215-610 m (700-2,000 ft).

(3) There were no correlations between severity of reaction and group size or terrain/vegetation type.

(4) Calves responded to aircraft more than did other classes during both spring and fall, although to a lesser degree in the fall.

(5) Cows with newborn calves did not abandon them, even when aircraft passed or landed nearby; however, caribou were most reactive while on the calving grounds.

(6) The authors provide the following guidelines:

    (a) Most potentially injurious reactions to aircraft by caribou during fall or spring migration could be avoided by aircraft maintaining flight altitude of 150 m (500 ft) AGL; aircraft could avoid causing even mild escape responses if they maintained altitudes of 305 m (1,000 ft) AGL;

(b) During calving, rut, and early winter, aircraft should maintain altitudes of at least 305 m (1,000 ft) AGL to avoid potential injury to caribou.

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Carlton, J. 1982. Last chance for the border caribou? Defenders 57(4):7-11.

This article in the popular press describes the present situation regarding the small band of caribou that continues to use mountainous areas in northeastern Washington, northwestern Idaho, and southern British Columbia. Besides a brief description of habitat use and population status, a summary is provided of human activities that have or could affect the caribou's habitat.

The following pertinent information is included:

(1) Hunting caused a major decline in mountain caribou during the first half of this century. Habitat destruction caused by fire contributed to the decline and prevented a resurgence in numbers.

(2) For the past 20 yr, human activities have been the dominant influence upon the small herd. Various intrusions into their range may have disrupted traditional movements (the caribou now use habitat in the USA only periodically, even though adequate range is available south of the border) between portions of their range. The construction of Trans-Canada Highway 3 through Kootenay Pass (the only route used by the caribou to reach the USA from B.C.), large-scale logging operations with accompanying access roads, and cleared rights-of-way for gas and power transmission have destroyed habitat and may have restricted movements to smaller and more isolated ranges than formerly. Cars have struck and killed caribou on Highway 3.

(3) The U.S. Forest Service is proposing timber sales in the Selkirk caribou's essential habitat. At the same time, the U.S. Fish and Wildlife Service has initiated action to list mountain caribou as an endangered species.

[Rev. note: This article is a good summary of the problems facing the Selkirk caribou. The author's conclusions are not backed up with documentation, but the problems of restricted habitat and human disturbance are so apparent that none is really necessary.]

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Clement, H. 1982. Beverely and Kaminuriak caribou monitoring and land-use controls. Prog. Rept. No. 6. NWT Wildlife Service. Rankin Inlet, NWT.

This report summarizes the work of the NWTWS' Caribou Monitor during spring migration of the Beverly and Kaminuviak herds in 1981. The Monitor advises a land management decision maker on permit actions within caribou protection zones, which consist of the calving grounds of these herds.

Activities requiring permits within these areas are automatically shut down (as a condition of the permit) from 15 May through 31 July. Land managers may release permits from these restrictions upon the advice of the Monitor - i.e., subsequent to calving and postcalving concentrations in proximity to permitted operations. Further, if calving occurs outside of the Caribou Protection Area, the Monitor can recommend that permits there be closed down, too (three-day notice except in emergencies).

Besides the timing restrictions, permittees are restricted from building camps or blasting within 10 km (6.2 mi) or drilling within 5 km (3.1 mi) of "Designated Crossing Sites" (water crossing areas) appearing on a map provided with the permit.

As a result of this land management mechanism, eight permittees within the Beverely Caribou Protection Area were monitored. Five were denied early releases based on the Caribou Monitor's recommendations. All were granted releases by 14 July. No restrictions were required for the five operations within the Kaminuriak Caribou Protection Area, presumably because caribou did not calve in proximity to any of the operations.

The Caribou Monitor closes the report by saying that because restrictions were imposed, no caribou-man conflicts occurred [implying that the potential existed].

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Cooper, S. 1981. Beverly and Kaminuriak caribou monitoring and land use controls, 1980. Northwest Territories Wildl. Serv. Prog. Rept. No. 4. 74 pp.

This paper describes the movements of the Beverely and Kaminuriak caribou herds from 12 May to 31 July 1980, in relation to caribou protection areas designed to protect these herds from land use activities (primarily mineral exploration) during precalving spring migration, calving and postcalving periods, and at major water crossings in the Baker Lake district, Northwest Territories, Canada. Aerial surveys were used to monitor caribou distribution and movements and to facilitate the implementation of land use restrictions in the caribou protection zones. The reaction of caribou to aircraft and land use activities was occasionally recorded during the aerial surveys and by industry personnel.

Relevant observations and conclusions included the following:

(1) During one monitoring flight on 27 June, cows nearly always reacted by changing direction, quickly standing from a bedded position, or by initiating panicked running when overflown by a Beaver aircraft at 300

m (1,000 ft) AGL. No visible movement of resting bulls or nonbreeders was observed.

(2) Approximately 8,000 Kaminuriak bulls and nonbreeders entered an area in late June for a few days where a drill camp and several diamond drills were operating. Industry personnel reported that the reaction of the caribou to helicopters, camps, drills, and land crews was "casual avoidance and collective disregard." It was reported that caribou drank from the salt water tank at one drill site.

[Rev. note: The reported caribou reactions to land use activities should be viewed with caution as they appeared to be collected incidentally to other activities and by untrained observers and are thus not likely to be representative of all caribou-land use activity encounters.]

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Cringan, A.T. 1969. History, food habits and range requirements of the woodland caribou of continental North America. Pages 90-105 in G.W. Cox, ed. Readings in conservation ecology. New York: Appleton-Century-Crofts. 595 pp. [reprinted from Trans. N. Am. Wildl. Conf. 22:485-501. (1957)]

This field research/review paper examines the historical distribution of woodland caribou in North America, its current [as of 1957] distribution, and reasons for its decline throughout much of its range. Food habit and range requirement studies were conducted during 1949 on the Slate Islands, Lake Superior, Ontario, Canada. Slate Islands, a group of eight islands totaling some 15 mi^2 in area, currently have woodland caribou as the sole ungulate occupant and have no large mammalian predators. The vegetation of the islands has been influenced by an extensive fire sometime between 1887 and 1907, by a period of logging activity coinciding with the fire, and by a period of logging around 1930.

Relevant observations and conclusions included the following:

(1) Woodland caribou formerly ranged from Prince Edward Island and Nova Scotia to western Alberta or British Columbia, south into New York, New Hampshire, Vermont and Maine in the east, and Minnesota, Wisconsin and Michigan in the Great Lakes region, north to southern Ungava in the east and the Northwest Territories in the west.

(2) Currently [1957], woodland caribou are present in Quebec, Ontario, Manitoba, Saskatchewan, Alberta, Northwest Territories and possibly British Columbia. Estimated numbers of caribou present in these areas range from 20,000 to 25,000 animals, two-thirds to three-quarters of which are in Manitoba, Quebec, and Ontario. Populations in Quebec, Manitoba, and Ontario were said to be increasing [in 1957].

(3) All populations have declined or have been eliminated since settlement of North America by Europeans. Populations in New York, New Hampshire, Vermont, Wisconsin, and Prince Edward Island disappeared by 1900.

Populations in Michigan, Minnesota, Nova Scotia, New Brunswick, and Maine disappeared between 1900 and 1946.

(4) The author noted that hunting was an important factor in the decline or extinction of populations before 1900, although populations continued to decline even with harvest controls. Loss of mature forest by settlement, logging, mining, and forest fires was considered to be the cause of the woodland caribou decline over the last 200 yr.

(5) Terricolous and particularly arboreal lichens were considered critical to the survival of Slate Islands caribou during winter. Arboreal lichens in climax forest were considered to be a stabilizing factor on caribou numbers by providing a stable food supply, even though terricolous lichens may be overgrazed. This was due to the fact that lichen-covered trees became accessible to the caribou as deadfalls. This regular supply of arboreal lichen was believed to inhibit the development of a predator-prey type oscillation between the caribou and their prey, lichens.

[Rev. note: The author noted that terricolous lichens were heavily grazed and many stands were reduced in areal extent by many years of grazing. He appears to have attributed the importance of arboreal lichens to caribou primarily on their greater abundance and not on any quantified dietary preference for arboreal lichens. The observed heavy use of terricolous lichens over that of arboreal lichens may in fact indicate a preference for terricolous lichens by caribou. Because a plant species is abundant, it should not be directly inferred that it is also an abundant element in a herbivore's diet. Euler et al. (1976) and Bergerud (1974) disagreed with Cringan's conclusion that lichen-containing climax forest was essential to woodland caribou survival.]

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Danilov, P.I., and V.A. Markovsky. 1983. Forest reindeer (Rangifer tarandus fennicus Lonnb.) in Karelia. Acta Zool. Fennica 175:33-34.

This paper summarizes the history of wild reindeer population size and distribution in the Karelia region of the USSR since the mid nineteenth century. The authors' work focuses on forest reindeer (Rangifer tarandus fennicus), but they conclude that some stock descended from domestic reindeer herds is also present in the current wild population. Karelia, at a latitude and with vegetation generally similar to Alaska's Interior, has supported reindeer throughout this period. The following relevant observations and conclusions are presented:

(1) The distribution and numbers of wild reindeer were substantially affected by domestic reindeer husbandry, because reindeer herders killed wild deer in efforts to decrease the number of semidomestic animals lost to the wild herds living in the forests. As a result, wild reindeer were very rare north of a line between Kem and Kalevala (i.e., the domestic reindeer breeding zone).

(2) Hunting, especially intensive from 1910 to 1930, resulted in a sharp decrease in animal numbers and further restricted distribution in the rest of Karelia and almost resulted in their extirpation.

(3) Protection from hunting has resulted in a resurgence in wild reindeer numbers and a reoccupation of the herd's former range. In addition, cessation of domestic reindeer herding has allowed the wild herd to occupy North Karelia, so that at present, wild reindeer occur throughout Karelia as far as the species' southern distribution boundary.

(4) Presently, the wild reindeer population has stabilized (a total of about 7,000), and permits are apparently issued for limited hunts. The authors caution that intensive tree felling is continually decreasing forest areas with reindeer lichens, leading to the possibility of "overloading and destruction of winter habitats." They recommend an expansion of hunting to 200 permits annually. If done in the suggested localities, this harvest would reduce pressure on winter range, as well as removing animals with undesirable characteristics descended from domestic "izemsky" (tundra) reindeer.

[Rev. note: The authors' attribute changes in distribution and population to various factors with certainty, although evidence is not presented in this short paper. Their conclusions, however, generally agree with those of studies of other, much larger Rangifer herds. See especially the literature on the Western Arctic Caribou Herd (Alaska) with regard to interaction with domestic herds and human harvest.]

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Darby, W.R. 1978. Beverly and Kaminuriak caribou monitoring and land use controls, 1978. N.W.T. Wildl. Serv. Completion Rept. No. 1. 83 pp.

This paper describes and presents the results of monitoring program implemented from April to August 1978 to record the movements of the Beverly and Kaminuriak caribou herds in the Baker Lake area, Northwest Territories, Canada. Special land use controls were in effect to protect caribou on spring migration routes, primary calving and postcalving areas, and at major water crossing sites. An additional function of the monitoring program was to determine the effectiveness of the special land use zones and restrictions.

Aerial surveys were used to map and monitor the movements and activities of the Beverly and Kaminuriak herds during spring migration, calving, and post-calving periods. Major water crossings were monitored by aerial surveys and by limited on-ground observations. Reactions of caribou to aircraft and exploration activity were recorded whenever possible. A literature review provided a basis for determining periods and areas of caribou sensitivity to disturbance and to evaluate the effectiveness of the land use controls.

Relevant observations and conclusions included the following:

(1) Cows and calves in dense postcalving aggregations will sometimes canter in response to light aircraft flying at 300 to 600 m (1,000-2,000 ft) AGL.

(2) Interactions between caribou and land use activities occurred on 18 occasions. These interactions involved males and nonbreeding caribou and mixed age-sex groups. It was reported that camp activity did not deter use of the area by caribou or interfere with migration (the majority of these observations were reported by camp personnel).

(3) A series of recommendations for caribou and caribou habitat protection, based on adequate research and on interim data, are presented for both exploration and long-term development phases. These include aircraft altitude and timing restrictions, closures, fencing, and habitat restoration. Also included are recommendations for impact-related further research.

[Rev. note: The reactions of caribou to land use activities should be viewed with caution as these observations were primarily reported by camp personnel who are likely unskilled observers.]

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Darby, W.R. 1980. Beverly and Kaminuriak caribou monitoring and land use controls, 1979. N.W.T. Wildl. Serv. Prog. Rept. No. 3. 51 pp.

This paper describes a revised land use control system and the results of a field monitoring program of the Beverly and Kaminuriak caribou herds during the period April to September 1979. Land use controls for mineral exploration and industrial development were implemented to protect these herds during calving, postcalving, other sensitive periods, and at major water crossings in the Baker Lake area, Northwest Territories, Canada.

Aerial surveys were used to monitor herd distribution and movements. Major water crossings were monitored by aerial surveys and limited ground observations. Observations of interactions between caribou and land use activities during 1979 were obtained from second-hand records.

Relevant observations and conclusions indicated the following:

(1) Approximately 10 to 15 caribou bulls and nonbreeders [herd not specified] occupying an area about 0.5 km (0.3 mi) from an operating diamond drill, trotted approximately 0.5 km (0.3 mi) away from the drill site when a helicopter slinging equipment approached the area from behind the drill and landed onsite. Four additional interactions between helicopters and caribou were reported but were not described in detail.

(2) Some avoidance and curiosity reactions between caribou and humans on the ground were reported. No details were given other than one involved one person and a mixed group of eight caribou and the other four people and about 3,000 cows and calves.

(3) Land use control zones for Beverly and Kaminuriak caribou were considered to be properly located for protection of the herds during the desired time periods. Land use conditions associated with the control zones were also deemed appropriate, with a few exceptions.

(4) Recommendations [limited in extent in this report but referencing those made by Darby (1978)] for monitoring programs and land use controls are presented.

[Rev. note: The reactions of caribou to helicopters and humans reported in this report should be viewed with caution as they appear to be collected incidentally to other activities and often as second-hand reports by untrained observers.]

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Darby, W.R., and L.S. Duquette. 1985. Woodland caribou and forestry in northern Ontario, Canada. Address at fourth international reindeer/caribou symposium, Whitehorse, Y.T. August, 1985.

In this report the authors examine the effects of pulpwood logging on four small woodland caribou herds in Ontario. Habitat utilization by caribou and forest practices in woodland caribou habitat are summarized. Preliminary recommendations to mitigate the effects of pulpwood logging on woodland caribou are presented.

Relevant observations and conclusions include the following:

(1) Woodland caribou distribution in Ontario has receded northward [over 200 km (120 mi) since 1900--cf. figure 1] since 1900, yet average caribou density has not increased. These observations suggest that woodland caribou have declined in Ontario.

(2) Woodland caribou in Ontario usually are found in herds of less than 50 individuals that winter in groups in mature coniferous forest and that spend spring, summer, and fall solitarily or in very small groups in open muskegs, lakeshores, and islands. Although some groups have apparently traditional movements, fidelity to these movement routes is not absolute. Traditional movements may be nonexistent in some groups.

(3) Logging for pulpwood has expanded in caribou ranges in Ontario in the past few decades. Most of this is clearcutting directed toward mature coniferous forests. Clearcuts have ranged from 50 to several thousand ha (125 to several thousand acres) in size. Selective cutting is rare. Forestry activities are governed by 20-yr agreements between the government and the paper companies.

(4) In four case histories the authors examined, small caribou herds declined in numbers or disappeared after portions of their range were logged. In one case, logging is considered responsible for the demise of a herd of 36 animals as a result of the loss of winter habitat and because of increased wolf predation. Large clearcuts on the herd's

winter range not only destroyed forage and winter cover, but also reduced the vegetation to earlier stages of succession which attracted white-tailed deer. Although wolf densities were not reported, wolf-killed deer were common. It is likely that predation was at least partially reponsible for the decline. Although transmittal of meningeal disease (Parelaphostrongylus tenuis) from deer to caribou could have been possible, predation was a more likely cause of the herd's decline.

In a second case a herd of 10 animals disappeared after large areas of their summer and winter range were logged. Although predation could not be entirely discounted as a cause for this herd's decline, in the authors' opinion habitat destruction was a more likely cause.

In two additional cases caribou abandoned use of clearcut areas when these were on peripheral parts of their winter range. These herds continued to use adjacent uncut areas.

(5) The authors conclude that (a) if only a peripheral portion of the winter range is cut and if deer are not present (and high wolf densities with them), caribou may not leave their home range; (b) if widespread cutting occurs, resulting in high densities of deer and moose, caribou are likely to disappear; and (c) caribou avoid clearcut areas in coniferous forest.

(6) The authors suggest a number of mitigation techniques, including but not limited to:

(a) Avoid logging in sensitive habitats such as calving areas, migration routes and core wintering areas. Maintain a "no cut" buffer of 2 km (1 mi) around prime winter range, and 1 km (0.5 mi) around significant calving areas respectively [Rev. note: the terms "core," "significant," and "prime" were not defined].

(b) Restrict cutting to one large clearcut (130-500 ha, 300-1,300 ac) on the periphery of caribou range rather than spread the same amount of cutting over numerous small cuts of less than 130 ha (300 ac) throughout the herd's range. This will ensure that large, unbroken areas of habitat remain.

(c) Implement wolf control if wolf densities increase as deer and/or moose densities increase following logging.

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Darby, W.R., and W.O. Pruitt, Jr. 1984. Habitat use, movements, and grouping behavior of woodland caribou, Rangifer tarandus caribou, in Southeastern Manitoba. Can. Field-Nat. 98(2):184-190.

This report summarizes field research on woodland caribou conducted near Aikens Lake, Manitoba, between March 1975 and April 1977. A herd of 30-40

individuals inhabited the 1,600 km² (576 mi²) study area, located in the boreal forest (taiga) zone.

Relevant observations include the following:

(1) Habitat use of this herd appeared similar to that reported in the literature for other woodland caribou herds. Habitat use included mature conifer forest uplands more than any other habitat type except semiopen and open bogs, which were used during October, December, and January. In spring, caribou feed on terricolous and saxicolous lichens exposed by sublimation of old feeding craters or by snowmelt in clearings, lake margins, or south-facing slopes.

(2) Calving occurred in early May. No calving aggregations were found, nor did there appear to be specific calving areas.

(3) All caribou were found in singles or pairs between May and September. Aggregations began during the rut and continued during winter.

No impacts information was presented.

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Dauphine, T.C. 1975. The disappearance of caribou reintroduced to Cape Breton Highlands National Park. Can. Field-Nat. 89(3):299-310.

This report presented results of field studies about the fate of 51 woodland caribou reintroduced to Cape Breton Highlands National Park, Nova Scotia, in 1968-1969. Caribou had been present in the remote highlands of Cape Breton Island until the 1920's, when they were apparently extirpated by overhunting. White-tailed deer first appeared about 1915 and were abundant for the 30 yr prior to the caribou reintroduction. Moose had become very scarce or extirpated by 1900 and were successfully reintroduced in 1947. Wolves have been extirpated since the early 1900's. The habitat had remained relatively untouched by agriculture, logging, or fire until the time of introduction, although use of the lower-elevation areas, mostly deciduous shrubs and forest, is now primarily restricted to white-tailed deer and moose. There are major human settlements and agricultural areas or ports on the northern and southern park boundaries.

Relevant observations and conclusions include the following:

(1) Following the caribou reintroduction, many caribou, including newborn calves, were sighted near the release site in 1969 and in 1970. Almost all sightings were within a 24-km (15-mi) radius of the release site, and observations suggested that the caribou had remained together and apparently were somewhat synchronous in seasonal movements. By summer 1972 the herd had disappeared.

(2) Dispersal, predation, and poaching were ruled out as potential causes for the decline.

(3) Over 72% of the Cape Breton white-tailed deer examined for presence of meningeal worm (Paraelaphostrongylus tenuis) were infected. Some caribou exhibited overt symptoms of meningeal worm infestation prior to the decline. The pattern of the decline matches that of other woodland caribou reintroduction failures that were attributed to meningeal worm infection. The author concludes that meningeal worm infection is the most likely cause of the failure of the Cape Breton reintroduction.

(4) Similar attempts at reintroductions in Maine, southern Ontario, and Wisconsin had failed because of meningeal worm infection from white-tailed deer.

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Davis, J.L. 1980. Status of Rangifer in the U.S.A. Pages 793-797 in E. Reimers, E. Gaare, and S. Skjenneberg, eds. Proceeding of the second international reindeer/caribou symposium, Røros, Norway. Direktoratet for vilt og ferskvannsfisk, Trondheim. 799 pp.

This paper from 1979 examines the status of reindeer and caribou populations in the United States, with particular emphasis given to Alaska, where all 22 reindeer herds and 25 of 26 caribou herds are found.

Reindeer herd sizes are estimated from direct counts during roundups or aerial surveys. Size estimates of small caribou herds are made by aerial surveys and involve either total counts or sampling and extrapolation. The larger herds are most frequently censused by an aerial-photo count-extrapolation technique.

During 1979, the Alaskan reindeer population numbered approximately 25,000 animals, while the Alaskan caribou population was estimated at roughly 287,000-303,000 animals. The only other caribou herd in the US, situated on the northern Idaho/Washington border, numbered about 30 caribou in 1979.

It is proposed that up to 1,036,000 km^2 (400,900 mi^2) of Alaska's 1,515,150 km^2 (584,800 mi^2) total area is suitable Rangifer habitat. During spring, summer, and fall, the better ranges include extensive areas altitudinally or latitudinally above tree line. Winter habitats most suitable to caribou and reindeer include areas of low to moderate snowcover, with little or no crusting, and adequate forage. The Idaho/Washington caribou inhabit heavily timbered mountainous areas, high meadows, and alpine uplands.

In general, most Alaskan caribou and reindeer herds and the caribou herd along the Idaho/Washington border appeared to be stable or increasing during 1979. Harvests of reindeer vary greatly between herds, ranging from zero to levels essentially equal to annual increments. Harvests of caribou, with the exception of five herds (Adak, Andreafsky, Kenai, Kenai Mountains, and Macomb) were all less than 5% of the herd's total numbers.

The author believes current reindeer management reflects an awareness of past problems that occurred from range overstocking. However, increased interest in the reindeer industry and lucrative foreign markets for antlers

may create conflicts between reindeer and caribou interests. Although some caribou ranges have been affected by habitat deterioration, overexploitation by man and predation appear to be the most proximate causes of major caribou declines in the early 1970's. Short-term management of caribou must address harvest and predation, and long-term management will involve habitat protection.

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Davis, J.L., and A.W. Franzmann. 1979. Fire - moose-caribou interrelationships: a review and assessment. Proc. N. Am. Moose Conf. Workshop 15:80-118.

This paper examines the widely held belief that fire-initiated plant succession caused a widespread decline in North American caribou populations and, in particular, extirpation of caribou on the Kenai Peninsula, while at the same time improving conditions for moose. The authors examine several points upon which this theory is based and conclude that as an explanation for caribou declines it is unfounded. They believe that human harvest was the proximate cause for the declines and show that adequate habitat to support a viable caribou herd existed on the Kenai Peninsula throughout the period in which the extirpation took place.

The following relevant information is presented:

(1) Three assumptions that form a foundation for the commonly held "fire is detrimental" theory are examined:

a) Fires increased following settlement. Although the record is unclear as to whether fire occurrence increased with settlement in Canada, the authors agree that it did increase with the settlement of Alaska.

b) The quality and/or quantity of caribou range were reduced because of wildfire.

c) The lichen requirements of caribou are sufficiently high that reduction in abundance can cause a major reduction in the caribou population.

Assumptions b) and c) are closely related. The assumption of the importance of lichens leads to the assumption that a reduction in climax vegetation can have an impact to caribou. The authors cite several studies that show that Rangifer do poorly on pure lichen diets and others in which animals have done better (in terms of meat yield) on low lichen diets. In many areas, lichens form only a minor portion of the diet or are completely lacking.

Fires may actually improve caribou ranges by increasing productivity of high-value forage, by returning nutrients to the soil, and by increasing heterogenity of habitats. In discussing the effects of fire, the authors cite D. Miller's work on the Kaminuriak Herd (Miller

1976), where he stated: "There is a plentiful supply of forage in the area despite caribou use and fires. Snow cover rather than scarcity of forage limits the ... [carrying capacity] ... of the taiga."

(2) The correlation between caribou declines and increased wildfires suggests the existence of direct or indirect impacts to caribou, other than lichen range destruction. Several are discussed here: a) physical barriers in taiga (jackstrawed trees); b) low production of forage and deep snow in early seral stages after a fire; c) increased predator populations; and d) exposure to parasites. These are all quite speculative. The initial two are supported by observations of caribou avoiding newly burned taiga areas. The predation theory has been advanced by Bergerud and is supported by several examples in which "buffer" prey species have flourished in seral habitat, thus stimulating increasing predator populations, which ultimately affect caribou. The last theory is based upon circumstantial evidence that white-tailed deer expanding their range into seral habitats might have introduced meningeal worms into caribou, causing a decline in caribou.

(3) Although no good records of the abundance of caribou on the Kenai Peninsula were found, indirect evidence that they existed there commonly and over a long period is presented (e.g., early explorers found Natives there enrobed in caribou garments). There <u>are</u> good records, though, documenting heavy hunting pressure on caribou before and at the turn of the century, and several sources from that time cite overharvesting as a predicted cause of extirpation on the Kenai Peninsula in future years.

(4) Although several authors blame fire-caused habitat changes for the disappearance of caribou from the Kenai (e.g., Palmer 1933, Leopold and Darling 1953, Buckley 1958, Lutz 1956, Klein 1965), the authors found several reasons to disagree with these analyses and to state that hunting was a much more likely proximate cause of decline. For example, caribou were successfully reintroduced to the Kenai Peninsula in 1965 and 1966 in habitats apparently unaffected by fire. Wolves had been eliminated from the peninsula prior to the elimination of caribou. Thus, predation did not seem to be a logical cause, either.

(5) The authors were able to find little specific on moose-caribou interrelationships. There is some dietary overlap between the species but little evidence of serious competition (largely because plant species used by both ungulates appear in different proportions in their diets). Indeed, moose and caribou have increased simultaneously in many areas.

(6) The authors conclude that range destruction supposedly caused by fire was not a causal factor in caribou declines in the early 1900's. They cite overexploitation subsequent to the appearance of efficient firearms as the major cause. Bergerud (1974) is quoted as saying that it is "paradoxical that caribou, which are probably more vulnerable to hunting than most ungulate species, should be considered the exception . . ."

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Davis, J.L., and P. Valkenburg. 1979. Caribou distribution, population characteristics, mortality, and responses to disturbance in northwest Alaska. Pages 13-52 in P. Lent, ed. Studies of selected wildlife and fish and their use of habitats on and adjacent to NPR-A 1977-1978. National Petroleum Reserve-Alaska Work Group 3, Field Study 3. USDI, NPR-A 105(c) Land Use Study, Anchorage. xxxiii + 226 pp.

This report summarizes the distribution, movements, population estimates, and reactions to aircraft disturbance of Western Arctic Herd (WAH) and Teshekpuk Lake Herd (TLH) caribou in 1977-1978. Distribution, movements, and some population data were gathered during fixed-wing and rotorcraft aerial surveys and sex/age composition from ground surveys. Population estimates for the WAH were derived by the Air Photo Direct Count Extrapolation technique. Although the primary study area was National Petroleum Reserve-Alaska (NPR-A), data from the remainder of the WAH range were also included. During aerial surveys in spring 1978, responses of caribou to fixed-wing and rotor-wing aircraft were evaluated, using the techniques and disturbance criteria of Calef et al. (1976) [Rev. note: see Calef et al. 1976 for details].

Relevant observations and conclusions include the following:

(1) Although the peak of calving for the WAH in 1978 (June 6-8) was a few days earlier than that of 1977 (June 10), the patterns of use of the Utukok calving grounds were identical. In 1978, the "core" calving area, with densities of approximately 19/km^2, was surrounded by a "peripheral" calving area.

(2) The TLH calving area in 1978 appeared to be east of Teshukpuk Lake, between Harrison Bay and Cape Halkett [Rev. note: prior to 1978, the TLH had not been surveyed and was considered to be a portion of the WAH].

(3) Overwintering calf survival was lower for that portion of the WAH wintering near Pt. Lay than for other portions of the herd wintering elsewhere. Predation did not appear to be a factor, but several dead or moribund animals with extremely high infestations of warble and/or nose bot larvae were found, suggesting that an unusually heavy insect infestation could be at least partially responsible.

(4) Although there were no clear-cut differences between the responses of caribou to fixed-wing and rotor-wing aircraft in April 1978, there was a direct correlation between the altitude of the aircraft and the severity of caribou's reaction. Differential responses among different group sizes could not be clearly determined from the data, although the data suggest that the larger groups reacted more strongly [especially south of the Brooks Range, see figure 2-8 and table 2-5].

(5) From literature review and analysis of their own data the authors suggest several guidelines, including (but not limited to) the following:

(a) Until more is known about the effects of development on caribou during calving or on the calving habitat, increased human activity and development should be prohibited on or adjacent to calving areas.

(b) Aircraft flights at altitudes of less than 160 m (500 ft) over caribou should be minimized; during May to August, minimal flying height should be 660 m (2,000 ft).

(c) Because caribou may respond more to people on the ground, ground crews and/or vehicles should not approach caribou to within 1,000 m (3,000 ft) during calving.

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Davis, J.L., R.E. LeResche, and R.T. Shideler. 1978. Size, composition, and productivity of the Fortymile Caribou Herd. Fortymile Caribou Herd Studies, 1973-1975. ADF&G, Fed. Aid in Wildl. Rest. Final Rept. Projs. W-17-6, W-17-7, Job 3.13R. Juneau. 69 pp.

This paper reviews the historical accounts of the size of the Fortymile Caribou Herd and reports the size, composition, and productivity of the herd during the period July 1973-June 1975 as determined by aerial photo-direct count-extrapolation, fall sex-age composition counts, and spring postcalving counts. The Fortymile Herd in Alaska is found in the White Mountains-Tanana-Yukon uplands, and portions of the herd sometimes winters in the western Yukon Territory, Canada.

Relevant observations and conclusions included the following:

(1) Historical records indicate that the Fortymile Herd may have numbered up to 500,000 animals during the 1920's, although the estimate for this time period should probably be qualified as 500,000 ± 300,000. A decline in numbers began after 1928, reached its maximum rate of decline in the mid 1930's, and reached its low point of 10,000-20,000 caribou in 1944. The period from the early 1940's to the mid 1950's was one of continuous herd growth, with numbers increasing to approximately 50,000 by 1955. The population declined, possibly beginning in 1960, to an estimated 20,000 animals by 1969. Two periods of egress to the Porcupine Herd occurred during this 15 yr interval, in 1957 and in 1964, although only the 1964 egress may have produced a sustained net loss of animals. Population estimates of 20,000 in 1969, less than 15,000 by 1970 and through 1972, are considered quite liberal in retrospect. A more reliable estimate for this period is a minimum of 8,000-10,000 caribou. The 1973 herd size estimate was 5,312, and estimates for 1974 and 1975 indicated a minimum of 4,000 animals.

(2) The reasons for the decline in numbers of the Fortymile Herd were not documented, although data implicate several factors. Prior to 1970, hunter harvest never exceeded probable yearling recruitment. During the period 1970-1972, harvest greatly exceeded the yearling recruitment rate and contributed greatly to the population decline during this

period. For example, yearling recruitment in 1971 was estimated to be 424-640 animals; however, mortality from hunting alone was 2,360 animals.

(3) Circumstantial evidence and inferences about the Fortymile Herd indicate that predation, primarily by wolves, was the major factor in the historic decline of caribou numbers. The decline was reversed during the 1940's, perhaps as late as 1947, when predator control was initiated. The herd apparently increased through 1959, except possibly from 1954-1955, when predator control apparently ceased, and then declined continuously since 1960 [and the end of widespread predator control]. Yearly calf production during the period 1953-1975 was good to excellent, but yearling recruitment was mediocre, implying heavy calf mortality at some point during the first year of life, most likely the result of predation, because weather and range condition were not considered to be major factors in the herd's decline. Predators other than wolves (e.g., bears, golden eagles) singly or in combination, may at times be as important as wolves as a cause of caribou predation.

[Rev. note: Essentially only one habitat study of the Fortymile Herd's range had been conducted to the date of this paper, that by Skoog (1956). Davis et al. (1978b) examined the relationship of fire and the Fortymile Herd concurrently in their paper.]

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Davis, J.L., R.T. Shideler, and R.E. LeResche. 1978a. Movements and distribution of the Fortymile Caribou Herd. Fortymile Caribou Herd Studies, 1973-1975. ADF&G, Fed. Aid in Wildl. Rest. Final Rept. Projs. W-17-6, W-17-7, Job 3.15R. Juneau. 42 pp.

This report reviews the historical distribution and movements of the Fortymile Herd and reports the field monitoring of the herd during 1973 through 1975 with limited observations from 1976 also presented. Seasonal movements and changes in group size are presented for this herd, which occupies the Tanana Hills-White Mountains in Alaska eastward to the Ogilvie Mountains, Yukon Territory.

Relevant observations and conclusions included the following:

(1) Around the 1920's, when the Fortymile Herd was at its maximum size, the range used by this herd was extensive, approximately 220,150 km² (85,000 mi²). Caribou ranged from the Nenana area in the west to east of Dawson, Y.T. Caribou ranged from portions of the Porcupine River drainage in the north to the foothills of the northern Alaska Range on the south. During this period there were three major wintering areas - the White Mountains/Circle area, the Ogilvie Mountains, and the Fortymile/Ladue River area. The main calving area was apparently in the White Mountains northwest of the Steese Highway; however, some calving may have occurred in other areas as well (see Skoog 1956).

(2) As the herd declined in the 1930's and 1940's, its range contracted to approximately 90,650 km² (35,000 mi²). The Fortymile and Sixtymile rivers area and the North Fork of the Ladue River became the main wintering areas, with only a few animals wintering in the White Mountains. The calving area was in the White Mountains until 1963, after which the calving area(s) shifted southeastward to the Tanana Hills.

(3) By 1955 and possibly earlier, some calving occurred at the head of the Middle Fork of the Fortymile River and along the Birch Creek/Chena River/Salcha River divide, although most of the calving at this time occurred in the White Mountains.

(4) During 1962-1964, the herd calved in the upper Chena, Salcha, Charley, Goodpaster, and Fortymile rivers and upper Birch Creek. During 1965, a calving area was observed in the Mt. Veta area (upper Middle Fork Fortymile River), and from 1966-1969 caribou used the Mt. Harper area (upper Goodpaster, Charley, and Middle Fork Fortymile River). These areas were also used in 1970-1972, although some data suggest that some cows have calved in the Clums Fork area (upper Birch Creek) during this period and possibly since 1957. The Fortymile Herd calved in the Clums Fork area during 1973-1976.

(5) More calving takes place above timberline than in timbered areas on the Clums Fork calving ground. Fortymile caribou likely select the Clums Fork area for calving because of its diversity of micro-habitats rather than on the basis of early spring snowmelt.

(6) Initiation of fall migration was not correlated with the first snowfall.

[No impacts information was presented.]

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Davis, J.L., R.T. Shideler, and R.E. LeResche. 1978b. Range reconnaissance - Fortymile Caribou Herd. Fortymile Caribou Herd Studies, 1973-1975. ADF&G, Fed. Aid in Wildl. Rest. Final Rept. Proj. W-17-6, W-17-7, Job. 3.16R. Juneau. 42 pp.

This paper reviews the relationship between wildfire and caribou in Alaska, with a primary emphasis on the effects of wildfire on the Fortymile Herd. Additionally, wildfire and its effects on the decline of the Kenai Peninsula Herd were also reviewed.

Relevant observations and conclusions include the following:

General conclusions concerning caribou and wildfire:

(1) Wildfires in Alaska increased following white settlement, but in northern Canada, information concerning an increase in fire was contradictory.

(2) No evidence supports a causal relationship between declines in caribou populations and periods of increased occurrence of wildfire, especially in Alaska.

(3) Destruction of caribou range by wildfire does not appear to be entirely responsible for the declines because caribou do not appear to be dependent on lichens, and effects of wildfire on lichen range are not necessarily harmful.

(4) Wildfire may have contributed to caribou population declines through changes in seral stages which may enhance faunal changes such as increased predator density or influx of disease or parasite vectors.

(5) Decimating or regulatory factors involved in the caribou population declines likely included hunting and increased natural predation, singly or in combination, and possibly in conjunction with increased fires.

Kenai Peninsula:

(1) Factors other than fire were likely responsible for the decline of the Kenai Herd during the early twentieth century. Overhunting and adverse weather in marginal caribou habitat were possible primary causes because not all caribou habitat was destroyed by fire.

(2) Murie (1935) and Skoog (1968) suggested that the Kenai Peninsula was simply an "overflow area" that received caribou from interior herds during periods of high populations and extensive movements. Skoog (1968) considered the Kenai Peninsula marginal habitat because of its precipitous terrain, deep snows in the mountains, and the rather limited suitable areas above timberline containing stands of sedge-meadow or heath-lichen.

Fortymile Herd:

(1) It was estimated that 75-100% of the Fortymile range had been burned in the last 75-120 yr. Average lichen regeneration time is approximately 40-60 years.

(2) The number of caribou present on the Fortymile Herd's range during this century has been well below the calculated carrying capacity.

(3) At no time during the period 1955-1976 has the population level of the Fortymile Herd approached the estimates of carrying capacity. In 1956, a conservative estimate of carrying capacity was 70,000-90,000 caribou while the population was 50,000 animals. In 1976, the population had declined to 4,000 animals, whereas the carrying capacity had only decreased to approximately 61,000 animals.

(4) It was recommended that naturally caused fires be allowed to burn unless developed areas, personal property, or critical habitat for another species are threatened, because elimination of fire could ultimately eliminate optimal successional stages and reduce lichen production. Fire suppression should be considered and perhaps

initiated only after the total of human-caused and naturally caused fires over a period of years exceeds an average of 2% per year of the herd's range, the calculated habitat that could be burned per year without reducing the carrying capacity.

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Davis, J.L., P. Valkenburg, and R.D. Boertje. 1983. Demography and limiting factors of Alaska's Delta Caribou Herd, 1954-1981. Acta Zool. Fennica 175: 135-137.

This study attempts to determine whether the rapid growth of the Delta Caribou Herd (DCH) following wolf control in 1954 and again in 1976 was due to cause and effect or merely coincidence. Because of inadequate data for the period 1954-1960, herd growth could not be unequivocably attributed to wolf control. The study looked not only at wolf control but also at alternative hypotheses for low calf:100 cow ratios during the 1970-1981 period.

The following relevant points are made:

(1) Biological indices led the authors to conclude that the nutritional status of the DCH was good throughout the period. Rapid growth, early maturity, high pregnancy and natality rates, and early parturition all indicate that nutrition was not limiting the DCH population.

(2) Following wolf control in 1976, DCH fall calf:100 cow ratios grew from 2:100 (1974) to 45:100 (1976). This occurred as adjacent herds in similar ecological circumstances exhibited a near-constant rate of fall calf survival (MaComb Plateau 15:100 in 1974, 20:100 in 1976; McKinley [Denali] 18:100 in 1974, 16:100 in 1976).

(3) Other potential limiting factors (immigration/emigration, disturbance, disease, etc.) failed to account for the timing and degree of population change [Rev. note: no evidence presented in this paper].

(4) Excessive harvest is cited as a major factor in the precipitous decline of the DCH in 1970-1973. However, the authors point out that the herd would have declined even without hunting and indeed continued to decline from 1973-1975 after hunting was halted. Human harvest, then, was a proximate limiting factor that affected the rapidity of decline, while the ultimate limiting factor remained predation.

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Davis, J.L., P. Valkenburg, and R.D. Boertje. 1985. Disturbance and the Delta Caribou Herd. Pages 2-6 in A.M. Martell and D.E. Russell, eds. Proceedings of the first North American caribou workshop, Whitehorse, Y.T., 1983. Can. Wildl. Serv. Spec. Publ., Ottawa. 68 pp.

This report was appended to the federal aid progress report and was presented at the First North American Caribou Workshop, Whitehorse, YT, 28-29 September 1983. A summary of demographic parameters, observations of the reactions of caribou of the Delta Caribou Herd (DCH) to human-induced disturbances in their range, and a discussion of the effects of distance are presented. Three types of man-made disturbance were considered - sensory disturbance (primarily noise and aircraft overflights), habitat alteration (fire), and physical structures (airstrips, roads). The DCH ranges over the foothills on the north side of the Alaska Range, between the Richardson and Parks highways.

Relevant observations and conclusions include the following:

(1) The DCH has grown from 1,000 animals during the 1930's to 1950's, to about 5,000 by 1963, and to at least 6,500 in 1982.

(2) Natural mortality has been low in recent years, ranging from a low of 3% to a high of 4-8%.

(3) A military artillery and bombing range are located in the northern part of the DCH's range, and surrounding the calving area. Although most of the military activity has occurred north of the calving area since at least the 1950's, the traditional calving area has been subjected to high-intensity auditory stimuli (artillery, low-level bombing). In addition, civilian light aircraft overflights are common throughout most of the herd's range. The DCH is probably subjected to more sensory [primarily auditory] disturbance than any other Alaskan caribou herd. Two major transportation routes, the Richardson and the Parks highways, roughly correspond to the eastern and western boundaries, respectively, of the DCH range; there is no information suggesting that these highways restrict movements of the DCH. The DCH is located in an area of relatively high thunderstorm activity, and exposure to this source of loud natural noise may be a factor in their apparent habituation to sensory disturbances.

(4) Few fires larger than 40 ha have occurred in the DCH range. At least two fires larger than 20,000 ha have burned near or in the core calving area in the past 4 to 5 years. In 1979, one fire burned a large area just north of the traditional core calving area - this area was used for calving in 1982, when persistent snow on the traditional core calving area forced the DCH to calve farther north. In that year, the calving portion of the herd used the area burned in 1979 in spite of the availability of unburned but apparently similar habitat nearby. In both 1979 and 1983 caribou were exposed to heavy smoke during calving. The authors conclude that their observations of the DCH do not support the concern about the effects of fire on caribou calving habitat that other authors have suggested.

(5) The authors conclude that man-caused disturbance has not been an important limiting factor on DCH. In contrast, wolf predation and hunting have been shown to be limiting factors to herd growth prior to 1976.

[Rev. note: Although I agree with the authors' statement that the DCH is annually subjected to more disturbance than any other Alaskan caribou herd,

further clarification is necessary. Much of the primary noncalving range of the DCH lies outside military operations areas, and in these areas many of the more dramatic sources of disturbance (e.g., artillery, low elevation military aircraft) are relatively minor. Nevertheless, the calving portion of the DCH uses a portion of the military operations area during the period of time when cows are generally considered to be most reactive to such disturbance. The authors argue that this suggests that caribou are more adaptable to disturbance than previously thought. An alternative (but not necessarily exclusive) explanation is that caribou demonstrate a greater site affinity toward traditional calving areas than we have previously believed. In either case, productivity has not been demonstrated to be affected by the current level of human activity in the area.]

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Davis, J.L., P. Valkenburg, and H.V. Reynolds. 1980. Population dynamics of Alaska's Western Arctic Caribou Herd. Pages 595-604 in E. Reimers, E. Gaare, and S. Skjenneberg, eds. Proceedings of the second international reindeer/caribou symposium, Røros, Norway. Direktoratet for vilt og ferskvannsfisk, Trondheim. 799 pp.

During the early to mid 1970's it became apparent that the Western Arctic Caribou Herd (WAH) was experiencing a severe population decline. Numbers of animals had plummeted from an estimated 300,000 in the 1960's to approximately 75,000 in 1976. This paper attempts to explain the reasons for the decline and recounts the measures that were taken to reverse this trend.

Estimates of herd size and population dynamics prior to 1975 were obtained from the literature and unpublished reports and files from the Alaska Department of Fish and Game. Herd size estimates after 1975 were obtained from calving ground count-extrapolation censuses and aerial photo-direct count-extrapolation censuses. Finally, iterative arithmetic models and computer simulations were used to account for the observed population changes.

The authors found that heavy harvest (including waste) by rural "subsistence" hunters and substantial predation by wolves were the primary causes of caribou mortality during the post-1970 decline. Reduced yearling recruitment, although unsubstantiated, may also have contributed. Factors leading to the recovery of the WAH are believed to be 1) stringent harvest restrictions that were implemented beginning in 1976; 2) a declining wolf population resulting from legal and illegal kills, an outbreak of rabies and other canine diseases, and a general decline in the abundance of caribou and moose; and 3) a probable increase in yearling recruitment.

[Rev. note: Contrast these conclusions with those of Doerr 1980]

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Dean, F.C., and D.M. Tracy. 1979. McKinley's shuttle bus system and the management of traffic impact upon wildlife. Pages 263-270 in R. Ittner, D.R. Potter, J.K. Agee, and S. Anschell, eds. Recreational impact on wildlands conference proceedings. Seattle. U.S. Forest Service No. R-6-001-1979.

This paper describes the results of studies done in Mt. McKinley National Park [now called Denali N.P.] in the mid 1970's in order to determine the reactions of animals to vehicle traffic on the park road. The work focused on large mammals, especially grizzly/brown bears. The paper goes on to recommend mitigation measures that could decrease impacts.

The following pertinent material is presented:

(1) Reactions of caribou to traffic were not easy to determine, because of the coincidence of the road and a major migration route and the steady decline of the population (McKinley Herd).

(2) The percentage of caribou that showed visible reactions to traffic and the ratio of strong to mild reactions decreased with distance from the road. Within 100 m of the road, over 60% of the caribou observed reacted visibly, while at 400 m or more, less than 10% reacted.

(3) Within 200 m of the road, the "average animal" went through 4½ mild reactions to disturbance and 2½ strong reactions per hour. This is much more frequent disturbance rate than other studies (Curatolo 1975, Thomson 1973) described in the wild. The authors showed that caribou near the road (within 200 m) spent more time travelling than those away from the road. Feeding time was decreased as a result.

(4) No significant difference was found in the reactions of caribou to moving versus parked buses. However, when passengers disembarked from vehicles, the number of strong reactions nearly doubled.

(5) Dean and Tracy suggest several measures to reduce impacts. Included are a prohibition on disembarkment from buses except at designated locations, a suggestion to avoid scheduling bus runs during crepuscular periods, and a "clumping" of bus traffic so that longer low-disturbance periods would be in effect. Also, the authors suggest that park authorities consider using buses to ferry people to reserved campsites rather than allowing private vehicles to use the road.

[Rev. note: This paper is different from most in that quantitative differences in reactions are documented, rather than being suppositions based upon a few observations. However, we are still at the point of looking at superficial indications of potential problems and cannot make conclusions about actual effects on caribou populations.]

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Doerr, J.G. 1980. Modeling the population decline of two Alaskan caribou herds. Pages 611-623 in E. Reimers, E. Gaare, and S. Skjenneberg, eds.

Proceedings of the second international reindeer/caribou symposium, Røros, Norway. Direktoratet for vilt og ferskvannsfisk, Trondheim. 799 pp.

Through data analysis and empirical modeling techniques, the author attempts to define the factors that were responsible for dramatic population fluctuations in the Nelchina Caribou Herd (NCH) from 1954-1972 and in the Western Arctic Caribou Herd (WAH) from 1961-1976. Demographic data were obtained from numerous researchers and both published and unpublished reports from the Alaska Department of Fish and Game and U.S. Fish and Wildlife Service. Collections of 522 and 736 2+ year old caribou incisiform teeth from the WAH in 1959-1961 and 1975-1976, respectively, were age-determined by counting cementum annuli.

The available data on human harvest, wolf predation, natural mortality, fall recruitment, and herd size and composition were incorporated into a simple population model. Given sets of natural mortality rates were used in "what if" simulations, or other mortality and recruitment rates were held constant and a set of natural mortality rates that produced a close fit to the demographic data was derived by substitution.

Relevant observations and conclusions include the following:

(1) Increased overwinter natural (excluding wolf predation and hunting) mortality of calves and increased hunting mortality of adults were the most important regulating mechanisms of herd size during highest population levels.

(2) The rapid decline of the NCH and the WAH largely resulted from excessive hunting, including a high number of wounded loss, waste, and illegal kills.

(3) Wolf predation appeared not to be a major mortality factor during the highest population levels of the herds or during their initial declines. Increased wolf predation rates largely resulted from declining caribou numbers.

[Rev. note: Compare these conclusions with those of Davis et al. 1980.]

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Dufresne, F. 1946. Alaska's animals and fishes. Portland, Oregon: Metropolitan Press. 297 pp.

This book is a series of individual accounts describing life histories, descriptions, food habits, habitat, distribution, and abundance for fish, game, furbearers, and marine mammals found in Alaska. Information is sometimes brief, depending on the species. [Rev. note: This book was written in nontechnical language and was likely intended for popular reading.]

Relevant observations and conclusions pertaining to caribou include the following:

(1) The author attributes the demise of caribou on the Kenai Peninsula and elsewhere in Alaska to fire. In 1883, a fire apparently burned for months on the Kenai Peninsula, with caribou herds vanishing shortly thereafter. Fire eliminated lichens, which were replaced by willows, birches, and cottonwoods, providing abundant forage for moose, whose numbers increased greatly after the fire. A similar scenario was reported to be occurring throughout central Alaska; caribou were decreasing because of fire eliminating lichens, with a concurrent increase in deciduous shrubs and moose.

(2) The author described competition between introduced reindeer and caribou in northwestern Alaska. Overgrazing of caribou range was reported to have occurred from reindeer herding. Intermingling and hybridizing between reindeer and caribou were also said to occur. [Rev. note: No quantification of these effects was provided.]

(3) Accelerated road building and airfield development was said to have tended to restrict caribou migrations. Herds were said to be dwindling perceptibly, no longer holding up traffic on rivers and highways and no longer numbering "millions" of caribou. The population [at the time of writing] was believed to number about one half million caribou statewide. There was also said to be an apparent drift toward "bleak Arctic ranges where this lover of solitude may still find space to conduct its eccentric movements."

[Rev. note: The author's view of the fire-lichen-caribou relationship is a dated viewpoint that has since been replaced with more balanced thinking on the natural role of fire and its long-term effects on the creation of vegetation homogeneity and lichen perpetuation (see Miller 1976, 1980). No mention of hunting as a factor in the decline of the Kenai herd was made (see Davis and Franzmann 1979). Quantitative information regarding the restriction of movements and decline in numbers was also not provided or available.]

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Dugmore, A.R. 1913. The romance of the Newfoundland caribou. Philadelphia: J.B. Lippincott Co. 186 pp.

This book endeavors to describe the life cycle and ecology of the woodland caribou in Newfoundland early in the century. Written in a rambling, popular style, it contains much lore but very little on impacts. Wolves and lynx were almost nonexistent on the island, so predation was virtually ignored in the text. The author alludes to the "enormous slaughter" that was an annual occurrence, implying that, potentially, overharvest could be a concern. However, he quotes J.G. Millais, author of the book "Newfoundland and its Untrodden Ways," as saying that if harvest was limited to 3 caribou per hunter, a maximum of 6 percent of the herd would be harvested, which was felt to be safe.

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Edmonds, E.J., and M. Bloomfield. 1984. A study of woodland caribou (Rangifer tarandus caribou) in west central Alberta, 1979 to 1983. Rept. by Prov. of Alberta, Energy and Renewable Resources, Fish and Wildlife Div. 203 pp.

A field study and literature review of mountain caribou in the foothills and mountains on the Alberta/B.C. border was conducted between 1979 and 1983. Field research consisted of radio-tracking caribou to determine habitat use and caribou distribution, fecal analysis and direct observation to determine food habits, and vegetation sampling to determine potential caribou habitat available. A review of provincial records and other historical literature was also conducted.

Relevant observations and conclusions include the following:

(1) There were two ecotypes of woodland caribou that inhabitited the study area (including adjacent B.C.). One, the woodland type, remains in the forested foothills. The other, the mountain type, generally move west to mountainous regions in the spring and back again to the foothills in fall. Although both mountain and woodland types winter in pine and pine/spruce forest in foothills, mountain caribou remain at higher elevations (above 1,350 m [5,000 ft]) than woodland caribou. During the remainder of the year, mountain caribou use subalpine and alpine areas whereas woodland caribou use forest and open muskegs around the 1,200 m (4,000 ft) elevation zone. [Rev. note: Similar ecotypes of woodland caribou are reported for areas of B.C. just to the west of this study. See Stevenson and Hatler (1985).]

(2) Numbers of caribou in and near the study area have declined overall since the early 1900's. Caribou numbers in the study area have declined at least twice since the 1940's. In the early 1940's when small sawmill operations increased steadily on the winter range, legal and illegal hunting to provision logging camps probably in combination with the extraordinarily severe winters of 1945-46 and 1946-47 and with predation, resulted in a sharp drop in reported caribou numbers by 1947. By the 1960's, mountain caribou had increased to perhaps 1,200 animals. During the 1960's there was a dramatic increase in human activities in the area--large scale timber harvest began, a railroad and road were constructed through the area, and coal exploration intensified. The mountain caribou population was estimated to be 600-700 animals in the early 1970's. In the 1970's oil and gas exploration in the area intensified and predator populations increased. The current population estimate is 275 mountain caribou and 25 woodland caribou, indicating that unlike mountain caribou woodland caribou did not increase following the area-wide caribou decline in the 1940's. Several small groups of mountain caribou are now isolated in parks and wilderness areas where logging and hunting have not occurred. Much of the former caribou habitat east and south of the study area has been logged, and only very small scattered groups of caribou are present and these are confined to small areas.

(3) Unlike mountain caribou farther west [see Stevenson and Hatler 1985], those in this study area fed on mostly terrestrial lichens and vascular plants during winter. Arboreal lichens comprised a small proportion of

the winter diet, usually only during a brief period of late winter/early spring when snow hardness precluded cratering. During the remainder of the winter both mountain and woodland caribou cratered through snow up to 100 cm (50 in) deep to obtain terrestrial lichens. Cratering sites were located in areas of maximum lichen abundance within an area with overall lichen cover because the most abundant terrestrial lichen habitat occurred in lodgepole pine and lodgepole pine/black spruce forest which was generally less than the stand age at which maximum terrestrial lichen abundance is achieved (e.g., less than 75 years old).

(4) During the study period, caribou evidenced increasing use of a recently constructed highway right-of-way primarily to obtain forage in revegetated portions, and salt on the roads. Collisions with highway vehicles and trains have occurred [6 known deaths during the study], and are anticipated to increase if caribou use the right-of-way more often. This could become an important source of mortality because of the small number of animals in the population.

(5) In addition to mortality by collisions with vehicles, caribou mortality sources include illegal and legal hunting and predation. Of these mortality sources, predation and hunting are the most important with respect to mountain caribou, whereas predation alone is most important with respect to woodland caribou.

(6) Current logging methods consist of clear-cutting large blocks of pine and pine/spruce forest on moderate slopes (i.e., the primary caribou winter range). This cutting regime does not maximize the regrowth of terrestrial lichens, and these large clear-cuts create behavioral barriers in that caribou avoid them because of lack of cover and excessive snow depths. Access roads created by logging can increase hunter and predator access to the area. Habitat changes to a seral successional stage will likely result in an increase in deer and elk, and subsequent increase in predators which could eliminate isolated, small caribou herds.

(7) Timber harvest guidelines emphasize methods that will maintain an adequate amount of pine and pine/spruce forest that will provide abundant terrestrial lichens. This means retaining some of this forest in stands that are older than 75 years, some subalpine forest (fir, pine, and spruce) in stands older than 100 years to retain arboreal lichen abundance used by caribou during early spring, and using small cut blocks that will mimic natural openings used by caribou. A three-pass cut system of 150 m (500 ft) wide strips cut on a 25-30 year rotation and not scarified is the preferred harvest system. Access roads should be "put to bed," and the use of roads which are "ATV useable" should be minimized. Control of snowmobile access to the area should be a major concern even in the absence of logging; however, the presence of access roads to logging areas will provide more access, and control of snowmobile traffic is even more important in these areas.

[Rev. note: This report provides an excellent summary of the status of woodland caribou in western Alberta, and the past, present and probable future effects of human activities on these caribou. As is the case with

small mountain and woodland caribou herds elsewhere in the Pacific Northwest (e.g., see Stevenson and Hatler 1985) the future of these caribou is in doubt in areas where forest managers are unable or unwilling to modify current forest practices to minimize conflicts with caribou.]

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Edwards, R.Y. 1954. Fire and the decline of a mountain caribou herd. J. Wildl. Manage. 18(4):521-526.

This paper reviews the decline of a mountain caribou herd in the Wells Gray Park area, British Columbia. A general decline of mountain caribou had occurred in British Columbia since 1900 and progressed south to north. Causes suggested for this general decline, none of which were very likely according to the author, included wolves, hunters (including Indians), and moose-caribou incompatibility. A major and severe fire occurred in the Wells Gray Park area in 1926 and is considered by the author to be the cause of the decline of the Wells Gray Herd.

Relevant observations and conclusions include the following:

(1) The 1926 fire burned 520 km^2 (200 mi^2) of forested land, and by 1940 an additional 466 km^2 (180 mi^2) were burned. Of the forest burned, 60 to 70% was mature lowland forest used by caribou as winter range.

(2) The caribou decline was first noted with alarm in 1935. Hunting of this caribou herd was stopped in 1940.

(3) The author concluded that loss of winter range from fire was the cause of the decline of the Wells Gray Park Herd.

(4) Management recommendations for the Wells Gray Herd included protection of the remaining mature forest from fire, vegetation management to increase the area of mature forest, and protection of the animals themselves.

[Rev. note: The number of caribou present in this herd, either before or after the fires, was not discussed in this paper. In addition, much of the information presented in this paper was gathered from local residents or from 4 yr of fragmentary data. The author's belief that fire caused the decline of the caribou should be viewed with caution as the fire-caribou relationship may be coincidental rather than causal. The effects of hunting, adverse weather, changes in patterns of migration, changes in levels of predation, or habitat loss from human activities were not considered for their potential impact on the numbers of the Wells Gray Park Herd.]

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Eriksson, O. 1975. Sylvicultural practices and reindeer grazing in Northern Sweden. Pages 108-12 in J.R. Luick, P.C. Lent, D.R. Klein, and R.G. White, eds. Proceedings of the first international reindeer/caribou symposium, Fairbanks, Alaska, 1972. Biol. Paper Univ. of Alaska, Special Rept. No. 1. 551 pp.

The effects of logging practices on reindeer in northern Sweden were presented in this 1972 study, which is essentially a literature review with conclusions by the author. Among the various practices considered are complete and semiclear-cutting techniques, controlled burning, use of herbicides, and methods of reforestation, including preparation of seed beds and fertilization.

Relevant observations and conclusions are as follows:

(1) The most obvious long-lasting effect of clear-cutting is the amount of slash that is accumulated, which makes it difficult for reindeer to get at ground vegetation during winter.

(2) Burning of clear-cut areas may stimulate the growth of higher plants but destroys the lichen carpet for decades.

(3) Mechanical preparation of seed beds destroys a certain amount of winter pasture and impedes reindeer movement by creating rough topography and deep furrows.

(4) Herbicides that were used to kill off deciduous growth had not been shown to be harmful to reindeer and should be tolerated by the reindeer herding industry.

(5) Nitrogen fertilizers were applied to middle- and old-growth forest stands to increase wood production. This seemed to have very little effect on reindeer winter range and should be tolerated.

The author presents several recommended guidelines, including the following:

a) A reduction in the rate with which old mature forests are clear-cut.

b) Mechanical preparation of seed beds should be prohibited.

c) Logging on reindeer winter range should be of a conservation type, where short-sighted economic aspects are not allowed to direct the methods utilized (e.g., clear-cutting).

d) There should be extended consultation between the forest and reindeer industries.

e) More research needs to be conducted on the effects of sylvicultural practices on reindeer range.

[Rev. note: See also Eriksson (1980) for effects of forest fertilization on reindeer feeding.]

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Eriksson, O. 1980. Effects of forest fertilization on the cratering intensity of reindeer. Pages 26-40 in E. Reimers, E. Gaare, and S. Skjenneberg, eds. Proceedings of the second international reindeer/caribou symposium, Røros, Norway, 1979. Direktoratet for vilt og ferskvannsfisk, Trondheim. 799 pp.

This field study was conducted during the winters of 1975-1978 in northcentral Sweden and examined the effects of forest fertilization on domestic reindeer grazing in winter. Habitat within the study plots consisted of an overstory of mature Scots pine with an understory of crowberry, lingonberry, heather, and lichens (mostly Cladonia spp.). The study consisted of two parts: one a pilot study to evaluate reindeer cratering activity in fertilized stands as compared to activity in nearby unfertilized control stands and the other an intensive study where cratering within fenced areas with alternating treated plots and control plots was recorded. The activity of chemical application produced a documented impact of interference with feeding behavior.

Relevant observations and conclusions include the following:

(1) Pilot study: After an unspecified number of reindeer had fed in an area containing fertilized (with ammonium nitrate) forest stands and unfertilized stands, it was observed that cratering intensity within the fertilized stands was significantly less (approximately 40%) than that in control stands.

(2) Intensive study, 1977: Fourteen reindeer, all age and sex categories, were placed in fenced areas containing fertilized and unfertilized study plots five months after fertilizer was applied to the plots. Cratering within ammonium nitrate treated plots was 35-50% of that recorded within control plots. Cratering in urea treated plots was 5-10% of that recorded in control plots. Mean body weight loss was 1.3 kg (2.8 lb) and 2.4 kg (5.3 lb) for the four day trials in the ammonium nitrate and urea treated plots, respectively.

(3) Intensive study, 1978: Fifteen reindeer, all age and sex categories, were placed in the fenced study areas used in 1977, and cratering intensity was recorded. Fertilizer had been applied to these plots 18 months previously. Ammonium nitrate treated plots had approximately 30% more craters than did the untreated control plots after four days of trials. Cratering in urea-treated plots was approximately 5% of that recorded in the untreated plots. Mean weight loss was 0.8 kg (1.7 lb) and 2.1 kg (4.6 lb) for the four day ammonium nitrate and urea trials, respectively.

(4) Calculations of plant biomass removed from the 1977 intensive trial plots revealed that 1) reindeer preferred "pure" forage to forage from fertilized vegetation, 2) reindeer grazed significantly fewer lichens per m^2 grazed within fertilized plots than within control plots, and 3) that reindeer grazed significantly more dwarf shrubs per m^2 grazed within fertilized plots than within control plots.

[Rev. note: The weight losses recorded during the intensive study trials should be viewed with caution as no pretrial weight calibration period was established to determine if weight loss was occurring before the trials began.]

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Espmark, Y. 1980. Effects of maternal pre-partum undernutrition on early mother-calf relationships in reindeer. Pages 485-496 in E. Reimers, E. Gaare, and S. Skjenneberg, eds. Proceedings of the second international reindeer/caribou symposium, Røros, Norway. Direktoratet for vilt og ferskvannsfisk, Trondheim. 799 pp.

This study, conducted in 1979, apparently examined the behavioral effects of undernutrition during late pregnancy on reindeer mother-calf relationships. Twenty pluriparous females, 4 and 5 yr old, were selected from a herd and segregated into two groups approximately one month before parturition. Individual food intake was controlled so that females in Group I (control) received a daily ration comparable to what was estimated to be normal under favorable winter conditions (260 g. crude protein/animal/day). Group II females (experimental) were maintained on a much lower diet (45-70 g. crude protein/animal/day) to simulate severe winter conditions. After calving, all animals received the same type and amount of food (400 g. crude protein/animal/day).

Observations of behavior began a few hours after mothers and newborn calves were moved to a common nursery pen. Each dyad was observed for approximately seven hours per day and behavioral studies lasted for three days.

One female in Group II escaped a few days after being placed in its pen, and one female in Group I gave birth to a stillborn calf. Of the remaining females, one from each group gave birth to a calf before the onset and after termination respectively of the study. Thus, eight females from each group and their calves were included in the behavioral study.

Relevant observations and conclusions include the following:

(1) There was a tendency for calves in Group I (control) to be born earlier than calves in Group II (experimental), although the difference of four days between mean birth dates was not statistically significant.

(2) There was also a slight tendency for calves of undernourished females to be somewhat physically retarded from birth, as indicted by the relatively long period of time between birth and the first occurrence of standing, walking, and nursing.

(3) Undernourished mothers appeared to be less concerned for and more intolerant of their calves than mothers in the control group, as indicated by a higher frequency of maternal rejection when calves tried to suckle, shorter nursing periods, and relatively little maternal

licking in connection with nursing. Only the difference in maternal licking rate, however, was found to be statistically significant.

(4) Effective nursing time was the same for both groups.

(5) No differences were found with regard to social affinity in the dyad, as measured by interindividual distance, and social relations were maintained as much on the initiative of the calf as of the mother.

(6) Overt maternal aggressive behavior was observed only infrequently and was estimated to be the same for both groups.

[Rev. note: The author acknowledges the fact that no detrimental effects were observed in this study, but also attributes more importance to minor behavioral differences than is probably warranted. Perhaps the most useful conclusion that can be drawn is that behavioral differences can occur between well-fed and undernourished cow-calf pairs and that these differences may influence calf survival in as yet undetermined ways.]

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Euler, D.L., B. Snider, and H.R. Timmermann. 1976. Woodland caribou and plant communities on the Slate Islands, Lake Superior. Can. Field-Nat. 90(1):17-21.

The authors used a system of pellet group transects in order to gauge the habitat use of an insular caribou population on the Slate Islands in Lake Superior. They found that caribou spent substantial amounts of time in winter away from climax vegetation. The islands were heavily burned in the early 1900's - at nearly the same time caribou immigrated to the island. When Cringan (1956) measured forest cover 40-45 yr after caribou had colonized the islands, less than 15% of the forest could be classified as climax. Because the habitat was of sufficient quality to support a herd of 30-40 animals, the authors hypothesize that woodland caribou are not necessarily dependent on climax forest. They believe that although caribou are adapted to lichens, they may not be necessary for survival. The authors note studies that document the versatility of the caribou's diet (e.g., Banfield 1954, Tener 1963, Bergerud 1972).

[Rev. note: This study falls nicely in line with Bergerud's (and others) theories about the relationship (or lack of relationship) of caribou to climax vegetation, although it is dangerous to generalize from this situation to cover arctic and subarctic habitats. One factor that definitely does not fit Bergerud's (1983) hypothesis on the population dynamics of insular, predator-free caribou populations is the fact that the herd has apparently remained stable over a period of several decades. Bergerud would predict an almost linear increase until densities became so great that range overutilization would occur. However, since Euler et al. state that previous surveys are of poor quality and may have reflected a tendency to match previous surveys rather than to report new, different results, Bergerud's theory shouldn't be discounted. The authors also state

that a recent count by Bergerud estimated nearly three times more caribou than the earlier surveys.]

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Freddy, D.J. 1979. Distribution and movements of Selkirk caribou, 1972-1974. Can. Field-Nat. 93(1):71-74.

This paper reports the movements and distribution of woodland [mountain?] caribou using an area of southern British Columbia, northeastern Washington, and northwest Idaho.

The following impact-related conclusions are presented:

(1) The Selkirk caribou are repeatedly found in close association with Englemann spruce - subalpine fir forests above 1,430 m (m.s.l.). No seasonal changes in elevations were evident, a difference from other woodland caribou in central B.C. (Wells-Gray Provincial Park). The caribou feed heavily on arboreal lichens (Alectoria spp.) in the spruce-fir forest, and this is in conflict with extensive clear-cut logging.

(2) Specific, repeatedly used movement routes are followed by these caribou. Kootenay Pass is the only route used to cross into the US. Use of ranges in the US has decreased recently, although this may be merely a shift in distribution causing temporary absence from areas, rather than an impact due to a barrier to movement. Freddy does state that a proposed expansion of the road through Kootenay Pass to a four-lane highway has the potential to obstruct caribou movements.

(3) Use of traditional movement routes implies that disturbance to them might disrupt caribou movements. Therefore logging near or along these routes should be discouraged.

[Rev. note: The fact that this population is restricted to a limited area, and to only a few vegetation types in that area, indicates a very precarious habitat situation, no matter what one's opinion regarding caribou dependency or nondependency on lichens.]

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Freddy, D.J., and A.W. Erickson. 1975. Status of the Selkirk Mountain Caribou. Pages 221-227 in J.R. Luick, P.C. Lent, D.R. Klein, and R.G. White, eds. Proceedings of the first international reindeer/caribou symposium, Fairbanks, Alaska, 1972. Biol. Paper Univ. of Alaska, Special, Rept. No. 1. 551 pp.

The Selkirk Mountain Caribou Herd is the only naturally remaining herd of caribou in the contiguous United States. This study, conducted in 1972 was designed to ascertain the abundance, composition, distribution and movements

of the herd and to prepare management recommendations for perpetuating these animals.

Relevant observations and conclusions include the following:

(1) A minimum of 35 caribou was believed to exist at the time this study was completed, and the animals appeared be to divided into at least three small groups with a somewhat discontinuous range.

(2) The animals wintered in the subalpine fir-Engelmann spruce forest in areas of moderate relief and fed primarily on arboreal lichens.

The authors proposed the following management recommendations for this herd:

(1) Logging should be prevented in those spruce-fir forest areas known to be of importance to caribou. Special land classification should be considered to preserve known essential winter ranges and travel lanes.

(2) Consideration should be given to maintaining areas of hemlock forest above 1,350 m (4,400 ft) near or adjacent to prime winter ranges to serve as potentially needed early winter ranges and as buffer zones.

(3) Controlling forest fires in and adjacent to prime winter ranges should be given high priority.

(4) Consideration should be given to closing roads into winter ranges [rev. note: this applies to logging roads only].

(5) The protected status of these animals should be continued with more effective law enforcement of illegal hunting.

(6) Additional aerial censuses are needed.

(7) To minimize highway fatalities, consideration should be given to installing speed controls, drive fences, and signs.

(8) To prevent the introduction of brucellosis into this herd, measures should be taken to allow only cattle free of brucellosis to graze within the caribou range.

(9) Consideration should be given to minimizing accidental killing of caribou by increasing hunter education programs, signs, or special permit systems.

[Rev. note: Several of the management recommendations presented above appear to have been composed independently of the objectives or results of this particular study.]

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Fuller, T.K., and L.B. Keith. 1981. Woodland caribou population dynamics in northeastern Alberta. J. Wildl. Manage. 45(1):197-213.

This paper reports results from a study done in the Birch Mountains area of Alberta in an attempt to gain knowledge about a population of woodland caribou in preparation for development of the Athabasca Oil Sands. The authors conclude that the population is ecologically distinct, with short seasonal movements, low density, and poor adult and calf survival. Habitat use is similar to that of other woodland caribou and is apparently influenced by food availability, snow depth, and social behavior. Age composition indicated that the population was declining.

Up to the present, the herd has not received much human harassment, although limited oil exploration has occurred in the past and some airplane traffic to a village and fishing lodge occurs. Dramatically increased disturbance will likely accompany oil exploration and development.

The reasons for poor survival are unknown. Hunters kill only 6-8 adults each winter [out of a population of approximately 44-50]. Wolf predation is implicated [p. 201] as a major cause of mortality. Moose populations support year-round wolf populations over most of the range of this caribou herd. The use of uplands by caribou may be related to the fact that this is the only place where year-round wolf populations do not exist. An additional confounding factor is that the 1972-1974 cohorts are under-represented in the population - these were years in which snow was deep.

[Rev. note: Although this report contains much valuable information about the ecology of a small, isolated woodland caribou population, there are several discrepancies in the information. First, the effects of handling mortality of 5 caribou (out of a total of 44), two of which had well-developed fetuses, is never discussed as a factor contributing to the decline of the herd. Second, although wolf predation is implicated as a major source of predation, the two wolf packs in the study area took only one caribou each during the study period.* Yet the authors strongly suggest that low calf survival was due to wolf predation (p. 203). Although it is possible that under conditions of even a low density of wolves and a small prey population, wolf predation alone could be responsible for a decline in the prey population, the amount of human-induced mortality along with low representation of several age classes could as easily be responsible.]

*Fuller, T.K. and L.B. Keith. 1980. Wolf population dynamics and prey relationships in northeastern Alberta. J. Wildl. Manage. 44(3):583-602.

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Gaare, E. 1968. A preliminary report on winter nutrition of wild reindeer in the southern Scandes, Norway. Pages 109-115 in M.A. Crawford, ed. Comparative nutrition of wild animals. Symp. Zool. Soc. Lond. No. 21. London: Academic Press. xix + 429 pp.

In this report the author discusses results of vegetation surveys and rumen analysis of European wild mountain reindeer (Rangifer tarandus tarandus) in the Dovre plateau of the Snohetta Range between 1950-1964. The author

characterized the study area as a high mountain plateau rising on the east side to mountain peaks of the Snohetta Range [ca. 2,000 m alt.], surrounded by steep valleys on the south, west, and north sides, and by a highway and railroad on the east side. In the period 1958-1962, the reindeer herd numbered 12,000-15,000 in the 36,000 ha (1,350 mi²) study area; by 1964 the herd numbered 6,000.

Relevant observations and conclusions include the following:

(1) Wild reindeer in Norway are restricted to the mountainous region in the south and are primarily found in the alpine areas, although they are also occasionally found in subalpine and birch forest areas. The entire wild reindeer population is now divided into individual herds whose boundaries are often artificial and determined by human activity [such as roads, hydro reservoirs, etc.].

(2) In this region, the same continental climatic conditions that promote increased growth by lichens also result in shallower snow depths in winter, hence greater availability to reindeer.

(3) Vegetation analysis on the east and west sides of the highway/railroad complex across the Dovre plateau indicate that the portion on the west side of the road/railroad complex was overgrazed. In 1950, lichens comprised 65-80% of the vegetation biomass; by 1964 this figure had declined to 5-25%. A similar trend was noted for woody plants such as Vaccinium, Betula, and Loiselurieto. Some lichens, such as Alectoria ochroleuca, were abundant in 1950 but apparently almost disappeared because of trampling rather than grazing. Total plant biomass also declined. East of the transportation corridor, where only a few reindeer were currently [as of 1964] present, lichens and woody plants were abundant. [Rev. note: Although the author did not explicitly state so, he inferred that the road/railroad complex was a barrier to movement from one side of the plateau to the other. He did mention (p. 110) that in a few years immediately prior to his study (i.e., early 1960's) small bands had crossed the complex.]

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Georgeson, C.C. 1904. Reindeer and caribou. Pages 377-390 in Annual report of Bureau of Animal Industry (1903). Washington, D.C.

This article is an account for popular consumption of the distribution of caribou and reindeer and of how wild animals have been domesticated for the good of mankind. Because the paper is largely a glowing account of the success of the Alaskan reindeer industry in its early years, little of relevance to the purposes of this review is included. However, in describing the distribution of caribou, the author in several places implies that this species had been displaced from portions of its potential range by settlement, and that at the southern edges of its distribution it was in balance with these impacts. Such statements as "In Newfoundland, which is as yet but thinly settled ... there are still large herds of caribou..." and "In ... Alaska ... it [i.e., caribou] is rapidly disappearing from the

regions most frequented by the prospector and miner" convey this impression of impact. The author also states that in "Alaska there are still large regions unexploited where caribou are found in numbers, but they are scarce along the trails." No evidence is given to substantiate these statements.

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Gilliam, J.K., and P.C. Lent, eds. 1982. Proceedings of the NPR-A caribou/waterbird impact analysis workshop, May 11-13, 1982, Anchorage, Alaska (final rept.). USDI, BLM, Anchorage, November, 1982.

This report documents the conclusions of a panel of caribou experts regarding potential impacts stemming from various hypothetical oilfield developments in the National Petroleum Reserve-Alaska (NPR-A). Panelists reacted to scenarios in order to predict impacts and to suggest mitigation, if any were possible.

The following relevant material is presented:

(1) Seismic and exploratory activities were treated generically, rather than under area-specific scenarios. Winter seismic work has not had a significant effect on caribou to date. The panel felt these activities are acceptable provided that activities cease by mid May, aircraft harassment and hunting prohibition stipulations are enforced, and adequate cleanup is performed.

(2) Summer seismic operations were considered to be acceptable as long as no operations took place from mid May to June 20, surveillance is undertaken to prevent aerial harassment, hunting is prohibited, and cleanup is adequate.

(3) Winter exploratory drilling is considered to have effects similar to winter seismic work. For deep exploratory wells, which require more time, reoccupancy of the drill site the following winter is preferred to continual operations through the summer. This is the only acceptable method when located in or adjacent to calving areas. All operations near calving areas should be terminated from mid May through June 20. Surface occupancy should be minimized.

(4) Activities associated with development and production cannot be curtailed upon a seasonal basis (although some aspects, such as road traffic, can be minimized and managed to be less disruptive through convoying, etc.).

Four alternate patterns of oilfield development were examined. The panel felt the significance of potential impacts were proportional to both the portion of a caribou herd that was likely to encounter developed areas and the number of times a given cow would encounter the development in a yearly cycle of movements. Further, the nearer the encounter to the peak of the calving period (i.e., the closer the development to the area used for calving), the more sensitized pregnant

cows will be. Therefore, alternate locations of the theoretical oilfield(s) could markedly change impacts to caribou.

The panel predicted that if oil development occurred in a calving area some of the arriving cows would attempt to carry on as usual, while others would be displaced to other areas. Theoretically, this could mean that cows would be using marginal habitats in densities higher than normal. If calving areas are picked by caribou because they offer significantly better chances for calf survival than do surrounding areas, then the consequences of displacing cows is of concern.

(5) Placing development in the range of a herd with restricted movements (e.g., Teshekpuk Lake Herd) may affect several seasonal habitats, thereby increasing the number of encounters per year and the portion of the herd affected. The panel felt such development was unacceptable.

(6) A pipe/road corridor from NPR-A to the west (to Cape Thompson) would in some years be encountered by 75% of the Western Arctic Herd. A route to the east towards TAPS would be encountered by the Central Arctic Herd twice a year (50% of the herd involved). The TAPS route is preferred, and some mitigation is suggested:

a) Pipe should be buried where possible, especially at traditional caribou crossings.

b) Convoying of traffic should be used May 15-July 15 during leasing and development.

c) Spacing between pipe and road may reduce barrier effect.

d) Phased leasing and development would lower traffic levels on haul roads.

(7) A scenario with oilfield development in the Utukok calving grounds of the Western Arctic Herd was estimated to have an unacceptable risk of negative environmental impact.

(8) Deferring leasing in the range of the Teshekpuk Lake Herd and on the margins of WAH calving areas was recommended, both in terms of reducing traffic and to let uncertainties in the delineation of calving areas be cleared up.

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Gunn, A., F.L. Miller, R. Glaholt, and K. Jingfors. 1985. Behavioral responses of barren-ground caribou cows and calves to helicopters on the Beverly Herd calving grounds, Northwest Territories. Pages 10-14 in A. M. Martell and D.E. Russell, eds. Proceedings of the first North American caribou workshop, Whitehorse, Y.T., 1983. Can. Wildl. Serv. Spec. Publ., Ottawa. 68 pp.

This report summarizes research conducted on the response of Beverly Herd caribou cows and calves to helicopter disturbance during the postcalving aggregation in June 1982. Observations were conducted during helicopter overpasses at 300 m (1000 ft) AGL and landings at distances of 300-2,200 m (1,000-7,000 ft). Observations of a total of 16 landings were completed. Post-disturbance data were gathered on 11 groups, and pre-disturbance data were gathered on 7 of the 11. The small sample size was due, in part, to the groups moving out of sight prior to the completion of the full cycle of observations and, in many cases, even prior to landing.

Relevant observations and conclusions include the following:

(1) None of the differences between activity patterns that were measured pre- and post-disturbance were statistically significant; however, the standard deviations post-disturbance were greater, suggesting greater variability of behavioral response to the helicopter than prior to disturbance. A major confounding factor was that caribou tended to move out of the observation area prior to the completion of observations [in itself an important observation, but one that renders statistical treatment difficult, to say the least].

(2) Caribou in 11 of the 16 aggregations for which the full range of observations could be collected moved 1-3 km before observations were discontinued.

(3) The observational technique used presented serious problems, including quantifying responses, due to the large number and mobility of the caribou, and difficulty for one observer to record all the data required.

(4) Although the approach of analyzing individual and group response to land use activity is useful to determine behavioral changes as a result of land use activities, this analysis does not measure demographic changes, if any, that may result from these behavioral changes. Therefore, demographic parameters should be monitored concurrently with behavioral parameters.

[Rev. note: Because many of the caribou groups on which the authors had obtained pre-disturbance data moved out of view prior to completion of post-disturbance observations, the possibility cannot be discounted that the data obtained represented only those animals that, through experiential or innate factors, were less reactive to disturbance. On the other hand, rapid movement is a characteristic of many North American caribou post-calving aggregations.]

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Harper, F. 1955. The barren ground caribou of Keewatin. Misc. Publ. No. 6 Univ. Kansas, Lawrence. 164 pp.

This monograph deals chiefly with the ecology, population, morphology, and taxonomy of the barren-ground caribou in the Keewatin region, Canada. The

author uses the outmoded epithet Rangifer arcticus arcticus to describe these animals. His work was conducted at and near Nueltin Lake, which is within the present range of the Kaminuriak Herd and possibly within the area of overlap with the Beverly Herd.

The following impact-related information is presented:

(1) Harper alludes to drastic change in the hunting practices of the region beginning with the advent of white men and advanced firearms. The author states that whereas the old ways of hunting (e.g., bows, spears) provided adequate harvest without endangering the species, current practices were resulting in "annual slaughters ... both excessive and wasteful." "Undue reliance on continued abundance" and an "indifference to the welfare or rights of posterity" were cited as attitudes.

The author cites harvests of 100 caribou for a typical trapper. These were used for dog food and fox bait as well as a small proportion to be used for human consumption. Many animals were killed and left in the field if shot in areas appropriate for a trapline. Natives are described as harvesting excessive numbers and as killing "for fun."

The author was concerned about both the potential for caribou populations to be negatively affected by hunting and the severe implications this would have for caribou-dependent cultures, such as the caribou-eater Chipewyans.

(2) The author states that a deterioration in antler size was observed and attributed it to selective harvest of large bulls. The reason for the decrease is similar to that of the European red deer (Cervus elaphus), but with a different motivation; instead of selecting for trophy racks, the Natives chose big bulls because of their yield of meat and fat.

(3) Near Nueltin Lake, excess kill of caribou had attracted a concentration of black bears (Ursus americanus). As the local Chipewyan population declined from disease, fewer carcasses of caribou were available for the bears, and these became a nuisance and danger to those people that remained. [Harper mentions no caribou mortality due to the bears, but it remains a possibility. Interestingly, Harper mentions the wolf only as a benign "sanitary" factor that kept caribou in balance with their range but didn't pose any threat to the population.]

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Helle, T., and J. Aspi. 1983. Effects of winter grazing by reindeer on vegetation. Oikos 40:337-343.

This paper discusses changes in vegetation composition that occur because of reindeer grazing. Basically, the authors report that Cladonia stellaris, which is the foliose lichen dominant in climax stands in Finnish Lapland [and in Alaska] decreases in abundance as grazing occurs, because it is a highly-preferred food. Cladonia rangiferina and C. mitis increase in

abundance by invading grazed sites. These species are adapted to vegetative regrowth subsequent to being broken off in cratering, and so a tendency towards a C. rangiferina/C. mitis monotype is seen in grazed areas.

[Rev. note: Note that the resistance to grazing by C. rangiferina and C. mitis is based upon "top-cropping." In many ranges in Alaska, the entire podetium is taken by grazers, because the lichens are not "rooted" to a sandy substrate as in many areas of Fennoscandia (D.R. Klein, pers. comm.; M.H. Robus, pers. obs.). Thus, their recovery is likely slower here.]

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Hemming, J.E. 1975. Plenary session: potential impact of accelerated northern development on caribou and reindeer populations and ecology - Alaskan problems and prospects. Pages 11-14 in J.R. Luick, P.C. Lent, D.R. Klein, and R.G. White, eds. Proceedings of the first international reindeer/caribou symposium, Fairbanks, Alaska, 1972. Biol. Paper Univ. Alaska, Special Rept. No. 1. 551 pp.

This paper, presented in 1972, provides a historical perspective of caribou and reindeer in Alaska and highlights potential changes that could occur to influence these animals in the future. Among the many topics the author briefly considers are early reindeer herding efforts; the introduction of the snowmachine and rifle in subsistence caribou hunting practices; habitat commitments to expanding ground transportation systems, oil and gas development, mining, and agriculture; and future land management, planning, and classification issues, including implications of the Alaska Native Claims Settlement Act (ANCSA) and, as it is now known, the Alaska National Interest Lands Conservation Act (ANILCA).

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Hill, E.L. 1985. A preliminary examination of the behavioural reactions of caribou to the Upper Salmon Hydroelectric Development in Newfoundland. Pages 85-94 in T.C. Meredith and A.M. Martell, eds. Proceedings of the second North American caribou workshop, Val Morin, Quebec, 1984. McGill Subarctic Res. Pap. No. 40. McGill University, Montreal. 327 pp.

Field research was conducted during the post-calving season on the responses of Grey River and Sandy Lake woodland caribou to the Upper Salmon Hydroelectric Development (USD) in Southcentral Newfoundland. [Rev. note: See Northcott (1985) for additional information on the project.] The investigators observed changes in caribou activity patterns in response to construction activities and/or facilities during early (1981) and peak (1982) construction, and after construction (1983, 1984). Animals within 1,500 m (5,000 ft) of construction activity or a facility were considered the "experimental" group, and those farther than 1,500 m were considered the "control group." Behavior patterns were broadly categorized as "E+" (i.e.,

energy obtaining or relaxing, such as eating, resting, nursing) or "E-" (i.e., energy-expending such as running, alarm pose, scratching).

Relevant observations and conclusions are as follows:

(1) The proportion of E+ behavior declined between 1981 and 1982, but increased between 1982 and 1983-84. This observation suggests that caribou reacted to the construction activity rather than to the facilities.

(2) During the construction period caribou in the experimental area exhibited a similar proportion of E+ behavior to those in the control area. This phenomenon was attributed to the presence in the experimental area of sufficient topographic variation and forest cover to "screen" caribou from much of the construction activity. Caribou could remain in these areas and thus minimize their exposure to the disturbance rather than approach a construction site. [Rev. note: An additional explanation could be that caribou in the experimental area exhibited "displacement feeding" in response to disturbance, and the observers could have attributed this behavior to E+ when in fact it was E- (i.e., a response to disturbance).]

(3) The number of caribou utilizing the USD declined between 1979 and 1982, and increased in 1983 and 1984. Movements of radiocollared caribou indicated avoidance of the development area during construction.

[Rev. note: See also Northcott 1985.]

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Holleman, D.F. 1977. Effects of nutritional and environmental factors on the accumulation and metabolism of radiocesium. Pages 144-158 in Industrial development in Alaska and its effects on the nutritional and physiological status of arctic animals. Progress Report, July 1976-September 1977. Institute of Arctic Biology, Univ. Alaska, Fairbanks. 173 pp.

This paper reports the progress to date [1976-1977] of research conducted on uptake and movement of fallout radionuclides in reindeer/caribou, their forage, and wolves in Alaska. Samples of skeletal muscle tissue from wolves killed in various areas of Alaska, samples of skeletal muscle of moose and Dall sheep from undisclosed locations, and samples of skeletal muscle and rumen contents of caribou collected near Old John Lake, Brooks Range, were analyzed for fallout radiocesium content. Samples of muscle from the ungulates were collected during January-March 1976. Wolves were collected during winters of 1974-1975 and 1975-1976. Fallout radiocesium levels in caribou forage from the Old John Lake area were measured for samples collected during June 1976.

Relevant observations and conclusions included the following:

(1) Mean radiocesium concentrations in lichen and rumen contents of caribou from the Old John Lake area [winter range of the Porcupine Herd] were similar. When corrections for absorption, digestion, and non-lichen foreage were made, results indicated the mid-winter diet of caribou was approximately 70% lichen.

(2) Radiocesium concentrations in skeletal muscle were the highest in caribou, with Dall's sheep and moose muscle concentrations of radiocesium 15-30 and 40-110 times less, respectively, indicative of the caribou's heavy reliance on lichen during winter.

(3) Fallout radiocesium concentrations of lichens were 3.8 to 4.6 times that of sedges/grasses, 1.9 to 2.3 times that of moss, 7.8-9.4 times that of miscellaneous non-lichen plants and 11.4 to 14 times that of green willow. All samples were from the Old John Lake area and were collected June 1976, except for willows, which were collected in August 1976. Fallout radiocesium values for non-lichen/moss forage were approximately five times greater in the Old John Lake area than at Fairbanks. [Rev. note: Sample sizes were very low, ranging from six for lichen to one each for the Fairbanks samples and the Old John Lake moss sample.]

(4) Radiocesium levels in wolf muscle tissue were highest in wolves from the Brooks Range and the Seward Peninsula, indicating high access to and use of caribou/reindeer as prey. Radiocesium levels were lowest in areas where moose or small game are the major prey items, such as Yakutat and the immediate Fairbanks area. Calculations indicated that caribou/reindeer constituted about 50, 8, and 5% of the daily dietary meat intake of Seward Peninsula, Denali Highway (Nelchina Caribou Herd) and Fairbanks South (Delta Caribou Herd) wolves, respectively. [Rev. note: Sample sizes were also low for wolves, ranging from 1 for the Brooks Range to 19 for the Denali Highway area.]

[Rev. note: Although no documented impacts information is presented, the lack may be due to the cessation of above-ground testing of nuclear weapons rather than to a lack of effects of radiation.]

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Jaakkola, T. 1975. Accumulation, distribution and decrease rate of Iron-55 in reindeer in Finnish Lapland. Pages 80-89 in J.R. Luick, P.C. Lent, D.R. Klein, and R.G. White, eds. Proceedings of the first international reindeer/caribou symposium, Fairbanks, Alaska, 1972. Biol. Paper Univ. Alaska, Special Rept. No. 1. 551 pp.

Because of large-scale nuclear detonations in 1961 and 1962, 55 Fe became one of the most abundant radionuclides in the biosphere. By the mid 1960's relatively high concentrations of 55 Fe were discovered in Alaskan Eskimos as well as in Swedish and Finnish Lapps. The high values were due to an accumulation of 55 Fe along the food chains lichen-reindeer (caribou) - man, and sea-plankton - fish - man. This study, from 1972, was designed to investigate, in particular, the distribution of 55 Fe in reindeer, the

changes of 55 Fe level, the decrease rate of 55 Fe in reindeer and the introduction of 55 Fe into some wild animals feeding on reindeer.

Some relevant findings were:

(1) In caribou, 74% of the body burden of 55 Fe was found to be in blood.

(2) The biological half-time of iron in reindeer blood was estimated to be 150 days, whereas in muscle it was estimated at 1.5 yr.

(3) By tracking 55 Fe in a wolverine and wolf (whether in blood and organs or muscle tissue), experimenters were able to determine the relative time that had elapsed since these animals fed on reindeer.

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Jakimchuk, R.D. 1975. Plenary session: potential impact of accelerated northern development on caribou and reindeer populations and ecology - Canadian Caribou and northern development. Pages 9-11 in J.R. Luick, P.C. Lent, D.R. Klein, nd R.G. White, eds. Proceedings of the first international reindeer/caribou symposium, Fairbanks, Alaska, 1972. Biol. Paper Univ. Alaska, Special Rept. No. 1. 551 pp.

The author proposes several tenets to facilitate questions concerning future caribou impact research in Canada. Among these are the belief that Peary caribou, which occupy a small and very exclusive niche in Canada, are more susceptible to impacts than mainland caribou because of the carrying capacity of their respective habitats (carrying capacity for a Peary caribou is 1/100 mi^2 as opposed to 1 caribou/mi^2 in the MacKenzie grazing reserve). The author also believes that vulnerable periods in the life cycle of the species (in this case, spring migration, calving, and postcalving) and behavioral reactions that occur during these periods will determine the significance of environmental interactions and the reaction of caribou to alterations of their environment. Finally, the author suggests that quantitative research is needed to determine appropriate levels of noise or construction and that these data should then be integrated into land use plans that mitigate the location and timing of certain activities.

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Jingfors, K., A. Gunn, and F.L. Miller. 1983. Caribou disturbance research on the Beverly calving grounds, Northwest Territories, Canada. Acta Zool. Fennica 175:127-128.

This paper briefly describes a method proposed for use in evaluating the effects of human activity upon caribou in calving areas. For technological reasons the researchers were unable to use physiological indicators and were unable to mark animals so that individuals' responses to disturbance could be studied. Accordingly, a set of behavioral responses was defined so that sampling of caribou behavior could be accomplished. Preliminary data from

undisturbed and disturbed caribou groups have been collected but not analyzed (at date of publishing). If successful, the technique would allow long-term study of subtle responses to disturbance without the need to identify individuals.

[No conclusions are made.]

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Johnson, D.R., and D.R. Miller. 1979. Observations on the reproduction of mountain caribou. Northwest Sci. 53(2):114-118.

This report summarized field research on mountain caribou conducted in the Kootenay Pass area of British Columbia. No dates were provided. The authors found approximately 25 caribou in a single, mixed band during late winter. Bulls dispersed from this band in early May and spent the rest of the summer as singles or as small (2-3 individuals) groups. Following calving in late May/early June, female groups consisted of a cow with newborn calf and her calf of the previous year (long yearling). Calf production has been determined from repeated counts to be 5/yr between 1972-1979. Two calves are known and one more suspected to have been killed by collision with automobiles.

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Johnson, D.R., and M.C. Todd. 1977. Summer use of a highway crossing by mountain caribou. Can. Field-Nat. 91(3):312-314.

This paper reports the results of using time-lapse photography to record crossings of a road in the area of Kootenay Pass, B.C. by mountain caribou in summer. The camera was placed at a repeatedly used crossing point. The following impact-related data are presented:

(1) Caribou seemed to cross the road where traditional movement corridors intercept the highway.

(2) Caribou do not seem to be deterred by increased traffic levels [at least to the extent observed on this highway], and some did not flee from parked cars. Caribou mortality [7 known since road was opened] does not prevent crossings.

(3) Caribou were observed to lick the road. The authors suspect them to be licking oil spots, as has been reported by loggers.

(4) Consolidation of pipelines, powerlines, and other facilities along road routes could increase impacts to where caribou would discontinue traditional movements.

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Johnson, E.A., and J.S. Rowe. 1975. Fire in the subarctic wintering ground of the Beverly Caribou Herd. Am. Midl. Nat. 94(1):1-14.

The authors examined fire occurrence on the wintering grounds of the Beverly caribou herd in the subarctic forest of the Northwest Territories, Canada. They believe that the fact that fire is a natural phenomenon in the taiga is unassailable. Much of the paper is devoted to description of the fire pattern in terms of timing and seasonal variation. The authors also examined work done by others that concluded that the extent of burning had increased from levels found prior to settlement. Johnson and Rowe also dealt briefly with fire-caribou relationships.

Their pertinent conclusions are as follows:

(1) Naturally ignited fires accounted for 99.9% of the area burned during the seven years covered by the study. Man-caused fires covered only 0.1%. Eighty-five percent of the fires were naturally caused. The average annual portion of the study area burned was 0.9%, although variation from year to year was large.

(2) The authors point out that other authors have shown caribou to be generalists in their food habits. Lichen is a major food item where it is available to the animals, but it is not required. Authors who find caribou surviving on ranges poor in lichens sometimes seem puzzled (Jakimchuk et al. 1974 is given as an example). Johnson and Rowe summarize:

> In short, it is unlikely that caribou are locked into a winter dependence on lichens. Fires recur in boreal vegetation and it is a reasonable supposition that caribou long ago adapted to that fact of life. Indeed, the question may legitimately be asked if periodic fires do not improve the caribou winter range in both the short and immediate terms by mineralizing nutrients and renewing the growth of sedges, forbs, shrubs, and even lichens.

(3) The short history of fire records shows no trend in fire occurrence or acreage burned. The authors critiqued two studies (Kelsall 1960 and Scotter 1964) that estimated ages and extent of old burns by indirect methods and felt that both were substantially flawed. Johnson and Rowe believe that the question of fire trends remains open.

(4) The mosaic of vegetation types now existing in the study area and its carrying capacity are probably close to the norm. A true "climax" state has never existed over large areas.

[Rev. note: This paper does a good job of revealing the weaknesses of studies purporting to show an increase in area burned following settlement in the NWT. Although it doesn't show conclusively that no change has occurred, it makes a good case that the present situation is likely "normal." The authors have escaped the rigid caribou-lichen dogma and have found evidence to support their position.]

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Juniper, I. 1980. Problems in managing an irrupting caribou herd. Pages 722-724 in E. Reimers, E. Gaare, and S. Skjenneberg, eds. Proceedings of the second international reindeer/caribou symposium, Røros, Norway. Direktoratet for vilt og ferskvannsfisk, Trondheim. 799 pp.

The George River Caribou Herd, located in eastern Canada, is recovering from a severe population crash. In 1976, it was estimated to include 178,000 animals. In this paper, the author expresses concern that the observed rapid population growth of this herd may cause it to exceed the carrying capacity of its range and result in another crash. It is noted that current hunting regulations were not designed to control expansion, and problems with implementing new regulations were 1) the difficulty in maintaining control over an expanded sport hunt, 2) the high preference by sport hunters for adult male caribou, 3) the problems of weight restrictions in aerial travel as related to an increased bag limit, 4) harvests by Natives were already sufficient to meet their needs, and 5) the investment of private capital in marketing caribou meat requires long-term access to the resource, which would be difficult to obtain because of public opposition.

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Kelsall, J.P. and D.R. Klein. 1979. The state of knowledge of the Porcupine caribou herd. Pages 508-521 in K. Sabol, ed. Transactions of the 44th North American Wildlife and Natural Resources Conference. Toronto, March 24-28, 1979. 630 pp.

This paper reviews past inventories and studies of the Porcupine Caribou Herd. It concludes that an extensive amount of work has been conducted on the herd but that unfortunately much has been duplicative, while some major data gaps persist.

The following pertinent information is presented:

(1) Several concerns are mentioned as potentially impacting the Porcupine Herd: a) the Dempster Highway bisects the southern wintering range and provides increased access for hunting and disturbance from traffic, b) a proposed gas pipeline that would parallel the Dempster Highway for most of its length, c) oil and gas exploration and development that could cause intrusion of a good deal of human activity upon winter, summer, and migration habitats, d) the possibility of electric generation stations and transmission lines to power facilities, and e) the possibility of new pipelines crossing the Porcupine Herd's range.

(2) There is ample evidence, say the authors, that major transportation corridors through caribou or wild reindeer range have had long-term adverse effects. Klein (1973), Villmo (1975), and Cameron and Whitten (1977) are cited for this statement. The activities mentioned above have the potential to disrupt caribou migrations and/or restrict ranges. Disturbance from traffic and other human activities can disrupt feeding or add to stresses already felt by the animals. Predators can use transportation facilities to their advantage.

(3) Beyond the obvious behavioral manifestations of stress, biologists can do little to assess metabolic and physiologic stresses. Although the ability to quantify these effects is presently lacking, the Porcupine Herd is likely to experience such stresses, because [at the time of writing] nearly half the herd wintered south of the Dempster Highway. Unless half of the winter range is abandoned, these caribou will be exposed to these stresses.

[Rev. note: This paper does a good job of summarizing the knowledge extant on the Porcupine Caribou Herd and outlines potential development-related problems. However, all the predictions of potential impact don't do much except set the stage for post-construction studies that could document effects and allow one to see how predictions relate to reality.]

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Klein, D.R. 1968. The introduction, increase, and crash of reindeer on St. Matthew Island. J. Wildl. Manage. 32(2):350-367.

This study presents the results of field research on the population dynamics of reindeer that were introduced to St. Matthew Island, Alaska, in 1964. The reindeer were subsequently studied during trips by the author to the island in 1957, 1963, and 1966. Inferences about the population dynamics were made from direct observation of the animals, analysis of skeletal remains, and collection and subsequent necropsy of live animals. During each trip, range conditions were also studied.

The 1944 transplant consisted of 24 female and 5 male yearling reindeer from Nunivak Island. In 1957 and 1963, respectively, 1,350 and 6,000 deer inhabited the island. Between 1963 and 1966, the population crashed to 42 animals. Total 1957-1966 harvest was only approximately 115 animals, most of which were collections for scientific purposes. Predators and warble flies were absent from the island. The author offers compelling evidence that the population increased to the point where it was approaching or exceeding its carrying capacity, and due to an extremely severe winter in 1963-1964, the population crashed.

Relevant observations and conclusions include the following:

(1) During the early period following the transplant, the population probably increased at the theoretical maximum. Calf/cow and yearling/cow ratios in summer 1957 were 73/100 and 45/100, respectively. By summer of 1963, these ratios had decreased to 60/100 and 23/100, respectively. Annual increments were estimated at 29% in 1957 and 17% in 1963. Thus evidence for a decline in productivity was noted as early as 1963.

(2) Analysis of physical condition (body and limb lengths, marrow fat, and body weight) indicated that in 1957, all physical characters of St. Matthew Island reindeer significantly exceeded those of parent stock on Nunivak Island. In 1963, however, adult body characters were much less

than for comparable sex/age classes in 1957, suggesting that range condition (as measured by reindeer body characteristics) was declining.

(3) Inspection of paired enclosed and unenclosed vegetation plots revealed that as early as 1957, depletion of lichen biomass was occurring, and a corresponding increase in grasses and sedges occurred. By 1963, willows began to show signs of deterioration due to heavy browsing. Lichen on the wintering areas had essentially been completely eliminated by 1963; however, summer forage abundance (i.e., non-lichen plants), although showing signs of overgrazing, did not suggest significant lasting damage.

(4) Densities of reindeer increased from 27/km² (10.5/mi²) in 1957 to 121/km² (46.9/mi²) in 1963.

(5) Although the winter of 1963-1964 was extremely severe throughout the Bering Sea, reindeer populations on Nunivak and St. Paul islands did not crash. Therefore, the die-off on St. Matthew Island cannot be attributed only to severe weather.

(6) The author concludes that the decline is a result of a combination of factors including overgrazing of lichen winter range, excessive numbers of reindeer competing for scarce winter forage, relatively poor nutritional condition of reindeer entering the winter of 1963-1964, and the proximate cause being the severity of the 1963-1964 winter (especially deep snow).

[Rev. note: Although this report contains no impact-related information, it is significant in that it provides strong evidence that Rangifer has no inherent reproduction-regulating mechanism that will ensure that the animals will not overutilize their food supply. This case provides partial support for the "predation/harvest" theory (vis a vis Bergerud 1979), and support for the "range-limitation" theory (Klein 1982), both of which agree that, ultimately, Rangifer populations are limited by habitat. This case is not relevant to the "density-dependent dispersal" theory (vis a vis Haber in Klein and White 1978) because the animals could not disperse from the island. The St. Matthew Island situation is extreme in that predation, fly harassment, and emigration were not factors affecting the population; hence it is not necessarily directly relevant to mainland Rangifer situations.]

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Klein, D.R. 1970. Tundra ranges north of the boreal forest. J. Range Manage. 23(1):8-14.

In this paper, the author describes in general the nature of northern tundra ranges and the large grazers that live there (i.e., caribou and muskox).

The following impact-related material is presented:

(1) Fire has been a factor in the destruction of vast areas of range and has been associated with alarming decreases in caribou numbers in

Canada and previously in Alaska. Fire can be particularly destructive to lichen range if all living parts of the lichen are consumed.

(2) Rangifer is lichen-adapted and makes better use of this forage than domestic grazers. "Top cropping" of lichens can allow lichens to recover in 3 to 5 years, whereas full cropping can cause a recovery period of 30 to 50 years. Trampling of lichens can have a significant effect upon range carrying capacity. [Top-cropping is rarely seen in northern Alaskan ranges, M.H. Robus, pers. obs.]

(3) Where intensive wolf control was practiced in northern Alaska, caribou numbers grew to over 300,000 and began to show "symptoms of over-population" (e.g., decreased calf production and survival). [Interestingly, no corresponding effects on range (e.g., decreased forage availability, destruction of lichen habitats) are listed.] When wolves were allowed to expand their populations these problems disappeared.

(4) Human harvests in the north were estimated at 25,000/yr in Alaska and a similar number in Canada. This was much reduced from Canadian harvests of the 1940's and early 1950's (estimated at 100,000 animals/yr) at a time when significant declines in caribou numbers were being experienced.

(5) An insular reindeer herd introduced to St. Matthew Island in the Bering Sea was ultimately controlled by relative forage abundance as mediated by winter conditions after it had expanded rapidly in size. The herd of 6,000 was virtually eliminated from starvation.

[Rev. note: The attitude of the author toward fire is wholly negative in this paper. Fire is cited as a cause for significant declines in caribou populations. Hunting, while mentioned, is not directly linked to population declines. One would infer from this paper that caribou are dependent upon lichens. Klein later softened his views on fire and lichen dependency to a considerable extent (see Klein 1982).]

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

The author believes that a review of reactions of semi-domestic and wild reindeer in Scandinavia to development should provide a basis for anticipating the problems to be encountered with caribou under similar circumstances, and that Scandinavian experiences may offer proven solutions to given problems.

The following impact-related material is presented:

(1) Highways through reindeer ranges are generally favored by herders because of the facilitation of access. However, well-traveled highways have obstructed movements of wild reindeer. Railroads have had similar

effects on wild reindeer. The Dovre-Fjell area south of Trondheim in Norway is a good example. After the completion of the road and railroad (1920's), reindeer were observed milling near the tracks rather than crossing in a deliberate fashion. Eventually, the herd ceased using the eastern region of their range. This restriction imposed by the transportation corridor, combined with a population increase stemming from protection from hunting at the same time, resulted in serious overgrazing and degradation of the western portion of the range.

(2) Reindeer favor using cleared roads and railroads for travel in winter; serious levels of mortality result from collisions with vehicles. This occurs in areas of deep, soft snow, where reindeer find movement difficult.

(3) Increased road access opens possibilities for increased recreational use near reindeer herds. Hunting with dogs is mentioned as a particularly disruptive activity.

(4) Some herders have begun the practice of trucking reindeer between seasonal ranges, usually because grazing conditions along the migration route are poor. Movement from summer to winter range in this manner has disrupted migratory behavior and has increased the number of animals that fail to follow the succeeding spring migration.

(5) Hydroelectric development has been perhaps the most significant detrimental influence on reindeer (domestic) in recent years. Impacts include the inundation of some of the most productive ranges for both summer and winter and the obstruction of herd movements by impoundments. Spring and fall migrations occur when ice on hydro reservoirs is thin and dangerous; in the spring this is compounded by sloping ice shelves caused by winter water drawdown. Winter water storage behind hydro dams can lower water levels downstream. This can cause ice shelves along stream banks with an "ice-covered moat" in between. Mitigation has included a) monetary compensation to Lapp herders, b) construction of huts along new, diversionary migration routes to facilitate the intensive herding required to change a herd's traditions, and c) wide, soil-covered bridges over dangerous stream crossings. The latter have worked only where they lie in the path of a traditional route.

(6) Forestry practices have several impacts upon reindeer (domestic). Herders feel that logging activities damage lichens on the forest floor, and of course arboreal lichens and their substrate are removed. The significance of the damage was unsubstantiated at the time this paper was written. A further complaint of the herders was that snow conditions within clearings make it harder for reindeer to feed than in undisturbed forest.

(7) Reindeer congregate around logging operations because of the availability of highly palatable arboreal lichens in felled tree crowns. Animals are frequently hurt or killed by falling trees in such situations.

(8) Aerially-applied herbicide mixtures of 2,4-D and 2,4,5-T at a concentration of 2,000 grams/ha. have killed reindeer, causing Sweden to ban such application. The herbicide was intended to release coniferous seedlings by suppressing broad-leafed plants. The practice of forest stand fertilization could also have implications for reindeer, either through direct toxicity [see Nordkvist 1983] or by stimulating growth in plants that could engulf and suppress lichens.

(9) Fencing has been introduced in order to simplify reindeer herding. Two-meter high cattle wire is effective when used in conjunction with traditional movements, although problems are created for other species with regard to movements. Fences that are not compatible with reindeer movements have been unsuccessful, as have ones constructed in winter ranges where they become drifted over.

(10) The use of reindeer as draft animals has decreased with the acculturation of Lapps and their settlement in villages. Increasingly, automobiles are used to access range areas, and snowmobiles are used for mobility on the ranges. These are a mixed blessing. Besides requiring a substantial cash outlay, with all the cultural implications that entails, the use of snowmobiles has affected herding practices themselves. If approached closely by a snowmachine, deer will panic and become unmanageable. Careless use of snowmobiles at calving can cause cow and calf mortality. Recreational use of snowmobiles, although limited at the time the paper was written, could also have serious implications.

(11) Air pollution may be reducing the growth rates of lichens in Scandinavia. A significant reduction in lichen productivity would decrease the number of reindeer that could be grazed there.

[Rev. note: Note that the last concern (lichen production) is at odds with later reviews of North American herds by Bergerud (1974) and Davis and Franzmann (1979) on the role lichens play in the winter diet of Rangifer. While a degradation of lichens is certainly of concern, it may not be as catastrophic as once thought, assuming situations in North America and Fennoscandia are somewhat equivalent.]

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Klein, D.R. 1973. The impact of oil development in the northern environment. Proceedings of the 3rd Interpetrol Congress. Rome, Italy.

This paper reviews the known effects of oil exploration upon northern ecosystems and predicts future conflicts. A large portion of the paper deals with recommended policies and research aimed at gathering baseline information in preparation for future development.

Relevant material includes the following:

(1) Human disturbance during and immediately after birth can decrease survival of caribou calves.

(2) A single episode of harassment resulting in caribou fleeing lasting 10 minutes can increase daily energy expenditure by about 20%. The energy expenditure of a harassed caribou in mid winter may well exceed the energy present in the food the animal can consume, creating a negative energy balance.

(3) Russian work (Zhigunov 1968) shows that aircraft disturbance in extremely cold weather can lead to pulmonary emphysema in caribou, which can lead to pneumonia.

(4) Exploratory work is perhaps the most threatening stage of development. This is because (a) it is based on a minimum of advance planning; (b) this work is subcontracted to small operators, who are less intent on keeping a good public image than are the large oil companies; and (c) the same operators use cost-cutting actions that are not environmentally acceptable. Secret and duplicative exploratory work by several companies multiplies the effects.

(5) The construction of pipelines, roads, railroads, electric powerlines, and plowed winter roads or seismic lines have the potential for disrupting caribou movements. Ramps and pipe overpasses have met with failure or limited success in passing caribou.

(6) Atmospheric pollution from production facilities could affect lichens negatively.

[Rev. note: For the time when it was written, this paper is a useful review of impacts associated with oil development. Much of the impacts associated with the developmental phase of oilfield management are speculative.]

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Klein, D.R. 1975a. Plenary session: potential impact of accelerated northern development on caribou and reindeer populations and ecology - remarks of the chairman. Pages 3-4 in J.R. Luick, P.C. Lent, D.R. Klein, and R.G. White, eds. Proceedings of the first international reindeer/caribou symposium, Fairbanks, Alaska, 1972. Biol. Paper Univ. Alaska, Special Rept. No. 1. 551 pp.

This paper from 1972 presents introductory statements by the chairman of the plenary session that examined impacts of development on caribou or reindeer populations and their ecology. The author provides a number of examples and general observations that underscore the importance of the topic being consisdered. These include the following:

(1) Approximately 1,500 reindeer were killed annually by accidents on highways in Finland, and around 2,000 were killed annually by trains in Sweden prior to 1972.

(2) Range lands for reindeer in Scandanavia have been extensively altered by intensive forestry practices or flooding resulting from hydroelectric development.

(3) A gas pipeline constructed on the Taimyr Peninsula of northcentral Siberia and laid directly on the ground had obstructed the migration of wild reindeer. Ramps to facilitate movement over the pipeline had proved unsuccessful.

(4) Atmospheric pollutants originating from the northcentral Siberian city of Norilsk have caused deterioration of the lichen range in the surrounding area.

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Klein, D.R. 1975b. Plenary session: potential impact of accelerated northern development on caribou and reindeer populations and ecology - response from the discussants. Pages 20-32 in J.R. Luick, P.C. Lent, D.R. Klein, and R.G. White, eds. Proceedings of the first international reindeer/caribou symposium, Fairbanks, Alaska, 1972. Biol. Paper Univ. Alaska, Special Rept. No. 1. 551 pp.

This panel discussion examines in greater detail some of the issues that were raised in the plenary session of an international caribou/reindeer symposium held in 1972. Among the more relevant topics discussed were the effects of the [then unbuilt] Trans Alaska Pipeline System (TAPS). Concern was expressed about the possibility of fractioning larger herds into smaller, separate components and whether this might not be beneficial in forcing caribou to utilize habitats that had previously been ignored. Early research results with reindeer and a prototype pipeline near Nome were presented, indicating that caribou had a strong aversion to crossing a pipeline unless it was buried, or insect harassment forced them to do so. Blowing snow was also considered a potential problem if it collected in drifts near the pipeline and prevented caribou crossing or become unstable in the spring (due to melting) and trapped newborn calves.

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Klein, D.R. 1980a. Conflicts between domestic reindeer and their wild counterparts: a review of Eurasian and North American experience. Arctic 38(4):739-756.

This paper summarizes the conflicts that have occurred when wild and domestic Rangifer are present on the same range [most of the impacts in such situations are upon domestic herds, and as such are of limited interest for the purposes of this review]. The information used is from arctic and sub-arctic regions in North America and Eurasia. Most of the impacts can not only be extrapolated to Alaska, they have occurred here.

The following relevant information is presented:

(1) Loss of domestic reindeer to caribou herds is and has been a significant problem wherever the two occur on adjacent or identical ranges. When domestic reindeer mix with wild animals, they become unmanageable and join the wild herd. This problem can wipe out small reindeer herds and can be a serious drain on the productivity of domestic reindeer herds - Klein cites annual losses to caribou herds of from 2.4% to 15.7% [the latter figure also containing other unknown losses] in various regions of the USSR. Such problems are actually increasing in many areas, since wild herds are increasing in size and range in several regions where herding of domestic reindeer occurs. [For example, the Western Arctic Herd is recovering from low populations and has recently extended its winter range use into reindeer grazing permit areas on the Seward Peninsula.] In the USSR, wild reindeer herds that were hunted to the verge of extirpation in attempts to reduce conflicts for controlled, "rational" reindeer herding are now receiving protection as "rare" animals and are similarly expanding into herding areas.

The only impact upon caribou from this aspect of the intraspecific problems is the potential for the influx of domestic reindeer genetic material to the wild gene pool. The author believes that the number of reindeer added to caribou herds is small in proportion to total herd size and that domestic animals probably fare poorly under the rigors of life in the wild (i.e., hunting, predation, long migrations, difficult winter foraging, etc.). Further, Klein feels there is little chance for genetic exchange because of the domestic animals' smaller size, weaker migratory urge (so that they would not compete well with wild bulls), and asynchronous breeding periods. Further, any reindeer calves would be born before the herd reached its calving grounds, with probable dire consequences for both mother and calf. With the exception of the Alaska Peninsula, where a small caribou herd may have been overwhelmed by large abandoned reindeer herds, the author discounts genetic "deterioration" as a serious problem.

Close herding of domestic reindeer can reduce losses to caribou herds. [Rev. note: This type of herding has never been prevalent in Alaska, where herders have always tended to be preoccupied with subsistence tasks that were much more traditional than reindeer herding. In other countries, increasing use of snowmobiles may be leading to a tendency to "loose herd." Under certain weather conditions, close herding becomes impossible, and intermingling of wild and domestic animals cannot be prevented.]

(2) Migrating caribou herds often bring trailing predators (i.e., wolves) to areas used by domestic herds. Reindeer may be more vulnerable to predation than are caribou, and where loose herding is practiced, wolves can have significant impacts on domestic herds.

(3) Exchange of diseases and parasites between reindeer and caribou can take place in both directions (i.e., the most heavily infected herd can infect the other). Under close herding, with control of scavengers and with high animal densities, domestic herds are often more highly diseased than more dispersed wild herds. Under very intense, therapeutic management, the opposite could be true.

Brucellosis is the most feared disease that could be easily transmitted between herds, although documentation is poor. Nasal bot and warble flies are common parasites of Rangifer, and herders often accuse wild herds of reinfecting drug-treated domestic deer. Klein disputes this, doubting that complete eradication is ever achieved because some domesticated reindeer escape round-ups and are not vaccinated. One interesting example of an impact to wild populations was the introduction of warble and bot flies to uninfected caribou in West Greenland through the careless introduction of infected reindeer to that area. Caribou thus infected have exhibited deteriorated condition and increased mortality rates.

The timing of contact between wild and domestic herds in northwest Alaska works to minimize this type of conflict, since the wild and domestic herds are far apart at the prime times for transmission of diseases and parasites (i.e., calving, summer, breeding).

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Klein, D.R. 1980b. Range ecology and management - progress made and directions for the future. Pages 4-9 in E. Reimers, E. Gaare, and S. Skjenneberg, eds. Proceeding of the second international reindeer/caribou symposium, Røros, Norway, 1979. Direktoratet for vilt og ferskvannsfisk, Trondheim.

This paper provides a brief, generalized review of recent reindeer/caribou studies and suggests areas of reindeer/caribou biology where further research is needed. This generalized review is worldwide in scope. Topics discussed included comparative studies of basic biological parameters between reindeer/caribou populations, the importance of lichens and forage resources, the importance of wildfire and snow cover, the responses of plants to grazing and the modeling of grazing systems.

[Rev. note: As the majority of references used in this paper are to be annotated in detail separately, further elaboration of this paper will not be made.]

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Klein, D.R. 1982. Fire, lichens, and caribou. J. Range Manage. 35(3):390-295.

In this paper, the author examines several important and highly debated subjects regarding caribou range relationships. Several papers within the past decade or so have opposed formerly held theories, such as the destructive role of fire with regard to caribou range and the dependency of caribou upon lichens. Klein believes that in the enthusiasm to embrace fire as a natural force in the taiga, people have made unwarranted assumptions - namely, that lichens are not important in the winter diet and that caribou are fire-adapted in that they have a beneficial relationship with fire. [Even

though he is bolstering portions of the "old" philosophy, this paper represents a significant modification of Klein's positions published 12 years earlier (see Klein 1970).]

The following is a synopsis of pertinent points:

(1) The author makes the point that just because no correlation has been found between habitat destruction and caribou declines it does not mean that one can reject food limitation as a factor in caribou population control, as he alleges Bergerud (1974) has. Klein states that a host of factors operate upon caribou herds and that the effects of any single factor vary over time. He believes that the Nelchina Herd decline showed signs of food limitation (Pegau 1975) and that the Western Arctic herd showed signs of overpopulation prior to its decline in the mid 1970's [Rev. note: Klein uses a high incidence of brucellosis as an indication of poor nutrition, but no direct indicators of a change in range condition are given]. The author states that these declines were undoubtedly aggravated by hunting, and possibly by high predator pressure. He closes this section by saying that Bergerud's hypothesis remains untested and that examples exist where caribou are limited by food in the absence of predation [a point Bergerud would agree with - see Bergerud 1983].

(2) Klein makes some excellent points regarding the importance of lichen in the winter diet of caribou. New studies of free-ranging caribou indicate that they can maintain a positive energy balance on a lichen-rich diet in winter (Hollemann et al. 1979). Lichens are high in digestible carbohydrates and provide a good source of energy. They are rarely consumed exclusively but are mixed with winter-green plants that are high in nitrogen. A factor that should be noted is that lichens comprise a large biomass that's available for grazing in the arctic and subarctic when most vascular plants have translocated nutrients underground. The ability of caribou to switch to alternative forage in winter if deprived of lichens is not verified. Further, the existence of caribou on islands without lichens usually occurs in relatively mild, maritime conditions and where they have no predation pressure.

(3) The author goes on to list both short-term (mostly negative) and long-term (mostly positive) effects of fire to caribou range. He believes that short-term negative effects (e.g., destruction of lichens, effects on migrations, reduced forage availability) outweigh long-term benefits (e.g., vegetation type diversity, rejuvenation of decadent stands), at least from the standpoint of a caribou herd (as opposed to the long-term benefit of the species).

(4) Klein states that caribou do not show specific responses to fire (e.g., serotinous cones in black spruce, reproductive plasticity in moose, etc.). Therefore, he feels it is better to say that caribou have existed with fire in the taiga, not that the species is "fire-adapted." Fire influences caribou in that it modifies the amount of winter habitat that can be used.

[Rev. note: Klein makes some good points here, although he doesn't completely overturn the "revisionist" theories of caribou habitat relationships. He makes the biggest impression in discussing lichens and their importance in the winter diet, using better documentation in mounting his argument than Bergerud has in the past. In discussing population-limiting factors, Klein maintains that food is a limiting factor to caribou herds and that this refutes Bergerud's (1974) hypothesis. However, Bergerud's purpose was in showing that hunting and predation could cause declines of caribou herds numbering well below the range's carrying capacity, and the evidence seems to bear him out. Even Bergerud wouldn't argue that range is ultimately limiting to caribou - indeed, he states this in his 1983 Avalon Peninsula paper (Bergerud et al. 1983). The point is that many other factors operate on caribou populations (which Klein agrees with) and that some of these can act as proximate limiting factors at a point below which the herd is stressed by food limitation. Klein's statement that at high population levels caribou have been limited by food is logical but, unfortunately, poorly documented. The fact that insular populations are limited by food in the absence of predators is supported by both Klein and Bergerud.

Finally, Klein's statements regarding detrimental and beneficial effects need discussion. He seems to focus on the utility of a given piece of habitat, much as a reindeer herder using a limited winter range area would. Admittedly, if caribou winter ranges are so limited that it all must be grazed in order to support the herd, the short-term effects of fire are of real concern. However, if extensive potential winter ranges are available and the rate of habitat modification (i.e., fire occurrence) is in balance with regrowth rates, then even the short-term negative effects may not operate on the caribou herd. It is only when winter range becomes restricted that fire would become a serious concern, and even then long-term habitat decadence due to fire exclusion would eventually entrap the caribou manager.]

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Klein, D.R., and V. Kuzyakin. 1982. Distribution and status of wild reindeer in the Soviet Union. J. Wildl. Manage. 46(3):728-733.

This paper discusses the status of wild reindeer in the USSR and briefly reviews the numbers and distribution of various herds.

The impact-related information in this paper is as follows:

(1) Overhunting, whether from meat harvest or from intentional "control" activities, seriously depleted many wild reindeer herds in the past. In many places where these animals have become rare, wild reindeer are completely protected (e.g., Kola Peninsula). In other areas, where distance between seasonal ranges is too great for efficient reindeer herding or where range resources are of low density (where wild reindeer are more efficient at grazing than domestic herds), efforts to reduce wild herds have been replaced with highly organized harvest operations that utilize the wild grazers.

(2) Industrial development has affected a large herd (300,000) in the western Taimyr region. An aboveground pipeline from a gasfield to the industrial city of Norilsk was completed in 1969. This deflected substantial portions of the herd during migration; while retrofitted elevated sections of line were installed, only 25% of the herd used them. After a second pipeline was constructed parallel to the first, fences were constructed to guide wild reindeer to the east, away from the pipelines. This has allowed animals to avoid Norilsk and to travel to winter range in the Putorana Mountains.

A complicating factor in this situation is the use of icebreakers on the Yenesei River to allow ships to serve Norilsk (through the port of Dudinka). This creates an ice-lined open water channel that has resulted in reindeer entrapment and death and acts as a deterrent to migration to winter ranges east of the river.

(3) Intensive, large-scale reindeer herding has displaced wild reindeer herds from portions of their range historically. This was largely through "control" activities mentioned above. Now that domestic herding has abandoned ranges as the result of collectivization or lack of efficiency, wild herds are expanding (except where affected by industrialization). This will lead to increased competition for forage between domestic and wild herds, as well as the other intraspecific conflicts between these two forms of Rangifer [see review of Klein 1980a].

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Klein, D.R., and R.G. White, eds. 1978. Parameters of caribou population ecology in Alaska. Biol. Pap. Univ. Alaska Spec. Rept. No. 3. viii + 49 pp.

This paper reports on a symposium and workshop convened in order to examine caribou population status and dynamics, and to identify research priorities for use in future modelling exercises. Little is included regarding impacts, although synopses of herd status in Alaska, NWT, and the arctic islands are given, and some estimates of harvest are made. One contribution of the workshop is that it summarizes information along the three prevailing "schools of thought" about factors that are the strongest influences on reindeer/caribou population dynamics. Aspects of these three "schools of thought" were articulated in presentations by A.T. Bergerud, G.C. Haber, and E. Reimers.

(1) E. Reimers. Wild Norwegian reindeer on favorable range had larger body weight, earlier calving, higher reproductive rates (25-35% calves in populations on favorable range vs. 12-20% calves in populations on unfavorable ranges), and higher pregnancy rates (100% pregnancy rates for females on favorable range, vs. 70-90% pregnancy rates for females on unfavorable range). [Rev. note: "Favorable" and "reproductive rate" - i.e., calf survival as opposed to birth rate - were not defined.] The effects of insects on activity budgets and forage intake were studied for an island reindeer population where insects are absent

(Svalbard) and several mainland populations. Although activity budgets during insect-free periods were similar for mainland and Svalbard populations, Svalbard adult and juvenile reindeer had much greater body fat at the end of the summer than mainland populations. [Rev. note: This discussion, together with that of D.R. Klein and R.G. White, stresses the importance of forage quality and quantity as influencing Rangifer population dynamics.]

(2) A.T. Bergerud. North American caribou have reproductive rates [Rev. note: again, "reproductive rate" is not defined; however, presumably it means "birth rate"] of 70-90% irrespective of nutritional status. Predation and human harvest are much more important influences on caribou population dynamics than is range condition, although the Canadian High Arctic Islands populations are an exception.

(3) G.C. Haber. Elaborating on the theory of Skoog (1968) that caribou herds in Alaska have a density-dependent response (i.e., emigration) to high populations, a model has been developed which predicts the response of caribou populations at varying densities of caribou and wolves. At high caribou densities [5/mi^2] caribou emigrate to areas of lower densities in response to "... limitation of food quality or quantity." The model predicted the net annual increment to caribou populations under varying levels of wolf predation and caribou density as follows:

(a) Wolves low; caribou density less than 1/mi^2; increment = 14%

(b) Wolves normal; caribou density less than 1/mi^2; increment = negative

(c) Wolves normal; caribou density = 2/mi^2; increment = 8-9%

(d) Wolves normal; caribou density = 5/mi^2; increment = 0

(4) An additional noteworthy observation is that of J.L. Davis that "the recent increase in the number of herds [in Alaska] is more likely the result of refined knowledge rather than the actual creation of new calving areas."

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Koskela, K., and M. Nieminen. 1983. Deaths among reindeer caused by traffic in Finland during 1976-80. Acta. Zool. Fennica 175:163.

This very short paper briefly describes mortality of domestic reindeer occurring along Finland's transportation system. The following points are made:

(1) From 1976 through 1980 the mean number of reindeer killed annually by cars and trains was 2,010. This was 1.7% of all adult reindeer counted in the herds.

(2) Certain places accounted for a disproportionate number of kills [however, no information or conclusions are presented as to why this is so].

(3) In the one herd for which a breakdown of mortality from cars was given, 57.1% of the dead deer were female, 23.0% were calves, and 16.1% were male.

(4) Most railroad-caused deaths occurred in winter, when reindeer have a hard time moving through deep snow. Train-induced mortality was again skewed towards females (62.9%). The greatest number of calves were hit by trains in the summer.

(5) During summer, insect harassment drives reindeer onto railroads and roads, where vehicle movement helps to repel insects, and hot pavement causes exhaled CO_2 to rise straight up, making it harder for mosquitos to find the animals.

[Rev. note: The lack of data or analysis makes interpretation of this paper well-nigh impossible.]

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LaPerriere, A.J., and P.C. Lent. 1977. Caribou feeding sites in relation to snow characteristics in northeastern Alaska. Arctic 30(2):101-108.

This paper reports the results of work that analysed snow characteristics at caribou winter feeding sites. The authors found preference for shallow snowpacks and, within shallow areas, preference for soft snow.

No impact-related information is included.

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Leader-Williams, N., and M.R. Payne. 1980. Status of Rangifer on South Georgia. Pages 786-789 in E. Reimers, E. Gaare, and S. Skjenneberg, eds. Proceedings of the second international reindeer/caribou symposium, Røros, Norway. Direktoratet for vilt og ferskvannsfisk, Trondheim. 799 pp.

Three reindeer herds on South Georgia Island originated from transplants in 1911 and 1926. The Barff Herd arose from the first transplant of 10 Norwegian reindeer; the Royal Bay Herd was formed when members of the Barff herd spread around the face of a retreating glacier that had previously formed a restricting boundary; and the Busen Herd originated from a transplant of seven Norwegian reindeer in 1926. The most recent census in 1976 indicates that there are 1,000 reindeer in the Barff Herd, 550 in the Royal Bay Herd, and 450 in the Buseu Herd.

The habitat of these herds is classified as subarctic tundra, where 60% of the land surface is covered with permanent ice and snow. Plant communities are dominated by the coastal tussock grass, Poa flabellata, which forms 95-100% of the animal's winter diet and 10-30% of their summer diet.

There are no predators, and life expectancy for males is 7-8 years, and for females it is 11-12 years. Human harvest has not exceeded 30 reindeer/yr since whaling stations were closed in 1964-1965. However, research programs during the period 1972-1976 culled the following numbers of animals from each herd: Barff Herd -370, Royal Bay Herd -100, and Busen Herd -120.

It was noted that Poa flabellata had become increasingly overgrazed in recent years, and the authors suggest that decreasing winter range-carrying capacity was the most important factor controlling herd growth.

[Rev. note: This island situation is unlike the St. Matthew Island case (Klein 1968) because (a) each herd had undergone culling for several years prior to the report, and (b) the predominate winter food source was a graminoid rather than lichens.]

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Leopold, A.S., and F.F. Darling. 1953. Wildlife in Alaska: an ecological reconnaissance. New York: The Ronald Press Co. 129 pp.

This book reports the authors' findings and impressions from a four-month visit to Alaska during the summer of 1952. In their chapters devoted to caribou and reindeer, several conclusions regarding impacts to caribou are made.

The authors believe a great decline of caribou herds south of the Arctic Circle had occurred in the early 1900's. They use Murie's (1935) population estimates in comparison to contemporary ones by the U.S. Fish and Wildlife Service to demonstrate the decline. While acknowledging that Murie's estimate was based upon much more meager information than the others, they felt that the differences were so overwhelming that a real decline had to have occurred. Leopold and Darling examined three factors that could have been involved in the decline: 1) hunting, 2) range condition, and 3) predator pressure.

(1) The authors state that hunting was the earliest and most important (for a time) cause of caribou herd declines. Despite grave excesses, a sufficient reservoir of caribou remained in the interior of Alaska when law enforcement took effect to recolonize southern and coastal ranges from which caribou had been extirpated. The fact that caribou had not responded quickly is attributed to problems with range condition.

(2) At the time of their trip, Leopold and Darling believe caribou herds were limited by range condition. They state that there was very little climax vegetation left south of the Arctic Circle and, because they equated caribou winter range with lush lichen growth, that this situation obviously limited caribou. The increase in fire attributable

to white man's settlement was significant enough, according to the authors and the people they talked with, that it consumed climax habitats at an alarming rate, thus reducing caribou carrying capacity. The authors do not claim to have looked at large portions of caribou winter habitat but say that the sample they saw had suffered badly from fire.

(3) In the range condition discussion, an interesting adjunct to the effects of fire is the effect of reindeer grazing in depleting western ranges of lichens. The Alaskan reindeer industry lost control of its herds in the late 1920's or early 1930's and an irruption, followed by a population "crash," was the result. [Rev. note: This is true, although the peak of reindeer numbers was exaggerated by the use of calculated "book" recruitment rates, rather than actual ones, in estimating herd sizes; see Stern et al. 1977*.] The authors point out that western Alaskan ranges remained unused by caribou for many years after the reindeer had disappeared, and they conclude that a lack of lichens due to reindeer overgrazing was the cause. [Skoog 1968 disagrees.]

(4) The authors recognize wolf control as a way to reduce pressure on a prey population when mortality (from human, predator, and other causes) exceeds annual increment. However, they urge caution in its use. [Rev. note: They are so focused on the range condition situation that they express a fear that the removal of a factor (i.e., wolves) that slows growth of caribou populations could allow the herd to expand to the point where it could overexploit its limited (according to them) remaining winter range and suffer catastrophe.]

As the result of their perception of the problem, Leopold and Darling castigate the U.S. Fish and Wildlife Service for its single-minded devotion to wolf control and urge agencies to cooperatively emphasize fire control programs in order to allow the range to recover.

The authors report caribou numbers in arctic Alaska, in contrast to the west coast and the interior, to be higher than ever before recorded. Possible reasons for this include shifts in location of big herds, a decline in utilization of caribou by Eskimos (due to a change to cash economies), and the low fire occurrence in the arctic. Here again, the authors fear overgrazing and are especially concerned with intensive wolf control allowing the caribou herd to increase drastically on lichen-poor ranges.

No information on man's influences other than those above are discussed.

[Rev. note: It seems clear that Leopold and Darling's analysis of the caribou situation suffered from the limited time they had in which to address the problem. In addition, one can surmise that wildlifers of the day were preoccupied with range carrying capacity as the primary limiting factor for cervids. Much of what is said regarding fire is not backed up with evidence. Since caribou have evolved with extensive natural fires in Alaska's interior, it is hard to believe that the additional increment of man-caused fires could totally decimate winter ranges. Additionally, recent work suggests that productivity can improve in burned areas and that burn-caused habitat heterogeneity benefits caribou in the long run [see

review of Miller 1976]. Also, lichens may be less crucial to winter diet than Leopold and Darling thought (see reviews of Murie 1935, Bergerud 1974).

The discussion of reindeer-affected ranges makes more sense. Because large-scale die-offs of reindeer were documented in the 1930's, it is plausible that real range depletion occurred. However, it should be noted that areas presently exist on the Seward Peninsula that have lichens that are older than the time elapsed since 1950 (Robus, pers. obs.; Skoog 1968), so evidently complete depletion had not occurred inland of the coast. Other explanations for the fact caribou had not reoccupied these areas were not discussed.

It is ironic that two distinguished and well-meaning ecologists contributed so directly to the clamor for fire suppression in Alaska. Once initiated, the fire control monolith probably caused more habitat impacts than any other man-caused perturbation and has resisted the efforts of other ecologists to tame it until recently.

In fairness to the authors, they repeatedly stated that their short sojourn in Alaska did not allow anything but the chance to form impressions and conclusions based upon the information given to them by others. What is perhaps most remarkable about this book is the degree of reliance others have placed upon it. Over the years, as more and more workers cited it, its tentative nature has been forgotten. It is interesting to read the authors' conclusions without the encumberance of the chain of citations written since they wrote it. Although hampered by a lack of personal knowledge of caribou and an over reliance upon their knowledge of the ecology of other cervids, Leopold and Darling did a remarkable job of assessing Alaska's wildlife.]

*Stern, R.O., E.L. Arobio, L.L. Naylor, and W.C. Thomas. 1977. Socio-economic evaluation of reindeer herding in relation to proposed national interest lands (d)2 in northwestern Alaska. CX-9000-6-0098 NPS, Pac. NW Region, USDI; IAB, Univ. Alaska, Fairbanks.

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Luick, J.R. 1977. Biological effects of orally ingested crude oil by reindeer. Pages 44-59 in Industrial development in Alaska and its effects on the nutritional and physiological status of arctic animals. Prog. rept., July 1976-September 1977. Institute of Arctic Biology, Univ. Alaska, Fairbanks. 173 pp.

This laboratory study investigated the physiological effects of ingestion of crude oil by reindeer, because of the likelihood that caribou grazing near petroleum development areas and transportation areas will be exposed to and/or ingest crude oil. Crude oil was given to reindeer intraruminally, mixed with lichens, pelleted livestock ration, or grass hay, and made available in buckets to reindeer.

Relevant observations and conclusions included the following:

(1) Little change in rumen protozoa, dry matter digestibility, and morphological and biochemical blood profiles over a period of up to 26 days was recorded in 2 reindeer given 30 or 300 ml of Prudhoe Bay crude oil. The reindeer given 300 ml of oil died 60 days after infusion; however, pathologic findings could not conclusively attribute the cause of death to petroleum ingestion.

(2) Five reindeer drank from 0 to 7.4 g of crude oil when given free access to crude oil during a 24-hr period.

(3) Five reindeer given oil-contaminated lichens consumed an average of 72% (179 g) of the amount given. These reindeer had not eaten lichens for several months prior to the experiments; thus the consumption of the contaminated lichen may have been somewhat biased.

(4) Reindeer given oil-contaminated pelleted ration or grass hay ate quantities similar to that consumed for oil-contaminated lichen, even when noncontaminated ration or hay was available ad libitum.

(5) Oil-contaminated lichen was preferred by reindeer over oil-contaminated hay or pelleted ration in three of four trials.

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Luick, J.R. 1980. Circumpolar problems in managing populations of wild and domestic reindeer. Pages 686-688 in E. Reimers, E. Gaare, and S. Skjenneberg, eds. Proceedings of the second international reindeer/caribou symposium, Røros, Norway. Direktoratet for vilt og ferskvannsfisk, Trondheim. 799 pp.

This paper, presented in 1979, constitutes the chairman's introductory remarks to the Management and Husbandry session of the Second International Reindeer/Caribou Symposium. It provides a brief and general survey of development impacts on reindeer/caribou and mentions a few problems associated with reindeer herding efforts in Alaska. Among the points the author makes are 1) multiple ownership (federal, state, native, and private) of reindeer grazing lands makes herding operations unecessarily complicated; 2) demand for reindeer meat and velvet antlers has increased and provides an incentive to expand reindeer herding operations; and 3) non-Natives are beginning to recognize the opportunities presented by raising reindeer and are challenging laws that restrict ownership only to Natives.

[No impact-related information is presented.]

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Martell, A.M., and D.E. Russell. 1983. Mortality rate in the Porcupine Caribou Herd. Acta Zool. Fennica 175:139-140.

The paper discusses differences in techniques for estimating mortality rates for caribou herds and points out the deficiencies of current methods. A new method is proposed that would overcome problems of using life tables for unstable age structure populations like caribou in order to estimate mortality. The authors propose following radioed calves until maturity in order to obtain better estimates of early mortality rates and using cohort analysis to estimate adult mortality rates.

The following relevant observation is included: Subsistence hunters using the Porcupine Herd do not discriminate on the basis of animals' age but do on the basis of body size. This results in a significantly higher mortality rate for adult males than for females but a male mortality rate lower than for herds that are heavily sport-hunted (i.e., where trophies are selected for).

[Rev. note: Insomuch as the article's main function is to propose new work, little of interest from the standpoint of impact analysis is included.]

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Mercer, E., S. Mahoney, K. Curnew, and C. Finlay. 1985. Distribution and abundance of insular Newfoundland caribou and the effects of human activities. Pages 14-32 in T.C. Meredith and A.M. Martell, eds. Proceedings of the second North American caribou workshop, Val Morin, Quebec, 1984. McGill Subarctic Res. Pap. No. 40. McGill Univ., Montreal. 327 pp.

In this report the historical distribution and abundance of all Newfoundland caribou herds in relation to human activities such as hunting, logging, and road and railroad construction is reviewed, and results are presented from original research conducted between 1980 and 1984 on the distribution of the Avalon Peninsula Herd in relation to roads on the herd's summer range. Historical information was gathered from literature and interviews with local residents. The data on the Avalon Peninsula was gathered from aerial and ground surveys during the summer.

Relevant observations and conclusions include the following:

(1) There were an estimated 40,000 caribou in Newfoundland at the turn of the century. A decline between 1915 and 1930 resulted in only 3,000 animals left by 1930. In 1967 there were only 8,000 animals. By 1982, natural reoccupations of former caribou range and artificial introductions between 1961-1982 resulted in an estimated minimum of 33,000 animals. In 1982, island-wide densities of native caribou averaged 0.58 caribou/km^2 (1.58/mi^2) whereas introduced herds averaged 0.23 caribou/km^2 (0.60/mi^2). Caribou of native and introduced herds are all distributed away from areas of human activity. Centers of habitation [cf. Skoog 1968] and calving areas, in particular, are located at maximum distances from road networks and settlements. Distribution of several herds has changed following the construction of heavily travelled roads and railroads in their range. Although these

distributional changes have occurred, there is no evidence that physiological or demographic changes have resulted from the disturbance.

(2) Caribou declined on the northern Avalon Peninsula where settlement and presumably overhunting occurred first by the late 1800's. Historical accounts mention the scarcity of caribou around human settlements. By the early 1900's, the herd had become fragmented into smaller herds. Several of these "subherds" were extirpated between the 1900's and the 1950's. After 1955 the Avalon caribou population increased and reoccupied the most recently vacated ranges first, presumably because they were preferred habitat.

(3) Until the 1970's, Avalon Peninsula caribou rarely were observed from the road system. In 1970 a small group of bulls remained north of the Peters River Road. In the years after, increasing numbers (including cows and calves) approached the road, and in 1978 the first group was observed to cross. After that time, increasing numbers crossed that road and were remaining in the vicinity of other roads. Caribou remained 3-4 km (1.8-2.4 mi) from the road systems, and were obviously distributing themselves relative to the road systems. The road consists of a gravel berm 1-3 m (3-10 ft) high, with an electric line paralleling it at distances of less than ½ km (1/3 mi). Traffic averages 15 vehicles/hr during daylight hours in the summer. The traffic and other human activity along the road, rather than the road itself, appear to be causing the avoidance by caribou. Although there is 182 km^2 (70 mi^2) of summer range available in the area bounded by the road system--caribou use less than 20.7 km^2 (8 mi^2) of that available because of the avoidance of the road and towns.

(4) The authors believe that overhunting of caribou in the 1800's and early 1900's, perhaps together with avoidance by caribou of increasing human activity, resulted in large portions of caribou range being abandoned. Although caribou began to increase in the 1950's, they have yet to reach densities at which all preferred habitat is filled. The authors speculate that when that point is reached, further range shifts will occur and caribou densities will increase as less preferred habitat is occupied (including those areas not currently used because of human disturbance), perhaps until overgrazing results in another decline.

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Meredith, T.C. 1983. The caribou of Ungava: current use, future options. Acta Zool. Fennica 175:181-183.

The author discusses the use by subsistence and sport hunters of the rapidly expanding George River Caribou Herd. Subsistence harvest cannot expand significantly; sports hunts won't increase at current costs, and the herd is still expanding. Managers are concerned about the future, based upon the track record of managing caribou herds, and the author briefly discusses options, including laissez-faire, culling, and wolf-control, but arrives at no conclusions. No impact material is presented.

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Michurin, L.N. 1963. On the infestation of the wild reindeer with the larvae of Oedemagena tarandi L. on the Taimir Peninsula. Zoological Journal 17(1):149-151. [Transl. from Russian].

This paper presents data on the infestation of wild reindeer by warble fly larvae on the Taimir Peninsula, USSR. Data were obtained by counting larvae in carcasses and hides from reindeer collected from 1957 to 1961.

Relevant observations and conclusions included the following:

(1) Warble fly eggs are laid only in the new fur grown after shedding.

(2) The greater number of warble larvae found in adult male reindeer than in adult females was attributed to females having a delayed period of hair shedding and a more northerly use of summer habitat than do males. The adult males are more likely to be found in warmer areas during the active season of the adult warble fly.

(3) No impact information was contained in this paper.

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Miller, D.R. 1976. Biology of the Kaminuriak population of barren-ground caribou. Part 3: Taiga winter range relationships and diet. Canadian Wildl. Serv. Rept. Ser. No. 36. Ottawa. 42 pp.

The objectives of this study done in northwestern Manitoba were to appraise the amount and quality of vegetation on caribou winter range, to relate seasonal changes in food habits to availability, to estimate the ability of the taiga to sustain current use, and to collect data on the physical environment.

Most of the conclusions of this interesting study are not impact related; however, Miller's conclusions regarding the impact of fire upon the range's ability to support caribou winter use are pertinent.

The author found the capacity of the range to be five times greater [based only on standing crop of lichens and so actual capacity is even greater] than the present size of the Kaminuriak population. Fire has not jeopardized the herd's well-being but has had a positive effect by creating heterogeneity in vegetation patterns. This allows caribou to have several options for feeding, as they switch from terrestrial lichens (and other plants) to arboreal lichens and back to ground cover as snow conditions change through the winter. Also, heterogenous areas provide escape cover and movement areas. Miller also found rapid regeneration of lichens in all but the most severely grazed craters and hillsides.

[Rev. note: Although it looks only at one situation, this study does much to lend credibility to the theory that fire is a natural and not

automatically destructive component of the taiga ecosystem. Also, it leads one to question range carrying capacity as the proximate limiting factor for caribou.]

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Miller, D.R. 1980. Wildfire effects on barren-ground caribou wintering on the taiga of northcentral Canada: a reassessment. Pages 84-98 in E. Reimers, E. Gaare, and S. Skjenneberg, eds. Proceedings of the second international reindeer/caribou symposium, Røros, Norway, 1979. Direktoratet for vilt og ferskvannsfisk, Trondheim. 799 pp.

This field study examined wildfire effects on caribou responses on caribou taiga winter ranges of the Beverly Population (Saskatchewan) and the Kaminuriak Population (Manitoba). Range relationships were studied from 1966 to 1974, with wildfire aspects emphasized after 1970. Conflicting viewpoints as to the detrimental or beneficial effects of fire on caribou winter range prompted this wildlife reassessment study. Aerial photograph interpretation of caribou winter range was used to determine habitat types and size and distribution of recent wildfires. Aerial surveys, on-ground measurement of caribou feeding craters and habitat, and rumen samples were used to determine caribou habitat use and forage preferences.

Relevant observations and conclusions include:

(1) No evidence was found to support the view promoted by Scotter (1964) that an increase in the number of wildfires had occurred on caribou winter range in northcentral Canada in recent years.

(2) Caribou did not show a preference for feeding in old age stands during mid or late winter.

(3) The relative abundance of terricolous lichens apparently reaches a level that attracts foraging caribou at about 40 years after a fire.

(4) Wildfire on the taiga perpetuates forest diversity.

(5) Perpetuation of terricolous lichen forage supplies on much of the taiga is dependent on wildfire or periodic heavy use by caribou.

(6) Caribou forage preference for climax or near climax terricolous lichens was not shown to occur during the present study.

(7) Caribou used recently burned areas as migration routes, as treeless escape cover, and unburned islands within the burned area as feeding sites.

(8) Wildfires on taiga caribou winter ranges are not detrimental to caribou populations where caribou movements are relatively unrestricted by human developments.

[Rev. note: The author did not speculate on the frequency or the size of fire that would begin to influence caribou numbers. He did reference a paper by Bunnell et al. (1975) describing a computer model of the Kaminuriak herd and its range that predicted wildfire would have to increase tenfold (to approximately 10 percent of caribou winter range annually) before a reduction of lichen forage supplies would be expected to influence caribou populations.]

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Miller, F.L. 1974. A new era - are migratory barren-ground caribou and petroleum exploitation compatible? Trans. Northeast Fish and Wildl. Conf. 31:45-55.

This paper reviews the social behavior and movement patterns of the Kaminuriak Caribou Herd and discusses the potential impacts of proposed oil and gas pipelines on migration and behavioral patterns. The Kaminuriak population uses seasonal ranges in northern Manitoba, northeastern Saskatchewan, and in the southeastern District of Keewatin, Northwest Territories. [Rev. note: Due to the lack of documented effects of development on caribou behavior and movements for either the Kaminuriak herd or caribou in general at the time this paper was written, the author's conclusions are primarily speculative.]

Relevant conclusions and observations include the following:

(1) The affinity shared by parturient females for a common calving ground, the formation of postcalving aggregations, and the postcalving migratory movements are necessary for the maintenance of the social structure and discreteness of the population. Construction of oil or gas pipelines on or near calving or summering areas could interfere with the socialization of the herd, potentially leading to disorganization and disorientation of individuals and groups of caribou, with a resultant loss of identity within the population. This situation could ultimately lead to abandonment of migration routes, calving areas, and portions or all of summer or winter ranges.

(2) Several papers were reviewed that discussed caribou reactions to man-made barriers and disruption of behavior patterns. Miller et al. (1972) described persistent attempts by Kaminuriak caribou during spring migration (May, 1967) to cross a lake, even though humans and barrier fences were in place. Thomson (1972) reported that loud noises from aircraft and snowmobiles "disrupts ongoing activity, increases energy demands, and can cause physiological damage during gestation and calving" in reindeer. Papers by Child (1973) and Klein (1971) were also summarized.

(3) Barriers to movements during spring migration would present caribou with the alternative of either deviating from traditional pathways and traveling unknown routes or waiting until environmental conditions allow them to bypass the barrier and resume migration. Potential effects from barriers in this instance could include increased energy

demands, parturition prior to reaching the calving grounds, abortions, complications during parturition, trampling, desertion, and weakened cow-calf bonding, all of which could cause short-term and potentially long-term detrimental effects on the population.

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Miller, F.L. 1982. Caribou. Pages 923-959 in J.A. Chapman and G.A. Feldhamer, eds. Wild mammals of North America: biology, management, and economics. Baltimore: Johns Hopkins Univ. Press. xiii + 1,147 pp.

This chapter summarizes the current [as of 1980 ?] status of North American caribou herds, summarizes pertinent aspects of caribou biology (emphasizing recent research results), and discusses the techniques, philosophy, and controversies of caribou management. The author emphasizes that much of the management discussion is colored by his personal opinion [a refreshing admission].

[Rev. note: Because much of the caribou biology and management techniques portion is beyond the scope of this report, the following points are considered most relevant.]

(1) The range of the woodland caribou has decreased considerably since the 1800's, probably due to climax forest destruction and overhunting. White-tailed deer (Odocoileus virginianus) moved northward following the habitat change from climax forest and likely eliminated the woodland caribou from the southern portion of its range [Rev. note: no information about the mechanism of this elimination was presented]. An additional factor may have been the transmittal of meningeal disease ("moose sickness" - Parelaphostrongylus tenuis) from deer to caribou. Woodland caribou once were found in New England, Michigan, Minnesota, and the Canadian maritime provinces. Woodland caribou have been eliminated from the US, except for a very small remnant herd in northwestern Idaho/northeastern Washington.

(2) Several aspects of caribou social behavior should influence management of caribou populations. These include the following:

(a) Site fidelity. Caribou appear to be traditional in their seasonal use of range that was used by their parents, although further research is needed to determine if specific areas of the range are traditionally used. The management implication of traditional use of one area is that continued overharvest of the portion of the herd that utilizes that area could result in loss of that portion of the herd and, therefore, of continued use of that area.

(b) Social structure. The basic social unit of caribou is the winter band, consisting of a core of matriarchally related individuals (cow-juvenile band), juveniles (juvenile band), subadults (subadult band), or adult bulls (bull bands). Most band members have similar body and antler size. These bands form and break up

seasonally; however, continuity of learned use of certain areas is maintained over the seasons, primarily because most of the bands converge during the postcalving aggregations.

(3) Forage is the ultimate factor limiting caribou populations; however, other factors (e.g., predation, harvest, weather) usually prevent populations from reaching the levels at which forage becomes the controlling factor.

(4) "It is impossible to truly manage caribou until there is control of the harvest." Two sociopolitical aspects of current caribou harvest suggest that the aforementioned goal is difficult, if not impossible, to attain. One is the changing nature of Native harvest, and the other is the necessity for national and international management of some migratory herds. The advent of modern hunting methods (e.g. rifles, snowmachines, airplanes), a declining physical dependence on the land, and increasing political awareness of Natives are all aspects of harvest management that confound a sound approach. As a result, the current overharvest situation with respect to many of Canada's herds will likely be ameliorated only by a vigorous educational campaign that emphasizes both the limited capacity of caribou populations to withstand overharvest and the potential for maintaining viable populations if restraint is exercised. Interwoven with the changing acculturation of Natives in both Canada and the US is the difficulty in achieving consistent population management across jurisdictional boundaries.

(5) Predator control, when well thought out and properly executed, in conjunction with harvest constraints, is a justifiable management tool.

(6) Land areas with restrictions on land use that will provide sanctuary for caribou herds are useful to protect areas of special use (e.g., calving and postcalving areas, water crossings); however, it is unrealistic to expect that such areas would be large enough to protect all the seasonal ranges of a herd. Such special use areas would also need protection from hunting.

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Miller, F.L., and A. Gunn. 1979. Responses of Peary caribou and muskoxen to turbo-helicopter harassment, Prince of Wales Island, Northwest Territories, 1976-77. Can. Wildl. Serv. Occas. Pap. No. 40, Min. Supply and Serv. Canada, Ottawa. 90 pp.

Overt behavioral responses of Peary caribou (R. t. pearyi) and muskox (Ovibos moschatus) to simulations of three types of helicopter operations were investigated in this field study. The study was conducted during July-August 1976 and June-August 1977 on Prince of Wales and Russell Islands. The three types of helicopter (Bell 206B) operations that were tested were (a) reconnaissance and search overflights, which were flown between 20-325 m AGL; (b) simulated cargo slinging flights, which were flown generally 200-400 m AGL and at very slow airspeed; and (c) inspection/work

party flights, which included low level passes followed by a landing within 20-80 m of the animals. During the latter two simulations, observers on the ground recorded observations of the animals. Overt behavioral response categories identified included bedded, foraging, standing alert, walking, trotting/cantering, and galloping. Other behavioral reactions were also recorded, as were specifics (e.g., airspeed, altitude, wind and sun direction, distance to the animals) of each flight.

Because the report provides extensive and detailed documentation and conclusions, only general conclusions relevant to caribou impacts and mitigation are presented here:

(1) Intensity of responses of Peary caribou exhibited an inverse relationship with the altitude of the helicopter - proportionately fewer caribou responded at the extreme level with each ascending altitude class.

(2) Some proportion of any overflight at altitudes greater than 400 m AGL and a greater proportion of overflights at greater than 200 m AGL cause disturbance to Peary caribou.

(3) Cow/calf pairs exhibited more extreme responses to low (less than 200 m AGL) flights and remained more responsive to higher altitude flights than other age/sex classes. However, groups with cows and calves were more responsive than other types of groups only at altitudes above 200 m AGL. This apparent difference was because at altitudes below 200 m AGL all groups exhibited similar and extreme reactions to the first overflight.

(4) Caribou in groups greater than 20 tended to be more responsive than caribou in smaller groups, especially if calves were present.

(5) Caribou were most responsive to overflights when the helicopter was flying into the wind and when the caribou were between the sun and the helicopter.

(6) Responses of caribou to simulated work parties and photography parties indicated that the caribou that remained in the area after touchdown responded to the human activity around the aircraft. Work party simulations consisted of observors remaining within 50 m of the aircraft, whereas photography simulations consisted of observors approaching the caribou group. The latter simulation resulted in more intense responses. However, caribou responded to both simulations more intensely than to overflights (without landing or human activity around the aircraft). The intensity of the caribou response was inversely proportional to the distance between the observers and the caribou and the length of time during which the observers were present.

(7) The authors recommended that overflights be kept above 600 m AGL between May and November and above 300 m for the remainder of the year.

(8) The authors discuss the likelihood that harassment may result in physiological responses that were not manifested in overt behavior but that may in the long term be as important as immediate overt behavior.

Monitoring of physiological responses was technologically infeasible under field conditions at the time of this study (1976-1977).

[Rev. note: This study is the most intensive and extensive of any currently known aircraft harassment study. The utilization of an experimental approach that tests various factors (e.g., distance, age/sex composition of the group) that may effect responsiveness and the simulation of several different types of aerial operations associated with northern development add to its relevance. See also Miller and Gunn (1980).]

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Muller-Wille, L. 1975. Changes in Lappish reindeer herding in Northern Finland caused by mechanization and motorization. Pages 122-126 in J.R. Luick, P.C. Lent, D.R. Klein, and R.G. White, eds. Proceedings of the first international reindeer/caribou symposium, Fairbanks, Alaska, 1972. Biol. Paper Univ. Alaska, Special Rept. No. 1. 551 pp.

Anthropological research during the period 1968-1971 was conducted in Utsjoki, Finnish Lapland, to observe the effects of newly introduced snowmobiles and motorbikes on reindeer-herding practices. Besides the many sociocultural impacts that were observed, it was found that technological advancement resulted in greater efficiency in herding operations, which in turn stimulated better and more comprehensive marketing of reindeer meat. It was also observed that reindeer seemed to be "quite exhausted in the corral and became nervous and easily frightened" after a drive by snowmobiles.

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Murie, O.J. 1935. Alaska-Yukon caribou. N. Am. Fauna No. 54. USDA, Washington D.C. 93 pp.

This paper was written as an early effort to document the distribution, abundance, movements, food habits, and behavior of caribou in Alaska, and to some extent, in the Yukon Territory of Canada. Murie spent 3½ consecutive years (July 1920-December 1923) studying caribou, plus several subsequent trips. Although the data are meager for some of his conclusions, Murie's report gives a reasonable overall view of caribou in Alaska.

The following pertinent material is presented:

(1) The author mentions that excesses in hunting had occurred in Alaska but that with the establishment of law enforcement and cessation of market hunting, such problems had ceased. His only direct reference to impacts from hunting is that the caribou herds had not been exploited to the extent that bison had in the western US.

(2) Murie states that since the purchase of Alaska from Russia caribou herds had vastly decreased over a large part of Alaska but that with a

few exceptions (Kenai Peninsula, Alaska Peninsula) they were presently doing well. Caribou were increasing in the Colville River region. No reference to the cause of declines is made, except that caribou were disappearing from western ranges used for herding domestic reindeer.

(3) The reindeer industry had displaced caribou from some ranges, and since Murie felt that the industry was of "incalculable value" to Alaska, he felt this was acceptable in areas well suited to herding. However, in mountainous regions such as the Tanana-Yukon uplands he felt the caribou to be a much more suitable choice, and he advised against the introduction of reindeer to such locations. Murie opposed "hybridization" [his term] between reindeer and caribou, believing this would detract from the magnificent animals produced by the wild strain.

(4) Murie's food habits information is based on collections, not hearsay, and is enlightening. He states that while lichens (predominantly Cladonia spp.) are a preferred forage, they are not an exclusive nor even a required food item. He found grass-like species to be the most commonly found winter food of caribou in Alaska's interior, followed by lichens. [Rev. note: This flexibility in diet went largely unnoticed by many authors until relatively recently. Murie states that forage availability alters food intake, which could give the impression to workers dealing with caribou in lichen-rich areas that lichens were a requisite food item. Murie spent enough time in enough areas that he observed the variety of foods consumed.]

(5) Murie stated that the basic requirement for caribou was open space within which to roam and that man's impact would likely be felt along those lines. [Rev. note: In his realization of caribou's needs for open space, Murie predated Bergerud (1978) by over four decades.]

[Rev. note: Murie's task was monumental, and he did a creditable job in reporting many aspects of caribou ecology. However, his population estimates for the Tanana-Yukon Herd, often referenced by subsequent authors to document declines in caribou numbers based on whichever theory they were advancing, are suspect. Without the benefit of modern techniques, such as aircraft, aerial photography, radios, or telemetry, he estimated population by extrapolating observations taken at a point across a front of 40-60 mi and along a time span of 20 days. The fact that the estimate of massive numbers of caribou (500,000 to 1,000,000 +) was a leap of faith is reinforced by Murie's statement that he was "never fortunate enough to see the enormous herds reported by others..." It is probable that the enthusiasm of untrained observers influenced Murie to be optimistic in his calculations. It was a good try and probably the best that could be done at the time, but these numbers should not be taken too seriously and related without qualification to better documented censuses done later. For a review of recent Fortymile Herd population dynamics, see Davis et al. 1978b.]

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Nieminen, M. 1980. Evolution and taxonomy of the genus Rangifer in northern Europe. Pages 379-391 in E. Reimers, E. Gaare, and S. Skjenneberg, eds. Proceedings of the second international reindeer/caribou symposium, Røros, Norway, 1979. Direktoratet for vilt og ferskvannsfisk, Trondheim.

This paper discusses skull characteristics, particularly the size and shape of the cranial bones, of adult wild reindeer from Svalbard, Norway, and Finland and semi-domestic reindeer from Finland. Results indicated that three wild subspecies or perhaps almost distinct species of reindeer are living today in Northern Europe: the tall and longlegged forest reindeer (Rangifer tarandus fennicus Lonnberg) occurring as a small population near the Finland-Soviet Union border, the smaller and lighter mountain reindeer (R. t. tarandus L.) living in Norway, and the smallest Rangifer, the Svalbard reindeer (R. t. platyrhynchus Vrolik), characterized by a slightly shorter skull, a very short rostrum ["nose"] and short legs.

No impact information was contained in this paper.

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Nordkvist, M. 1980. Status of Rangifer in Sweden. Pages 790-792 in E. Reimers, E. Gaare, and S. Skjenneberg, eds. Proceedings of the second international reindeer/caribou symposium, Røros, Norway. Direktoratet for vilt og ferskvannsfisk, Trondheim. 799 pp.

As of 1980, approximately 200,000 reindeer were reported to exist in Sweden, not including an estimated 90,000 calves that are produced each year. All reindeer are semi-domesticated, and approximately 43,000 animals are slaughtered annually.

Although reindeer management practices in Sweden are systematic and very well organized, it is apparent that heavy annual losses continue to accrue.

Relevant observations and conclusions include the following:

(1) There is postnatal mortality of unknown significance due to congenital weakness; bad weather conditions; bad nursing qualities of some mothers; and fox, raven and eagle predation; etc.

(2) There is probably a high mortality among suckling calves from birth until two months of age (marking time). Drowning and other unspecified accidents, infections, and predators may be some of the causes.

(3) From calf-marking in July through the end of September many calves disappear for unknown reasons. Predation, internal parasites, and stress (hot weather, insects, round-ups) may all be hazardous to calves. An average loss of about 30% of the calves has been observed from July to December.

(4) The first winter brings additional risks. Bad grazing conditions, predation and accidents (avalanches, falling from cliffs, etc.) are

hazards during this period of the year. Losses of another 20-30% of the calf crop during the winter have been observed.

(5) Although adult reindeer are better able to survive, unfavorable grazing conditions, accidents, and predators still take a toll.

In addition, it is reported that in Sweden, owners of reindeer killed by predators are compensated by the government at an official rate. Consequently, good statistics are available to document the degree and type of predation that occurs. During 1977, roughly 3,000 reindeer were reported killed by predators. Wolverine and lynx were responsible for 80-85% of the predation. However, the author believes (for unexplained reasons) that this is only one-third of the actual number of animals killed and that roughly 5% of the total reindeer stock is removed by predation each year.

A five-year study of 1,053 cases of reindeer mortality in Vasterbotten County revealed that predators accounted for 51% of the recorded deaths, accidents were responsible for 17%, and the remaining 19% died of unknown causes.

[No impact-related mortality was reported for these Swedish reindeer.]

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Nordkvist, M., and K. Erne. 1983. The toxicity of forest fertilizers (ammonium nitrate) to reindeer. Acta Zool. Fennica 175:101-105.

This paper summarizes the results of toxicity experiments performed in order to determine the potential effects of extensive forestland fertilization upon reindeer. In Sweden, managers are attempting to counteract a forecast drop in forest productivity in the next century by using fertilizers. Since the inception of use, 1% of the forest in the counties where reindeer are raised has been fertilized, using ammonium nitrate predominantly.

Reindeer owners have suspected fertilizer to be hazardous to reindeer and their range, citing an avoidance of fertilized ranges for several years and cases of suspected poisonings near fertilizer storage facilities. This study is a component of a larger program to learn about effects of ammonium nitrate upon vegetation composition, nitrate accumulation in plants, health of animals, and reindeer cratering intensities. This study examines toxicity and suggests several mitigation measures.

Pertinent conclusions are as follows:

(1) Acute toxicity - 1.0 g NO_3 per kg body weight was the minimum lethal dose administered. This was given by stomach tube - reindeer did not voluntarily consume such levels of fertilizer.

(2) Chronic toxicity - A dose of 0.4 g NO_3/kg body weight induced signs of chronic toxicity. Well-fed animals coped better with such doses than did animals in poor condition, at least initially. After a week, both groups reacted similarly.

(3) Palatability - Although deer with salt-free diets licked troughs near piles of pelleted fertilizer, none was directly consumed. Reindeer showed an aversion to pellets, probably due to burning sensations on the tongue. Apparently there is small risk of voluntary intake of solid fertilizers.

By withholding drinking water, researchers induced reindeer to drink various strength solutions of ammonium nitrate. Five percent strength was rejected, but 2.5% could be forced upon animals. Once a deer has overcome its threshold of resistance to ammonium nitrate, it seems to become caught in a vicious circle of drinking, leading to excessive drinking, which can make even lower strength solutions poisonous (1% AN). Most animals could tolerate solutions of 0.5% AN.

Given the choice, reindeer consistently chose pure water over AN water.

(4) Residual levels of AN at field storage areas can enter solution in pools of water on hardened (i.e. truck-compacted) ground, where they may persist. The authors recommend fencing, maintenance, and clean-up of such areas to prevent potential poisonings.

(5) Technically correct application of AN does not seem to offer much possibility for dangerous levels to occur. The authors point out, however, that disturbance from helicopters applying chemicals is likely to be detrimental to reindeer already stressed by heat, insects, and herd management (e.g., calf marking). Therefore, they recommend that reindeer be excluded from areas to be fertilized for at least a week, or until after a major rain storm.

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Northcott, P.L. 1985. Movement and distribution of caribou in relation to the Upper Salmon Hydroelectric Development, Newfoundland. Pages 69-84 in T.C. Meredith and A.M. Martell, eds. Proceedings of the second North AMerican caribou workshop, Val Morin, Quebec, 1984. McGill Subarctic Res. Pap. No. 40. McGill University, Montreal. 327 pp.

Field research was conducted on the effects of the Upper Salmon Hydroelectric Development (USD) on the distribution and/or movements of caribou of the Grey River herd in Southcentral Newfoundland. This herd numbered 5,000 animals at the time of the study, and prior to USD construction ranged over the 3,500 km^2 (1,350 mi^2) of the project, primarily during post-calving and later summer movements. This research was part of a monitoring program to suspend construction activity at times of high caribou densities, as part of the mitigation for the USD project. The USD consisted of several dams, access roads, power canal, and diversion channels linking a lake-river complex. Construction began in 1981, and peaked and was completed in 1982. This study continued through 1983 and into 1984 to determine if any impacts persisted after construction. The location and movements of caribou in relation to the USD were intensively monitored by low-level helicopter flights along transects spaced at 1 km (0.6 mi) intervals. During construction, vehicle use along the main access roads at peak levels was 1 large

truck/min (i.e., 60 vehicles/hr). Public access and hunting on the USD were prohibited.

Relevant observations and conclusions include the following:

(1) Peak numbers of caribou using the USD declined between pre-construction (1980) to construction (1981-82), and recovered to near the 1980 level by post-construction (1984) although the total herd size remained the same through the 1979-1984 period.

(2) During construction, dispersal from post-calving aggregations did not follow the pre-construction pattern; there was little dispersal across the main access road and area of intensive construction. This trend has continued after construction, suggesting that a new dispersal "tradition" may have resulted.

(3) Although the locations of the post-calving aggregations varied somewhat even before USD construction started, aggregations were in areas away from intensive construction in 1981 and 1982.

(4) Caribou were able to physically cross the main dam and power canal. The power canal is contained within rip-rapped dikes 14 m (45 ft) in height with slopes equalling or exceeding 2:1. [Rev note: In spite of being able to physically cross these facilities most caribou avoided them; this suggests that the facilities were behavioral rather than physical barriers.]

(5) Caribou approaching access roads with traffic reversed their direction and moved 1.5 km (1 mi) from the road, concentrated in larger groups and either dispersed from the area, or crossed the road when it was closed or at night when trucks travelled in convoys.

(6) Although disruption of movements occurred and displacement of the location of the post-calving aggregation is suspected, these appeared to be related to traffic and associated human activity during construction of the USD and are likely transitory effects that apparently have had no effect on the herd's productivity because numbers remained stable between the time prior to and immediately after USD construction.

[Rev. note: See also Hill 1985.]

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NWT Wildlife Service. 1979. Transactions of the caribou disturbance workshop, Yellowknife, NWT, October 17, 1979. Unpubl. rept., NWT Wildlife Service, Yellowknife, NWT. 102 pp. + unnumbered appendix.

Results of a caribou harassment workshop held in Yellowknife, NWT, are presented in this report. Members of the workshop were Canadian territorial and federal caribou biologists and wildlife managers, and one USA caribou biologist. The workshop was held in order to assess the status of current

research on caribou harassment and to develop recommendations for future research direction. One reason for the meeting was the rapid increase in exploration and development of large mines, especially for uranium, in the range of several major NWT caribou herds.

Much of the discussion centered on the relative merits of using observations of overt behavior to determine the effects of harassment, as opposed to monitoring physiological functions (e.g., heartbeat, O_2 consumption). There was general agreement that although recording caribou overt behavior was easier, and more immediate information, research with other ungulates has shown that physiological responses, some of which are dramatic, occur in the absence of changes in overt behavior. There was also general agreement, however, that the immediacy with which wildlife managers are faced with resource extraction precludes the long period of technological development and baseline data collection required for physiological monitoring. The workshop resulted more in exchange of information than in reaching any conclusions; however, the following summarizes some of the recommendations that NWT managers could pursue:

(1) First priority should be placed on (a) examining relevant reindeer/caribou literature for research results applicable to the NWT situation and then pursueing quantitative behavioral studies in order to provide a baseline for the assessment of disturbance effects; (b) educating the public about the effects of harassment and disturbance; and (c) reviewing NWT's radiotelemetry data to determine if the effects of capture, handling, and subsequent monitoring have altered the behavior of the radio-collared animals;

(2) Second priority should be placed on (a) specific behavioral studies to determine the reactions of caribou to developmental features (e.g. roads, mine sites); (b) special emphasis should be placed on determining caribou reaction to harassment as water crossings; (c) studies of habituation of caribou to disturbance.

A specific observation of the effect of aerial harassment was provided by Bill Darby (NWT), who has numerous observations from fixed-wing aircraft of large aggregations (greater than 1,000 animals) of caribou responding to the aircraft by "galloping wildly." The plane was circling at 4,500 ft AGL in late June in one instance, and was merely flying over at 1,000 ft AGL in several others. He also felt that Kaminuriak Herd caribou responded more readily and more strongly than Beverly Herd caribou (p. 22).

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Palmer, R.S. 1938. Late records of caribou in Maine. J. Mammal. 19(1):37-43.

This review paper examines the records of caribou killed or observed in the state of Maine at the turn of the century. Woodland caribou (Rangifer caribou caribou) were not reliably reported in Maine after 1908.

Relevant observations and conclusions include the following:

(1) Caribou were reported plentiful in all areas in 1886.

(2) In 1896, caribou were reported to be rapidly disappearing. Two hundred thirty-nine were reported killed that year. [Rev. note: Although somewhat unclear, it appears that market hunting was occurring during the 1880's.]

(3) Hunting of caribou was prohibited in 1899. Prior to 1883, no bag limit was in effect. A bag limit of two was in effect from 1883 to 1894 and a limit of one was in effect from 1895 to 1898.

(4) Indians of Old Town and Tobigue, incensed at the excessive shooting of game in Maine by "sports and others," agreed among themselves sometime during the decade following 1900 to get their share of game while it lasted and proceeded to shoot game wherever and whenever possible. Reports conflicted on the effects of this killing on the decline of the caribou. A considerable effect occurred on the moose population, however.

(5) The decline of the caribou was attributed to increasing occupation of the land in conjunction with lumbering, extensive forest fires, and hunting.

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Parker, G.R. 1975. An investigation of caribou range on Southampton Island, Northwest Territories. Canadian Wildl. Serv. Rept. Ser. No. 33. 83 pp.

This field study, conducted during the summers of 1970-1972, examined the quantity and quality of forage produced on Southampton Island, Northwest Territories, Canada, in order to determine the capability of the range to support a reintroduced herd of caribou. Physiographic features and moisture regimes were used to divide the range into specific range types. Vegetation and soil in each range type were sampled, the flora described, and the dry weight of the standing crop of lichens and the annual production of sedges, grasses, and willows measured. Nutritional values of lichens and vascular plants were also measured.

Relevant observations and conclusions include the following:

(1) Forage quantity ranged from 0 to 3,000 kg/ha for lichens, depending on location. Sedges and willows averaged 400 kg/ha and 200 kg/ha, respectively, in the sedge-willow range type.

(2) Southampton Island was rated fair to poor as caribou range, based on the standing crop of lichens.

(3) Based on a number of factors, including range productivity, range use, and availability to caribou, the author estimated that a caribou population of 40,000 could be supported by the winter range on Southampton Island.

(4) In 1924, the Hudson's Bay Company established an outpost on Southampton Island and in the process provided the Inuit residents with firearms and ammunition. By 1930, caribou were scarce, and in 1935 it was noted that no more than 30 caribou survived on the island. [Rev. note: There was no pre-firearm estimate of caribou on the island.] It is estimated that the last caribou on the island died by 1955. Forty-eight caribou were reintroduced to the island in 1967.

(5) Caribou killed in mid August 1970 on nearby Coats Island (the source of the caribou reintroduced to Southampton Island and similar in area and geologic structure to Southampton Island) had substantial fat deposits. Proposed explanations for the exceptional body fat reserves included absence of natural predators, low insect densities during summer, and no extensive seasonal movements. [Rev. note: The similar exceptional summer fat deposits in Svalbard reindeer have also been attributed to absence of insects, predators, and disturbance by man. See Reimers 1980.]

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Parovshchikov, V.Y. 1965. Wild reindeer population and distribution in the Arkhangel'sk North. Zool. Zhurn. 44(2):276-283. (Transl. from Russian by Israeli Prog. Sci. Transl., 1967.)

The historical and current distribution and abundance of wild reindeer in the Arkhangel'sk North, USSR, was reviewed, and the status as of 1961 reported. [Rev. note: The study area is located in northeastern Soviet Union, between Finland, the Barents Sea, and the Ural Mountains.] The results of field expeditions and interviews with locals formed the basis of the discussion of current status.

Relevant observations and conclusions include the following:

(1) Until "comparatively recently" [Rev. note: this period was not defined by the author but presumably meant in recent historical times, that is the 19th and early 20th centuries], wild reindeer were widespread in Arkhangel'sk North and neighboring regions [and as far south as Kiev and Moscow]. Between 1885 and 1892, reindeer were observed to "congregate" near the town of Vologda [59° N, 37° E], and within 5-6 km (3.1-3.7 mi) of the railroad. "Even in prerevolutionary days, the wild deer stock was depleted by poaching."

(2) "Thousands" of reindeer that inhabited two islands (800 km^2 [309 mi^2]) had been extirpated by poachers by 1945.

(3) "Wild deer are rapidly vanishing from cultivated regions where the limited areas of island moss [lichens] are used as pasture for domestic deer [reindeer] belonging to the collective farms."

(4) The penetration of "elk" [moose] into forest tundra, wolf predation, severe icing and snow conditions, and fires reduced small local wild reindeer herds; however, hunting had been forbidden after 1935, and the

size and distribution of the herds expanded, although they have not expanded to their range of the late 19th century.

(5) Several herds' original "breeding grounds" have been divided by railroads and extensively settled valleys [Rev. note: in the context of the report, this appears to be a translation error - the author, I believe, means "calving areas"] and have not reestablished traditional migration routes.

(6) Reindeer in the Onega Lake region [62° N, 34° E], currently numbering 400, have migrated in small groups as far as 200 km (125 mi), and have crossed the railroad near Belomarsk [in Karelia].

(7) Many of even the smaller herds [numbering in the tens rather than hundreds or thousands] leave wintering areas in forest tundra to migrate to summer range on the Barents Sea coast, where adequate forage and relief from insects is present. Some of these migrations are 400 km [240 mi].

(8) In spite of the instances cited above, the author concludes that "there is no doubt that the wild reindeer, which was largely destroyed in prerevolutionary times and during the Civil War, is now slowly increasing in number."

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Pegau, R.E. 1970. Effect of reindeer trampling and grazing on lichens. J. Range Manage. 23(2):95-97.

The author reports the results of an experiment where reindeer were intentionally herded through lichen tundra areas in summer in order to gauge the effects of trampling lichens. Reindeer were moved into lichen areas on both rainy and dry days, in order to test the effects upon lichens in both flexible and brittle states. On a rainy day, grazing reindeer moving through the area once dislodged 15% of the lichens and shattered 2% into segments less than 1.25 cm (½ in) long. In dry conditions, similar movements dislodged or broke into pieces more than 1.25 cm (½ in) long 27% of the lichens. Eight percent were shattered to less than 1.25 cm (½ in). Tight milling of animals for insect relief completely destroyed vegetation cover on the top of a knoll.

On range where reindeer had grazed [more than a single pass, as described above] in favorable [i.e., wet] conditions during summer, 68% of the lichens were dislodged and 16% were shattered.

The author states that on summer ranges where lichens comprise at least 30% of the available forage, at least 15% of the lichens should be considered unavailable because of trampling.

[Rev. note: Because caribou are unlikely to be found on lichen ranges in summer, this article has limited usefulness for this review. Potentially, human-directed domestic reindeer grazing on lichen ranges used by caribou in

winter could reduce absolute abundance of lichens, but, at least in North America, it is hard to imagine that this could be of significance compared to the effects of snow conditions upon relative forage abundance, especially considering the vast potential winter ranges available for caribou.]

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Pitcher, K.W. 1982. Susitna hydroelectric project. Phase I final rept., big game studies. Vol. 4: Caribou. ADF&G. Submitted to Alaska Power Authority. 101 pp.

This paper reports the results of initial studies of the Nelchina Caribou Herd conducted from April 1980 through September 1981 in the area of the proposed Susitna hydroelectric project. The objectives of this study were to determine movements and movement routes and the timing of major movements of the Nelchina Herd, with emphasis on activities occurring near the proposed development, to monitor herd numbers and composition, to delineate subherds, and to determine the habitat utilization by the Nelchina Herd. Range use, movement patterns, timing of major movements and subherd status were determined by repetitive relocation of radio-collared animals. Potential impacts of the Susitna hydroelectric project were discussed. Considerable use of Skoog's (1968) and of other researcher's work on the Nelchina Herd was made in the assessment of potential impacts of the hydroelectric project on the Nelchina Herd.

Relevant observations and conclusions included the following:

(1) During the spring of 1981, many caribou used the frozen Susitna River during spring migration to the calving grounds. The section of the Susitna River between the Oshetna River and Kosina Creek used by caribou is within the boundaries of the proposed Watana impoundment. The drainages of the Black and Oshetna rivers and Kosina and Goose creeks were the primary calving grounds of the Nelchina Herd during 1980 and 1981, as they have been in most prior years. During the calving period, males were found in a wide variety of locations, including the area of the proposed Watana impoundment.

(2) The female-calf segment of the Nelchina Herd summered south of the proposed impoundment during 1980 and 1981. Historically, during most years between 1950 and 1973, varying proportions of the female-calf segment (ranging from 0-100%) crossed the Susitna River in the area of the impoundment to spend the summer north of the Susitna River. Major movements to summering areas were undertaken from mid June through July.

(3) Movements of caribou from summer to winter range during 1980 and 1981 occurred primarily east of the proposed impoundment, although some may have crossed the Susitna River in the area of the impoundment.

(4) Large movements of caribou across the proposed Watana impoundment did not occur during the study period or since about 1976. Historically, varying proportions of the herd wintered north of the impoundment in

the upper Susitna-Nenana area. This area was the major wintering area between 1957 and 1964. Crossings of the impoundment area undoubtedly occurred during spring, summer, and fall movements. Major herd crossings of the impoundment area usually occurred when population levels were relatively high. During recent years when major crossings have not occurred, the herd has been at low to moderate population levels. It appears likely that major crossings occurring in this area and use of the northwestern portion of the range will increase as the herd size increases.

(5) Up to five subherds of the Nelchina Herd exist, of which the subherd most likely to be affected by the hydroelectric project is one that is found in the upper Susitna-Nenana rivers area. This subherd was estimated to contain about 1,000 animals. This subherd would probably become more isolated from the main Nelchina Herd by construction of the Susitna hydroelectric project although the extent probably would depend on locations of access corridors between the project site and existing highways.

(6) A major potential impact to the Nelchina Herd is a barrier to movement, from the proposed Watana impoundment. Possible reactions of caribou to a large impoundment include complete avoidance and refusal to cross by the entire herd, avoidance by some segments of the herd and attempted crossing by others, and changes in migratory routes to enable the caribou to travel around the impoundment. Attempts to cross the impoundment would be most hazardous in spring, particularly to pregnant females on their way to the calving grounds. Attempted crossings at this time could result in increased injury or mortality from falls on ice shelves, ice sheets, or ice-covered shores. These conditions may also present formidable obstacles to movement. Additional hazards may occur during crossings at breakup due to barriers caused by jumbled ice floes and injury from falls on overflow and wet ice shelves. Crossings during summer and fall, when the impoundment would be ice-free, would pose less of a hazard, although young calves might have problems swimming across the impoundment if migrations occurred shortly after calving.

(7) Additional potential impacts include disruption of movements and disturbance from roads, railroads, airfields, and increased human access to the area.

(8) The Devil Canyon impoundment would occur in an area that presently and historically has received little caribou use and would probably be of minor significance to the Nelchina Herd.

(9) The size of the Nelchina Caribou Herd was estimated to be 18,713 animals in 1980 and 20,730 animals in 1981.

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Pitcher, K.W. 1983. Susitna hydroelectric project. Phase II, Ann. rept. 1982, big game studies. Vol. 4: Caribou. ADF&G. Submitted to Alaska Power Authority. 43 pp.

This paper reports the results of field studies of the Nelchina Caribou Herd conducted from November 1981 through October 1982 in the area of the proposed Susitna hydroelectric project. The objectives of this study were to determine range use, migration routes, monitor herd status and to delineate subherds. Range use and movement routes were determined by repetitive relocation of radio-collared caribou. Data from Phase I studies (dating back to April 1980) and earlier research are presented. Potential impacts of the Susitna hydroelectric project on caribou are discussed [Rev. note: see also Pitcher (1982)].

Relevant observations and conclusions include the following:

(1) The 1982 fall population estimate for the Nelchina Caribou Herd was 21,162 caribou, a slight increase over the estimate for 1981.

(2) Significant numbers of Nelchina caribou migrated through the area of the proposed Watana impoundment during three periods in 1982. During spring migration (7 May-20 May) perhaps 50% of the female segment of the herd moved through the upper reaches of the impoundment area enroute to the calving grounds. In mid August, about 15% of the female segment crossed the upper Watana impoundment area during their autumn dispersal. In October, perhaps 10% of the herd crossed the Susitna River twice in the area of the proposed Watana impoundment.

(3) The upper Susitna-Nenana River subherd, numbering an estimated 2500 animals, calved over a widely dispersed area separate from that of the main Nelchina Herd. The proposed access road to the Watana dam site would pass through the range of the upper Susitna-Nenana subherd [and the main Nelchina Herd if and when major movements to this area resume]. Probable impacts to caribou include collisions with vehicles, interference with movements, increased hunter access, and possibly increased predation. Additional potential impacts include disturbance from aircraft and other construction-related activities.

(4) A major potential impact to the Nelchina Herd is a barrier to movement from the proposed Watana impoundment. Potential effects of the impoundment during spring migration include a reduction of the optional migration routes available to caribou, and potential barriers of ice shelves, ice-covered shores, and jumbled, broken ice. These conditions would potentially be particularly deleterious to pregnant females that are often in the poorest physiological condition of the year in late spring.

(5) For the first few years after filling the impoundment, rafts of floating debris could obstruct caribou attempting to cross the impoundment during summer and fall.

(6) During the winter of 1982-1983, substantial numbers of the Nelchina Herd (possibly 25-40% of the herd) moved northeast of the Mentasta Mountains into the general area of Tok, Tetlin, and Northway. Nelchina

caribou are known to have used this area only three times in the last 30 yr. Such a movement demonstrates that caribou herds undertake erratic movements when populations are at moderate levels and not just when population levels are high.

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Pitcher, K.W. 1984. Susitna hydroelectric project. 1983 Ann. rept., big game studies. Vol. 4: Caribou. ADF&G. Submitted to Alaska Power Authority. 43 pp.

This paper reports the results of continuing (since 1980) studies of the Nelchina Caribou Herd in the area of the proposed Susitna hydroelectric project. The basic objectives of this study are to monitor herd status, determine range use and migration routes, and to delineate subherds. Data presented in this paper were primarily collected from November 1982 to October 1983, although information from earlier segments of the study, dating to early 1980, is also presented. Range use and movement routes were determined by repetitive relocation of radio-collared caribou. Potential impacts of the Susitna hydroelectric project are discussed. Background material from earlier reports is also presented. [Rev. note: see also Pitcher (1982, 1983).]

Relevant observations and conclusions included the following:

(1) The Nelchina Herd increased from an estimated 18,713 caribou in 1980 to 24,825 in 1983.

(2) Significant numbers of female caribou (probably over 50% in 1982) passed through the proposed upper Watana impoundment area enroute to the calving grounds. There was less use of the proposed impoundment area by females in 1983 than in 1981 or 1982. Historically, many caribou crossed the impoundment area enroute to the calving grounds after wintering in the upper Susitna-Nenana drainages (see Skoog 1968).

(3) The proposed Watana impoundment area was crossed regularly by the entire female-calf segment of the Nelchina Herd during many years between 1950 and 1973 while moving from the calving grounds to summer range north of the Susitna River during June or July. Low to moderate level movements occurred through the proposed Watana impoundment during spring migration, 1981-1983. About 10% of the herd has annually passed through the impoundment area as they left summer range. It is expected that massive crossings of the proposed Watana impoundment area will occur in the future as the Nelchina Herd moves between seasonal ranges.

(4) A separate subherd of the Nelchina Herd exists in the upper Susitna-Nenana River area. Calving by females in this subherd is dispersed over a wide area, whereas the main Nelchina Herd females calve in a relatively restricted area. About 50% of the subherd crosses the proposed Denali access road to the Watana dam site twice a year. Some calving occurs in the vicinity of the proposed road, but since calving

is rather dispersed over a large area, routing of the proposed road to avoid the calving area may be impossible.

(5) A major potential impact to the Nelchina Herd and the upper Susitna-Nenana subherd is a barrier to movement from the proposed impoundment and the proposed access road to the dam site. Attempted movements across the Watana impoundment by caribou could result in increased mortality, particularly of pregnant females, from falls caused by ice shelves, ice sheets, and ice-covered shores formed by winter drawdown of the reservoir. Rafts of floating debris could also pose problems for swimming caribou for the first several years after filling the impoundment. Collisions of caribou with vehicles may occur along the access road off the Denali Highway.

(6) Loss of habitat was not considered a potentially serious problem because the proposed developments are a small proportion of the total caribou habitat available in the Nelchina range and are located in areas of generally poor-quality habitat.

(7) Adverse impacts are also likely to occur from increased human access, leading to harassment from vehicles and aircraft, and increased harvest.

(8) The Devil Canyon impoundment and transportation routes to the west linking with the Parks Highway or the Alaska Railroad do not appear to be a serious concern as neither currently nor historically have many caribou occurred in this region.

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Pulliainen, E. 1980a. Predation on the wild forest reindeer in Kuhmo, Eastern Finland. Pages 677-680 in E. Reimers, E. Gaare, and S. Skjenneberg, eds. Proceedings of the second international reindeer/caribou symposium, Røros, Norway. Direktoratet for vilt og ferskvannsfisk, Trondheim. 799 pp.

After an absence of about 30 yr, the wild forest reindeer (Rangifer tarandus fennicus) was found in the extreme eastern region of Finland near the border that separates Finland from the Soviet Union. A maximum of 250-300 animals were found on the Finnish side of the border, while approximately 5,000-6,000 animals inhabited adjacent Soviet habitats. This paper examines the extent and impact of predation on the wild forest reindeer of Finland. Observations of reindeer mortality were more opportunistic than systematic and were made by members of the Border Patrol Establishment and the Forestry Board of Finland. In 1974-1978 the remains of 5-8 animals were found each year. Only single deaths were recorded, and three-fourths of the carcasses found in 1975-1978 had been eaten by wolves. Wolf numbers in the area increased from 1975 to 1978, but wolf-related predation remained fairly stable. This was thought to be due to the presence of other potential food sources (i.e., semi-domestic reindeer [Rangifer tarandus tarandus], small game, garbage, and moose).

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Pulliainen, E. 1980b. Status of Rangifer in the Karelian ASSR. Pages 771-773 in E. Reimers, E. Gaare, and S. Skjenneberg, eds. Proceedings of the second international reindeer/caribou symposium, Røros, Norway. Direktoratet for vilt og ferskvannsfisk, Trondheim. 799 pp.

The reindeer population of Soviet Karelia has increased in number and widened its range during the last 20 yr. Reindeer husbandry has ceased and the herds of wild and semi-domestic origin have mixed, so that hybrids occur in the northern parts of Karelia. A census of the population in 1965 indicated the presence of 3,000 animals. The population continued to increase until it finally stabilized at 5,000-6,000 individuals, as verified by a 1975 census.

Animals are typically found in pine, spruce, and mixed forests, pine bogs, and open bogs. Ground and arboreal lichens are primary food in winter, and bog plants and herbs, leaves from deciduous trees, and mushrooms are eaten during summer.

Predation is low, and human harvest is prohibited, although culling is planned because of overgrazing of lichen pastures. Natural mortality has been estimated at 1,000 animals a year. The pregnancy rate for reindeer in this population is estimated to be greater than 90%. The calf percentage of this herd is assumed to be 23%.

[Rev. note: The natural mortality (excluding predation) total of 1,000/year may be a translational or editorial error - this would be an annual mortality rate of 16-20%, an extremely high figure for a mainland Rangifer population.]

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Pulliainen, E., and L. Siivonen. 1980. Status of Rangifer in Finland. Pages 760-763 in E. Reimers, E. Gaare, and S. Skjenneberg, eds. Proceedings of the second international reindeer/caribou symposium, Røros, Norway. Direktoratet for vilt og ferskvannsfisk, Trondheim. 799 pp.

Reindeer in Finland are either semi-domestic descendants of animals from the Scandanavian Mountain Range and Kola Peninsula or are part of a small population of wild forest reindeer, recently observed in eastern Finland after being absent for almost 30 yr.

The semi-domestic reindeer typically utilize a number of different habitat types, including alpine heaths, mountain birch forests, coniferous and mixed forests, clear-cut areas, bogs, river valleys, and watercourses. During 1979, 156,000 semi-domestic reindeer existed in Finland, and numbers were increasing. Approximately 15,000 animals died yearly from natural causes, 2,000 were taken by predators, and 41,000 were harvested. There are 56

reindeer husbandry districts, and herd mixing is prevented by fences and annual round-ups.

Wild forest reindeer inhabit pine, spruce, and mixed forests, pine bogs, and open bogs. Approximately 400-550 animals existed near Kuhmo in 1979, and numbers were increasing. Mortality is reported as being very low, and no harvest was permitted.

[No impact-related information is presented.]

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Rajala, P., and B. Westerling. 1980. Responses of corral-fed reindeer to some commonly-used wood fertilizers in Finland. Pages 240-243 in E. Reimers, E. Gaare, and S. Skjenneberg, eds. Proceedings of the second international reindeer/caribou symposium, Røros, Norway, 1979. Direktoratet for vilt og ferskvannsfisk, Trondheim. 799 pp.

In this field/laboratory research study, conducted during the winter of 1969-1970 in Finland, 10 corralled domestic reindeer were offered (in a series of feeding trials over a 6 week period) urea, "Oulu saltpetre," and two other kinds of fertilizers used to promote forest growth. The purpose of the study was to determine whether it was probable that reindeer would consume harmful amounts of the fertilizers used in Finnish forests. Animals were exposed to fertilizers placed 1) one at a time on a clean snow surface, 2) individually in buckets paired with salt or a commercial ration, 3) in a "cafeteria" test with all fertilizers and salt placed side by side, 4) spread on a carpet of naturally occurring lichen, and 5) densely mixed into lichens.

Relevant observations and conclusions included the following:

(1) When fertilizer was placed on snow, in buckets separately, and in bowls cafeteria-style, reindeer sniffed but consistently refused to taste the fertilizer. When fertilizers were offered from the palm of the hand, some animals tasted the fertilizer and immediately showed an adverse reaction to it.

(2) Some reindeer somewhat willingly ate the fertilized lichen while others took a taste and refused to eat further.

(3) The dense mixture of lichen and urea was observed to cause bloating and weak diarrhea in two reindeer. "Oulu saltpetre" and the other two fertilizers produced no signs of illness but were eaten to a lesser degree than urea.

(4) In all instances, pure lichen was preferred to that containing fertilizers.

(5) The authors concluded that negligent spreading of fertilizers could endanger reindeer on fertilized pastures during periods when terrestrial lichens are the chief food items.

[Rev. note: Compare results from Eriksson (1980), who found that reindeer grazed fewer lichens in areas fertilized with urea than in unfertilized areas.]

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Reimers, E. 1975. Age and sex structure in a hunted population of reindeer in Norway. Pages 181-188 in J.R. Luick, P.C. Lent, D.R. Klein, and R.G. White, eds. Proceedings of the first internatioanl reindeer/caribou symposium, Fairbanks, Alaska, 1972. Biol. Paper Univ. Alaska, Special Rept. No. 1. 551 pp.

This 1972 study examined the impact of hunting on the sex and age structure of reindeer in the Rondane region of Norway. No restrictions as to the sex and age of harvested animals were in effect at the time. It was found that 96% of all males harvested were three years of age or younger. No males survived their fifth year. Corresponding figures for females were 57% three years or younger, and 4% survived to their tenth year of life. The reason for these age distributions were that hunters selectively harvested animals of large body and antler size. This selective hunting also resulted in a distorted sex ratio of approximately one male to eight females in the reproductive group. There was some indication that this sex and age distribution was responsible for decreased calf production and perhaps limited breeding success.

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Reimers, E. 1980. Activity pattern; the major determinant for growth and fattening in Rangifer? Pages 466-474 in E. Reimers, E. Gaare, and S. Skjenneberg, eds. Proceedings of the second international reindeer/caribou symposium, Røros, Norway, 1979. Direktoratet for vilt og ferskvannsfisk, Trondheim.

The purpose of this field/review study was to attempt a broad generalization of population regulation in Rangifer and to establish the relative importance of winter and summer range. Body weights, fat measurements, and ruminal nitrogen and crude fiber were compared in 2 + yr female reindeer killed during 1971 through 1977 from Hardangervidda [southern Norway] and Svalbard [islands north of mainland Norway]. Estimates of daily activity budgets and energy costs were calculated, based on data from this and other studies.

Relevant observations and conclusions include the following:

(1) Svalbard female reindeer showed a dramatic drop in body weight (45%) during winter, the bulk (79%) of which was due to mobilization of body fat reserves established during the previous summer. Corresponding weight changes in Hardangervidda female reindeer were small (5%).

(2) Svalbard female reindeer had a higher total and rate-of-weight gain, higher rumen nitrogen content, and lower rumen crude fiber content than did Hardangervidda female reindeer.

(3) Svalbard females spend more time feeding and less time walking and running during summer than do Hardangervidda females.

(4) Calculated energy requirements for growth and maintenance during summer for Svalbard and Hardangervidda animals were similar.

(5) Avoidance activities (from predators, insects, and man) undertaken by Hardangervidda reindeer reduced the available time for feeding and increased energy costs. [Rev. note: Thomson (1973), cited in this paper, estimated this herd was severely insect-harassed 27% of the time in July and August. Calculations of summer activity budget for this herd assumed the above level of harassment existed for the entire growing season because of presence of hikers and hunters.] Svalbard reindeer, in the absence of predators, insects, and man, are able to spend more time grazing, which allows greater forage selectivity and ingestion of higher quality food despite a poorer quality summer range; and the spend less energy on avoidance activities than do the Hardangervidda animals, thus allowing them to maintain high stocking rates and enter winter with tremendous fat reserves.

(6) Reindeer (in general) interaction with insects, predators, and man [hunting and disturbance] is necessary for the preservation of lichen pastures as reproduction and mortality responses from overgrazing are too slow working to counteract destruction of lichens. Svalbard reindeer are a special case because of the accumulation of large summer fat reserves, absence of harassment, and high winter mortality due to starvation because of heavy icing of winter range, which reduces the importance of lichens to the population.

(7) The possible harmful effects of hunting, in terms of increased animal avoidance activity, should be considered for the Svalbard population before allowing hunting to reduce population levels to prevent a precipitous population decline during winter.

[Rev. note: Other authors (e.g., Ringberg et al. 1980, Nieminen 1980, Soldal and Staaland 1980) have shown differences in skeletal and skull measurements and blood serum between Svalbard and other reindeer, suggesting genetic differences in these populations. The possible influence that genetic variation contributes to the differences in growth and fattening between Svalbard and Hardangervidda reindeer was not examined in this paper.]

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Reimers, E. 1983. Growth rates and body size differences in Rangifer, a study of causes and effects. Rangifer 3(1):3-15.

The author compares data from the literature on growth rates, body size, and demographic characteristics of several different wild and domestic reindeer herds (e.g., domestic, penned reindeer; caribou; feral reindeer). Results of field research conducted by the author on wild reindeer herds in Norway are also presented.

Relevant observations and conclusions include the following:

(1) In most cases, reindeer and caribou gain weight in summer and lose weight in winter. Calf weight gains have varied from 200 g/day by free-ranging domestic reindeer on overutilized range, to 570 g/day by wild reindeer on good range. Weight gains by adults were generally lower than that of calves. In cases in which supplemental feeding or extremely high quality winter range was available, reindeer can gain weight over winter.

(2) Pregnancy rates in several reindeer and caribou herds appear to be a function of rutting weight rather than age of the female--i.e., a female that attains a minimum weight by the time of the rut has a high probability of successfully breeding. This helps to explain why in some reindeer herds the pregnancy rate of calves is high whereas in other herds it is nil. Data from several Norwegian wild mountain reindeer herds suggest that if a female calf reaches 24 kg (50 lb) by the rut she will successfully breed.

(3) In utero mortality is extremely low for all reindeer and caribou populations studied to date. Postnatal mortality of calves is higher in herds on poor-quality summer and winter range. This mortality has been attributed to the smaller birth weights of calves, to poorer maternal care, and to lowered milk production by under-nourished females. Additionally, the time of calving is later for herds on poorer range because the period of high energy demands of lactation occurs after the peak of forage nutrient content ("greenup").

(4) Failure of maternal cows to gain sufficient body weight on summer range can also be attributed to interruption of their grazing time due to factors such as predators, insect harassment, or harassment by humans rather than merely summer range quality. Lack of sufficient winter forage intake by female reindeer, which occurs on severely overgrazed winter range, can contribute to reduced maternal body size the following spring and increased chance of postnatal mortality of her calf. Thus, the cycle continues in which the female can never quite "catch up" in body size unless she loses her calf immediately after parturition and can spend the summer foraging without the energy demands of lactation. [Rev. note: Although Reimers emphasizes the importance of summer nutrition to wild reindeer body size and demographics, Skogland (1983, 1985) uses data from the same Norwegian wild mountain herds to demonstrate that winter nutrition is the most important. It is likely that both investigators are at least partially correct--both summer and winter nutrition are important.]

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Ringberg, T., E. Reimers, and R. Sørumgaard. 1980. Growth and seasonal change in organ weights and carcass composition in Svalbard reindeer (Rangifer tarandus platyrhynchus). Pages 333-340 in E. Reimers, E. Gaare, and S. Skjenneberg, eds. Proceedings of the second international reindeer/caribou symposium, Røros, Norway, 1979. Direktoratet for vilt og ferskvannsfisk, Trondheim.

Morphometric data (body dimensions) and carcass composition data were gathered from Svalbard reindeer during 1975-1977 and compared with similar data from semi-domesticated European and Alaskan reindeer. Results indicated that Svalbard reindeer had significantly shorter legs, at least after the first year of life, than did semi-domesticated Norwegian and Alaskan reindeer. Body lengths were similar between adult Svalbard and Norwegian reindeer. Summer total body weights were similar; however, Svalbard reindeer had a much greater percentage of body weight as fat during summer. In late winter, after mobilization of fat deposits, Svalbard reindeer weigh considerably less than their mainland counterparts.

No impact information was contained within this paper.

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Salo, L.J. 1975. Review of recent reindeer studies in Finland by State Game and Fisheries Research Institute and University of Helsinki. Pages 420-422 in J.R. Luick, P.C. Lent, D.R. Klein, and R.G. White, eds. Proceedings of the first international reindeer/caribou symposium, Fairbanks, Alaska, 1972. Biol. Paper Univ. Alaska, Special Rept. No. 1. 551 pp.

This is a review of reindeer studies carried out in Finland by the Division of Game Research, State Game and Fisheries Research Institute, and the University of Helsinki prior to 1972.

Relevant observations and conclusions include the following:

(1) Logging may have positive effects on reindeer by providing arboreal lichens for winter feeding, by increasing human activity in an area and causing a corresponding decrease in predation (estimated to save the lives of 100-200 animals per year), and by habituating animals to the "call" of the chainsaw, thereby providing a source of food during years when difficult snow conditions exist.

(2) Accidental reindeer deaths may occur in logging areas if feeding occurs while logging operations are in progress. Results from 124 areas showed that 104 reindeer were killed during the winter of 1963-1964. This may be remedied by herding reindeer away from lots where timber is being cut and by providing hay in feed shelters away from dangerous areas.

(3) Reindeer will use artificial mineral licks, although they are not especially attracted to them. Optimum placement of licks is along trails and around corrals, approximately 1 m above the ground/snow surface.

(4) Golden eagles have been found to prey on newborn reindeer fawns (calves) in northern Finland. In a study conducted during the period 1957-65, 1,336 prey samples were collected from 27 nest sites in the region, with the result that reindeer accounted for 9.1% of the samples.

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Scotter, G.W. 1967. Effects of fire on barren-ground caribou and their forest habitat in northern Canada. Trans. N. Am. Wildl. Nat. Resour. Conf. 32:248-259.

This field/review paper examined the effects of fires on the winter ranges of barren-ground caribou in northern Canada and the role of fire in the decline of caribou herds in this area since the turn of the century. Field work was conducted in northern Saskatchewan and Manitoba and in the Northwest Territories near Great Slave Lake. [This area comprises winter range of the Beverly and Kaminuriak herds.] Field work was begun in 1959 to investigat what portion of winter range burned and whether an increase in the frequency of fire occurred, the effects of fire on the standing crop of terrestrial and arboreal lichens, and the effects of fire on range use by caribou. Winter range of the caribou herds studied was largely within the northern boreal forest. The literature was also reviewed for historical accounts of fire on caribou range in Alaska and Canada.

Relevant observations and conclusions included the following:

(1) Approximately 2.7% of the 764,000 km² (295,000 mi²) of winter range used by caribou was burned during the period 1961-1964, according to governmental fire reports. Forest cover-map data on forest age classes suggest that the amount of fire destruction had increased in recent years.

(2) Fire is destructive to the major forage lichens, as it takes from 70 yr to more than a century for the major forage lichens to recover to their former abundance and composition. The slow recovery time is due to the time required for the return of suitable growing conditions, the time required for the succession of lichens through a number of seral stages, and because of the slow growth rate of lichens.

(3) The average standing crop of high-value lichens was highest in forests exceeding 120 yr of age. Moderate-value lichens reached their peak abundance in the oldest forest age class, and low value lichens attained their maximum in the 31 to 50 yr age class.

(4) Arboreal lichens may be an important food source to caribou during periods of deep or ice-crusted snow and must be considered a serious loss of forage if destroyed by fire.

(5) Pellet groups and feeding craters were largely confined to mature forest. Occasional trails and feeding craters were seen in recent

burns but were attributed to caribou moving between segments of mature forest.

(6) The increased rate of forest destruction by fire accompanying settlement and exploitation, as well as possible changes in summer weather patterns, contributed to the loss of habitat of caribou. Data are insufficient to determine the extent to which forest fires have directly influenced the recent decline of the barren-ground caribou population.

(7) The reduced carrying capacity of the winter range does not appear to be the factor limiting the caribou populations to their present low numbers. It was proposed that fire was the factor that caused the decline, with man, wolves, and other factors maintaining the populations at low levels.

[Rev. note: The author's viewpoint that fire is detrimental to caribou is not shared by all authors, particularly in light of more recent research (see Miller 1976, 1980). The author, in fact, moderated his view towards fire, acknowledging that fire may destroy muskeg and bryophyte-covered areas, permitting replacement by lichens (see Scotter 1972).]

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Scotter, G.W. 1972. Fire as an ecological factor in boreal forest ecosystems of Canada. Pages 15-24 in Fire in the environment: symposium proceedings, May 1-5, 1972. Denver, Colorado.

This review paper examines the effects of fire on boreal forest vegetation, soils, and wildlife. The susceptibility to fire and the adaptations for regeneration are discussed for black and white spruce, jack and lodgepole pine, white birch, aspen, balsam poplar, tamarack, balsam fir, shrubs, herbaceous plants, mosses, and lichens. Caribou, moose, grouse, hares, and furbearers were the wildlife species for which the effects of fire were discussed. References reviewed were primarily from Canadian sources, with limited references from Alaska, the United States, Scandanavia, and the Soviet Union also reviewed.

Relevant observations and conclusions for caribou include the following:

(1) The net effect of fire on the ecosystem is complex and highly variable, depending on the site, frequency of fire, severity of fire, and other factors. Fire, through energy and nutrient release and conversion, may add to the stability and viability of boreal forest ecosystems.

(2) Fire adversely affects the habitat of barren ground caribou, as the recovery of their principal winter food, lichens, is slow following fire.

(3) There is little evidence that caribou numbers are presently being limited by the amount of winter forage available, despite the fact that

fire has the potential of markedly reducing the carrying capacity of the lichen winter range.

(4) Fire sometimes destroys thick carpets of bryophytes in upland areas thereby making them more productive for lichens and other forest plants. Fire also improves certain muskeg areas by destroying Sphagnum spp. and other bryophytes, which are replaced by forage more preferred by caribou.

(5) The determination whether the effects of wildfire are short- or long-term must be related to the nature of the forest burned, size of the area burned, intensity of the burn, and the distribution of unburned habitat within and surrounding the burn.

[Rev. note: This paper represents a change in the author's viewpoint on fire and caribou range from his earlier papers, which strictly claimed that fire was detrimental to caribou winter range (see Scotter 1967 for his earlier viewpoint).]

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Shtil'mark, F.R. 1984. Ecological niche of wild reindeer in the taiga in relation to human influences on forest landscapes. Pages 95-98 in E.E. Syroechovskii, ed. Wild Reindeer of the Soviet Union. Proceedings of the first interdepartmental conference on preservation and rational utilization of wild reindeer, 1974 (Transl. from Russian). Amerind Publ. Co., New Delhi. 309 pp.

This report provides several examples of the past effects of land use on the distribution of wild forest reindeer in the USSR and offers suggestions for increasing or maintaining these wild reindeer populations.

Relevant observations and conclusions include the following:

(1) The distribution of wild taiga reindeer in the Soviet Union has shrunk considerably since the 18th and 19th centuries, and is continuing to shrink. What was then a continuous distribution across the taiga regions of the USSR is now scattered populations isolated from each other by intervening human developments such as agriculture, urbanization, and domestic reindeer herding.

(2) Although the total number of Soviet wild reindeer has increased in the last few years [as of 1974], most of this increase is confined to a few herds primarily in the tundra regions (e.g., Taimyr, Yakutia). Taiga reindeer herds (such as Tyumen, Tomsk, Sakhalin) continue to decline. In the author's opinion, "... a general decrease in population of wild reindeer has been detected together with a reduction of their geographic range in the taiga zone. This is mainly due to human intervention - the unfavorable transformation of habitats and direct extermination. In practice, these types of human influences are coincidental; persecution of reindeer coincides with depletion of habitats."

(3) Habitat destruction, due to logging, wildfire, and transportation systems, has been intensive, especially in western Siberia. The author provides numerous examples in western Siberia and elsewhere; however, he emphasizes that such habitat destruction is not occurring uniformly across the USSR.

(4) The author agrees with Syroechovskii (1984a) that although lichens are important to wild reindeer and loss of lichen habitat will cause local extirpations and decreases in populations, the species will not become extinct in the USSR. The author believes that if hunting can be adequately controlled, wild reindeer could accommodate human development and land use by reinvading or being reintroduced into remote areas around intensive development. However, in order for this to occur, a system of state sanctuaries in the taiga zone, similar to those already set up in the tundra zone, would have to be established. This may be especially effective in the European portion of the Soviet taiga.

[Rev. note: This report provides a good summary of a common Soviet philosphy regarding wild reindeer--i.e., that habitat destruction and poaching need to be curtailed in order to allow wild reindeer populations to recover. When the recovery is sufficient, wild reindeer can then be treated as a commercially harvestable species that utilizes habitat not optimal for other land uses (e.g., agriculture, forestry).]

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Shtil'mark, F.R. and V.I. Azarov. 1984. Wild reindeer of the Konda River basin. Pages 180-182 in E.E. Syroechovskii, ed. Wild Reindeer of the Soviet Union. Proceedings of the first interdepartmental conference on preservation and rational utilization of wild reindeer, 1974 (Transl. from Russian). Amerind Publ. Co., New Delhi. 309 pp.

This report briefly summarizes the status of wild reindeer in the Konda River portion of northwestern Siberia [eastern side of the Ural Mountains]. An estimated 12,000 wild reindeer inhabitat the area [as of 1974]. Since the 1950's, the region has been subjected to increased industrial development related to forestry, oil/gas and mineral extraction, and related transportation development, including a major rail line.

Relevant observations and conclusions include the following:

(1) Wild reindeer winter in the Konda River basin and migrate to the Ural Mountains or to lower portions of the basin for summer. Winter range is predominately pine-lichen forest.

(2) A sharp reduction in available winter range (especially the important pine forests) was noted in recent years. This reduction was due to forestry activity (e.g., felling and tapping of forests for resin-based chemicals), mineral exploration activity, and forest fires. Although poaching from cross-country vehicles is widespread, the herd appears to

be holding its own because the actual number of reindeer poached is comparatively low.

(3) A limited commercial harvest, primarily for local use [and, one would assume, to supplant poaching], should be developed.

(4) Two major reindeer sanctuaries have been proposed for the region. These should be established quickly [however, the authors note ruefully that resin tapping and felling will not be excluded.]

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Simmons, N.M., D.C. Heard, and G.W. Calef. 1979. Kaminuriak Caribou Herd: Interjurisdictional management problems. Pages 102-113 in K. Sabol, ed. Forty-fourth North American Wildlife and Natural Resources Conference, Wildlife Management Institute, Washington, D.C.

This paper is a rather bleak recounting of management errors made since the 1950's in relation to caribou herds in the Northwest Territories, especially the Kaminuriak Herd. The only impact-related material presented is the fact that human harvest is cited as the main and continuing problem in the decline of the Kaminuriak Herd.

[Rev. note: The Canadians have had awesome problems in managing wildlife populations that cross provincial boundaries. Also, the fact that the Canadians cannot limit harvest by Indians or Inuit, at least in some provinces, adds up to a pretty grim situation. The government embarked on a public information program in an attempt to convince hunters to curtail harvest. Besides improving census coverage and techniques, no other actions are proposed.]

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Skarphedinn, T. 1980. Status of Rangifer in Iceland. Pages 766-770 in E. Reimers, E. Gaare, and S. Skjenneberg, eds. Proceedings of the second international reindeer/caribou symposium, Røros, Norway. Direktoratet for vilt og ferskvannsfisk, Trondheim. 799 pp.

Reindeer were introduced to Iceland on four occasions between 1771 and 1787. Contemporary reports indicate that numbers of animals increased rapidly until peaking around the middle of the 19th century. Since then, there was a gradual decline until about 1940, when only a small, residual population (less than 200 animals) remained. The major factors causing the decline appeared to be snow conditions that limited access to grazing in winter and range deterioration, both as a result of the animal's own activities and because of volcanic eruptions. For unreported reasons, the reindeer population has been increasing steadily since 1940, so that in 1976 it numbered 3,600 animals.

Mortality figures are unavailable; however, reindeer in Iceland have no natural predators, except possibly the arctic fox (Alopex lagopus L.). The main causes of natural mortality are thought to be animals falling over cliffs and starvation.

Icelandic reindeer inhabit both high ground plateaus and lowlands of the eastern fiords. Plant communities primarily used for feeding include sedge heath and snow patch communities and, to a lesser extent, bogs.

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Skogland, T. 1983. The effects of density dependent resource limitation on size of wild reindeer. Oecologia 60:156-168.

This review summarizes data from 12 different Norwegian wild reindeer herds comparing body weight and jawbone length [as anatomical indicators of individual condition] with various range and reproductive parameters. All the study areas are in the mountain tundra region and especially along the Langfella Mountain Range, which affects local weather conditions. As a result, a gamut of forage growth conditions ranging from xeric to mexic are available. These conditions in turn create a gamut of potential deficiencies in winter or summer range. Differences among the herds' ranges in terms of absolute forage abundance were determined by vegetation sampling on seasonal ranges during late winter (primarily lichen-heath), early summer (snowbed heaths and meadows), and autumn (primarily mires [bogs or fens]). [Rev. note: Relative forage abundance - e.g., that available under varying snow conditions - was apparently not measured.]

Three of the herds originated from domestic reindeer, whereas the others have originated from the Hardangervidda and Dovrefjell wild reindeer centers - i.e. the differences between herds are more likely due to environmental than to genetic factors.

Relevant observations and conclusions include the following:

(1) Average body size of male wild reindeer in the Knutsho Herd was larger than that of the parent stock (Snohetta Herd). Likewise, average body size of male wild reindeer in the Brattefjell-Vindeggen and Hallingskarvet herds was larger than that of the parent stock (Hardangervidda Herd). In both these situations, the new herds had been formed on range of high quality that had been populated by emigrants from the parent herds. A similar pattern occurred in other herds that have resulted from emigration of parent herds on poor quality range. However, the pattern of growth was nearly identical for all herds. In other words, the differences in adult body size were due to differences in initial calf weights and not to differences in age-specific growth rates among herds.

(2) Consistent differences among herds were found for mean calving dates (date at which 50% of calving had occurred [often called "peak of calving" by North American biologists]), with herds on higher-quality range calving an average of 10 days earlier than those on lower-quality

range. In addition, calving dates for the same herd occurred later in years in which there were deeper or longer-lasting snowcover.

(3) By comparing and analyzing average body size among herds, it was determined that reindeer density on winter range, especially when lichen volume was considered, was significantly and inversely correlated with individual body size.

(4) A comparison between mean female body weight, reproductive success, and forage availability among the different herds indicated that over a female's reproductive life, body size and number of calves surviving through lactation was lower in those herds with lower forage availability in winter. On poorer-quality range, females conceived at 1½ years, whereas on higher-quality range, females conceived as calves. In addition, 1½ year old females on poorer range were smaller than those on better range.

(5) Time of calving and fetal birth weight appears to be related. That is, calving appears to be delayed until the fetus reaches a critical size. Birth weight, in turn, is dependent on maternal condition during the previous autumn and spring, and early postnatal growth rates are dependent on milk production. Early postnatal growth (to two months) has been shown by other studies to be positively correlated with the probability of calf overwinter survival. For females from herds on poorer range, a "grazing syndrome" results, in which the female expends available energy on reproduction, sacrificing body size; however maternal body size affects initial calf size and survival.

[Rev. note: The conclusion from this report that population size as well as individual body size is correlated with winter range quality is contradictory to conclusions from White et al. (1981) that population productivity was as dependent on summer range quality as on winter range quality. This report also contrasts with the conclusion of Bergerud (1980a) that caribou adult females have a consistent pregnancy rate of 80-90% regardless of range condition or other factors.]

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Skoog, R.O. 1968. Ecology of the caribou (Rangifer tarandus granti) in Alaska. Ph. D. Dissert., Univ. Calif., Berkeley. University Microfilms, Inc., Ann Arbor, Mich. 699 pp.

This massive dissertation covers virtually all aspects of caribou ecology in Alaska. A brief review revealed the following relevant conclusions:

(1) The Alaska Peninsula Herd ceased north-south movements across the Kvichak River about 1895. Volcanic eruptions are cited as a possible cause for changes in distribution, but hunting is also cited as a contributing factor.

(2) Caribou were virtually eliminated from the lower Kuskokwim River area by 1890. This is attributed to the "large scale slaughter of the animals by the natives."

(3) Skoog says that contrary to popular belief, hunting did not depress caribou numbers on the Arctic Slope and Bering Sea coast, since at the time of decline, few rifles were available to Natives, and whalers rarely hunted. Also, he disagrees with the notion that reindeer forced caribou out of ranges, because caribou had already left the Seward Peninsula by the time reindeer populations became significant.

(4) Skoog believes that the Kenai Peninsula served as an overflow area for Southcentral Region caribou during times of high population. Fire is cited as one of the possible causes of extirpation there. Several references to hunting at the time of extirpation are presented, but no direct conclusion is made.

(5) Overall, Skoog finds little evidence that hunting caused declines in the total population of caribou in Alaska, although some shifts in distribution and localized impacts to populations likely occurred.

(6) Skoog feels that reindeer overgrazing has had no effect on caribou. The absence of caribou from these ranges is due to changes in caribou distribution that began prior to the establishment of reindeer. Hybridization is also not a problem due to small ratios of reindeer to caribou in mixed herds and the recessive characteristics of reindeer.

(7) Skoog feels that abundant winter range (lichen stands) remained in all regions of Alaska, despite extensive fires. This is because fires burned largely in lowlands and not in subalpine dwarf birch stands rich in lichens. He also observed caribou moving through recent burns. No fire impacts were seen. The ability of caribou to adjust their distribution to alternate ranges and the patchy pattern of burns has prevented problems, even though potential carrying capacity is reduced.

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Skrobov, V.D. 1984. Human intervention and wild reindeer. Pages 90-94 in E.E. Syroechkovskii, ed. Wild Reindeer of the Soviet Union. Proceedings of the first interdepartmental conference on preservation and rational Utilization of wild reindeer resources (Transl. from Russian). Sovetskaya Rossiya Publishers. Moscow, 1975. Published for USDI and NSF by Amerind Publ. Co., New Delhi. 309 pp.

This article briefly recounts the known and inferred history of wild reindeer stocks in what is now the USSR. In addition to describing locations and fluctuations of populations, Skrobov also relates declines with various human-caused influences.

The following pertinent material is presented:

(1) Agricultural development pushed wild reindeer out of portions of Karelia, eliminating them in southern portions of their range [Rev. note: no specific mechanism for the extirpation, direct or indirect, is given]. A railway line from Krasnoyarsk to Irkutsk stimulated agriculture in the areas it accessed and thereby created a gap in the geographic range of wild reindeer around the rail-line [no mention of a barrier to migration is given].

(2) In the Arkhangel'sk region, extinction of wild reindeer in some areas is attributed to agricultural expansion, development of reindeer husbandry, forest fires, and predation.

(3) Reindeer herding and breeding is cited as the cause for extirpation of wild reindeer in several regions [one assumes because of "control" activities on wild reindeer carried out to protect domestic herds].

(4) The direct human factor in declines of wild reindeer herds is hunting pressure.

(5) Indirect human factors include poaching, resulting from settlement of new industrial areas; displacement of wild herds by forage depletion caused by domestic herds and construction of transportation corridors in migration areas; destruction of animals and habitat through radioactive fallout, spread of disease by domestic animals, carelessly caused fires, industrialization, collisions between vehicles and wild reindeer on roads, tracks, etc., and the creation of open water barriers in winter.

(6) Mitigation recommendations include the following:

a. Augmentation of a chain of arctic and sub-arctic sanctuaries for wild reindeer.

b. Better enforcement against poaching.

c. Setting up crossings across urban and industrial lines of communication.

d. Regular surveys of wild herds.

e. Organization of special facilities in order to allow for efficient, "rational" utilization of wild herds.

f. Reintroduction of wild reindeer to former ranges where domestic reindeer are not now grazing.

g. Increased fire suppression and control.

h. Control of disease in domestic deer.

i. Optimization of wild reindeer stocking rates based upon pasture capacity.

[Rev. note: This review is the most comprehensive summary of human impacts upon wild reindeer contained in Wild Reindeer of the Soviet Union. However, it suffers from a lack of explicit description of how man's activities have disrupted wild reindeer. It is interesting to note that the attitude towards fire was similar to contemporary thought (as of the early 1970's) in North America.]

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Sokol'skii, S.M. 1984. Wild reindeer of the upper reaches of the Pechora River. Pages 172-175 in E.E. Syroechovskii, ed. Wild Reindeer of the Soviet Union. Proceedings of the firsti nterdepartmental conference on preservation and rational utilization of wild reindeer, 1974 (Transl. from Russian). Amerind Publ. Co., New Delhi. 309 pp.

This report summarizes the current status of wild reindeer in the upper Pechora River [northeastern Soviet Union]. Wild reindeer in this region are found in taiga only, predominately in pine forests associated with a sanctuary. Although the herd numbered 1,000 in the 1940's, human habitat destruction and competition with domestic reindeer have resulted in a current [as of 1974] estimate of only 300 reindeer.

Relevant observations and conclusions include the following:

(1) Since the 1950's, several small industrial centers have been formed in areas of the wild reindeer's historic range. Forestry, chemical manufacturing settlements, and increased domestic reindeer husbandry have carved the historic range to a small portion of its original range. Recently [as of 1974] seismic exploration began in the wild reindeer's current range; hence there is some apprehension about the herd's fate. Poaching losses are also high and are considered an important cause of direct mortality.

(2) Along with a decline in populations size, there has been a cessation of migrations. This cessation was exacerbated by overgrazing and destruction by trampling of range by domestic reindeer.

(3) Observations of wild reindeer foraging behavior indicated that harassment by predators and man resulted in reindeer reducing forage intake by approximately 50%.

(4) In order to preserve this herd, the sanctuary should be extended and intensive anti-poaching measures initiated.

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Soldal, A.V., and H. Staaland. 1980. Genetic variation in Norwegian reindeer. Pages 396-401 in E. Reimers, E. Gaare, and S. Skjenneberg, eds. Proceedings of the second international reindeer/caribou symposium,

Røros Norway, 1979. Direktoratet for vilt og ferskvannsfisk, Trondheim.

In this laboratory study, blood serum from 1,096 reindeer from seven domestic herds in Norway and from wild reindeer on Spitsbergen and Nordaustlandet [Svalbard] was tested by gel electrophoresis to measure genetic variation within and between reindeer populations. Genetic variation [frequencies of serum transferrin alleles] was observed between domestic reindeer herds, between domestic reindeer and wild reindeer, and between the two wild reindeer populations. Allele frequencies indicated that wild reindeer on Nordaustlandet are relatively isolated from the Spitsbergen population of wild reindeer. The lack of a common serum transferrin allele between domestic reindeer in Norway and wild reindeer in Svalbard indicates that it is unlikely that there has been any connection between the two populations in recent years.

No documented impact information was contained in this paper.

[Rev. note: Sample sizes were small for Spitsbergen (36) and Nordaustlandet (6) wild reindeer populations.]

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Stevenson, S.K., and D.F. Hatler. 1985. Woodland caribou and their habitat in southern and central British Columbia, volume 1. Land Manage. Rept. No. 23. British Columbia Min. Forests, Victoria. 355 pp.

The status of woodland caribou and their relationship with forestry practices and other human developments in southern and central British Columbia is treated in this comprehensive, two-volume report. Volume 1 (reviewed here) consists of an extensive review of woodland caribou populations and habitat status, historical movements and population numbers, current and past forest exploitation and management, evaluation of the information base, and management recommendations for the study area. Volume 2 is a detailed review of caribou observations, forest inventory, and habitat mapping on a unit-by-unit basis, and is intended more for provincial wildlife and forest managers than for the general reader. Information in this report was gathered primarily from review of published and unpublished literature, interviews with local residents and fish and wildlife and forestry officials, remote sensing data, and Ministry of Forests forest inventory and automated data bases. Information was collected between 1982 and 1985.

Relevant observations and conclusions include the following:

(1) There are two ecotypes of woodland caribou in the study area. The "northern" type is located in the western portion of the study area and a small area east of the Rocky Mountains where snow depths are generally less than 76 cm (3 ft) and where terrestrial lichens and vascular plants are the primary winter food source. The "mountain" type is located in the remainder of the study area where snow depths exceed 76 cm (3 ft) in depth, and where arboreal lichens are the

primary winter food source. Other characteristics that differ between the two types include the larger group size (up to 300 animals) of the northern type as opposed to the smaller group size (seldom more than 25) of the mountain type, and the pronounced winter altitudinal migrations of the latter. [Rev. note: See also Edmonds and Bloomfield 1984.]

(2) In the study area caribou numbers have declined since historic times. Caribou numbers are believed to have declined significantly in the 1930's, remained low in the 1940's, increased in the 1950's to peaks in the 1960's, and declined in the 1960's. The current estimate of total caribou in the study area is 2,860 animals, of which approximately 1,450 are mountain caribou.

(3) In each of the wildlife management units in the study area some caribou ranges have been abandoned. The overall distribution of caribou in the study area has diminished since historic times.

(4) Other investigators have concluded that overhunting, especially during the liberal hunting seasons of the 1960's, was responsible for initiating the declines of several herds including the Tweedsmuir and Telkwa. However, harvest data are so poor that any such conclusions are very speculative, and the opposite conclusion (i.e., that overharvest did not occur) can often be drawn from the same data. Caribou hunting in recent years has been very restricted in the study area, and only occurs in a few management units. The recent total harvest has been less than 1% of the estimated total population.

(5) Differences in the winter habitat use between mountain and northern caribou result in differences in the type and amount of conflicts with forest management. Although mountain caribou in different portions of the study area vary somewhat in their patterns of winter habitat use, in general, mountain caribou in early winter use low- and mid-elevation mature and overmature forests stands where arboreal lichens are available as litterfall or on windthrown trees, and where the closed canopy intercepts snow and allows caribou greater mobility and shelter. As the snow deepens and settles in late winter, caribou move to higher elevation forests where arboreal lichens are abundant. Movements to lower areas occasionally are necessitated by recent snowstorms that impede caribou mobility at higher elevations.

In contrast to the use patterns of mountain caribou, northern caribou show little or no elevational migrations during winter. Northern caribou remain on windswept ridges, or in muskegs or lodgepole pine forests where they feed on terrestrial lichens or vascular plants which they reach by cratering through the snow.

Forest management conflicts are most likely to occur with mountain caribou range because these caribou require the mature forests that are the current and future source of timber for the forest industry, and because recent usual forestry practices generally have completely destroyed caribou winter range, and such areas will likely not regenerate with sufficient arboreal lichen biomass to allow use for many caribou generations. There are fewer conflicts with northern

caribou because most logging occurs outside of northern caribou range, and some logging practices can likely improve conditions for terrestrial lichen regeneration.

(6) Access to caribou range in the study area is provided by logging and mining roads, highways, and hydro reservoirs. Access has been responsible for overharvest of caribou in the Kootenay Mountains, and for harassment of caribou in the Telkwa Range. Much of the harassment has been due to increased snowmobile use of these undeveloped roads, which causes disturbance of mountain caribou on previously remote winter ranges.

Mortality of caribou due to collision with vehicles and trains has been documented, and has been an important mortality source in some small herds.

(7) Forest fires have generally had a negative effect on mountain caribou range, but a positive or neutral effect on northern caribou range. Man-caused fires associated with construction of the Canadian Pacific Railroad in the late 19th century and fires in Wells Gray Park in the 1920's and 1930's, have burned large areas of caribou habitat that have yet to return to the stage of significant arboreal lichen production.

(8) Forest practices such as partial cuts, small-patch clear-cuts, retention of advanced regeneration and nonmerchantable trees, extended rotation periods, and progressive partial cuts are discussed as alternatives to the currently routine practice of large-block clear-cuts. [Rev. note: The authors discuss each of these methods in detail; however, the advantages and disadvantages will be only summarized here.] The advantages of most of these methods are that they retain some winter habitat, especially for mountain caribou, by either leaving some of the winter range unaltered, or by minimizing the destruction or maximizing the propagation of arboreal lichen habitat. They have the disadvantage of being more costly to plan [and supervise] and are less palatable to forestry officials and industry, and may turn out to be unsuccessful because of incidental problems. For example, partial cutting leaves some habitat for use by caribou and for regeneration of arboreal lichens but requires a more extensive road system than does clear-cutting; therefore, can increase the potential for legal and illegal harvest and harassment of wintering caribou.

In most cases harvest methods require a tradeoff between short-term, intensive disturbance, and long-term, less intensive disturbance. Unless the amount of timber to be cut annually is substantially reduced the management strategy that is selected will depend on the relative importance that managers assign to the effects of habitat alteration as opposed to human disturbance.

(9) The future of mountain caribou in the study area will depend on adherence to a long-term commitment to reduce timber harvest in areas where caribou management is a priority. In many situations it appears that timber harvest and sustaining mountain caribou winter habitat conflict to the point that they are mutually exclusive. In areas where

mountain caribou management is a high priority, the most effective management may be reservation of areas free from human activity.

[Rev. note: This report is comprehensive, well-written, and objective. The sections on limitations of the available information and research and management recommendations are valuable not only to those in the specific study area but also to caribou managers in other regions where similar types of data are (or are not) available. The "Management Analysis" section presents a clear methodology for rating the various management units in the study area according to their value to caribou, conflicts with forestry and other land uses, level of knowledge about them, and significance of caribou to the public. The framework and approach can be applied to other areas where caribou and land uses conflict. The evaluation of the suitability of various forest management techniques for maintaining mountain caribou is especially useful. The conclusion that, for mountain caribou at least, there is likely to be a significant economic cost (in terms of foregoing exploitation of other resources) associated with protecting winter range is a sobering one but certainly appears to be supported by the data presented.

The parallels between the effects of forest management practices on woodland and mountain caribou reported here, and those reported in Edmonds and Bloomfield (1984) are striking. Equally striking is the conclusion that in many cases, but not all, conflicts between the forest industry and caribou can be minimized if the forest products industry and management agencies were willing to modify forest practices.]

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Syroechkovskii, E.E. 1984a. Overview of the problem of wild reindeer in the Soviet Union. Pages 6-44 in E.E. Syroechkovskii, ed. Wild Reindeer of the Soviet Union. Proceedings of the first interdepartmental conference on preservation and rational utilization of wild reindeer resources, 1974 (Transl. from Russian). Amerind Publ. Co., New Delhi. 309 pp.

This report is an overview of the status of wild and domesticated reindeer in the Soviet Union, methods of utilization of wild reindeer, the rationale for establishing wild reindeer reserves, and areas of potential conflict.

Relevant observations and conclusions include the following:

(1) As of 1974 [the time of the conference] there were approximately 600,000 wild and 2.5 million domesticated reindeer in the Soviet Union. Domesticated reindeer are concentrated in the Magadansk, Yakutia, Kola, and Tyumen regions. Wild reindeer are concentrated in Taimyr and Yakutia.

(2) Numerous areas of reindeer habitat have been destroyed by various types of activities related to man. In Lovozersk alone, more than 148,000 ha (365,700 acres) of reindeer "pasture" were wiped out by fire in 1960; fires were caused by loggers burning brushpiles. Lichen-forest areas

of Tersk were completely decimated by logging. Lichen-forest areas throughout the Soviet Union are "almost doomed to extinction under human intervention" because of forestry-related and human settlement activities. Reindeer pastures in areas of the Soviet North have also been destroyed by large all-terrain vehicles used during petroleum exploration and transportation system development.

(3) Although the reindeer industry has been highly developed and subsidized, the commercial value (e.g., meat and hides) of wild reindeer in Taimyr exceeded that of domestic reindeer. Additional commercial value of wild reindeer can be obtained by developing a more advanced commercial and sport hunting industry, especially in areas of the Soviet Union where wild reindeer out-compete domesticated reindeer for forage [which is much of the remaining area where wild reindeer are found].

(4) Food habits studies have shown that in contrast to the lichen-dominated diet of domesticated reindeer, wild reindeer utilize primarily graminoids and heaths. The lichen species that are eaten by wild reindeer are not as preferred by domestic reindeer. Thus food habits competition between domestic and wild reindeer is not as intense as once believed.

(5) In order to protect wild reindeer and reindeer habitat from human activities, a system of large reserves should be established.

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Thing, H. 1980. Status of Rangifer in Greenland. Pages 764-765 in E. Reimers, E. Gaare, and S. Skjenneberg eds. Proceedings of the second international reindeer/caribou symposium, Røros, Norway. Direktoratet for vilt og ferskvannsfisk, Trondheim. 799 pp.

As of March 1980, the total number of free-ranging caribou (Rangifer tarandus groenlandicus) in Greenland was estimated at 8,000-9,000, while numbers of feral and domesticated reindeer (Rangifer tarandus tarandus) were estimated at 500 and 2,500 animals, respectively. For unreported reasons, R. t. groen- landicus was experiencing a rapid decline throughout most of its range, but the R. t. tarandus populations (both feral and domestic) seemed to be stable or increasing.

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Thing, H., and B. Clausen. 1980. Summer mortality among caribou calves in Greenland. Pages 434-437 in E. Reimers, E. Gaare, and S. Skjenneberg, eds. Proceedings of the second international reindeer/caribou symposium, Røros, Norway. Direktoratet for vilt og ferskvannsfisk, Trondheim. 799 pp.

During 1977 and 1978 high mortality was recorded among 2-3 month old caribou calves that were born north and east of Sdr. Strømfjord, in west Greenland. During observation and sampling of calves, various pathogens were found. The first year most of the sick calves were found to have a high incidence of parasites (i.e., coccidiae, tapeworms, and roundworms). The next year calves were found to exhibit symptoms of diarrhea, limping and swollen joints due to infection with E. coli (type 055).

Relevant observations and conclusions include the following:

(1) While parasites were found in great numbers, they did not appear to be the primary cause of the debilitating effects observed.

(2) E. Coli type 055 was the only potentially pathogenic bacteria isolated in pure culture from joints and infections in the abdominal cavity and around the heart. These bacteria were believed to be the cause of the diarrhea and subsequent joint infections.

(3) Prominent diarrhea and enlarged lymph nodes in calves indicated an alimentary route of infection. E. coli 055 was found in the feces of adult caribou, and calves were believed to be infected while eating.

(4) The authors concluded that, while E. coli was not believed to be specifically pathogenic, its effects were magnified by the fact that there was a shortage of food on the caribou's summer range. Animals concentrated in special feeding areas where the grass was very short and the density of fecal pellets was very high. This caused the calves to ingest large amounts of bacteria while feeding.

[No impacts-related information is presented.]

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Thomas, W.C., and E.L. Arobio. 1983. Public policy: implications for Alaska reindeer herd management. Act Zool. Fennica 175:177-179.

This paper summarizes the effects of public policy as embodied in law and land management policies upon the Alaskan reindeer herding industry. This industry has historically (at one time or another) occupied most of western and northern Alaska but now is restricted to the Seward Peninsula. The only reference to impacts is the mention of conflicts between caribou and domestic reindeer and restrictions to future expansion of the reindeer industry.

[Rev. note: This paper is written from the reindeer industry's perspective and dwells on the problems that policies impose on herders. For an outline of specific caribou/reindeer conflicts, see other papers by Klein (1980) and Adams and Robus (1981). Although no specific references to impacts to caribou are included, one may infer positive effects upon caribou through a reduction in or prevention of conflict between wild and domestic herds of Rangifer through restriction of reindeer herding.]

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Thomson, B.R. 1980. Behavior differences between reindeer and caribou (Rangifer tarandus L.). Pages 545-549 in E. Reimers, E. Gaare and S. Skjenneberg, eds. Proceedings of the second international reindeer/caribou symposium, Røros, Norway. Direktoratet for vilt og ferskvannsfisk, Trondheim. 799 pp.

This 1979 study is a comparative literature review of behavioral differences between racial types of Rangifer tarandus (L.), particularly European reindeer and North American caribou. Although the basic behavioral repertoire of these subspecies is fundamentally the same, several differences have been observed in communicative signals, reproductive behavior, and social organization.

Relevant observations and conclusions include the following:

(1) Four postures used regularly by North American barren ground caribou as social releasers, or sign stimuli, in communication are not found in wild or domestic European reindeer. These include the excitation jump, one-legged alarm pose, head-stretch threat, and head-bobbing from mother to calf.

(2) Variable reproductive behavior observed in reindeer but not caribou includes self-marking behavior, antler clashing, dominance rituals leading up to mating, and the time required to pass the placenta and leave the birthing area.

(3) Domestication of reindeer populations appears to have had no dramatic effect on behavior patterns but undoubtedly alters the social organization and structure of herds. Herding practices and selective slaughter in Finland have apparently resulted in fewer potential leaders, reduced home range area, and a higher tolerance to hard snow (Helle 1980).

(4) Finally, multiple suckling by two or more calves simultaneously is an attribute that is fairly common in reindeer but has been observed only once in woodland caribou and twice with barren-ground caribou.

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United States Congress. 1946. Protection of Dall sheep, caribou, etc., native to Mount McKinley National Park. Hearings before the committee on public lands, House of Representatives, Seventy-ninth Congress. U.S. Government Printing Office, Washington. 55 pp.

This reference is a transcript of both written and oral comments on a bill that would have required the Secretary of the Interior to control wolves and other predators to protect herds of Dall sheep, caribou, and other wildlife within Mount McKinley National Park. Testimony was primarily directed towards predator control of wolves to protect herds of Dall sheep that had been severely reduced by severe winters and unknown factors. Testimony was

mostly from several people who had hunted or travelled in the region and supported predator control. Caribou and/or reindeer were only briefly mentioned by those testifying. Often, these references to caribou were merely that several hundred were seen in the area of the park, with no or only generalized reference to time of year or location. Three individuals attributed wolves as being the major cause of the decline of reindeer herds in Alaska.

An army general reported observing 50,000 to 75,000 caribou in 1939 and 1940 migrating from the direction of the "Endicotts" north of Fairbanks into the Portage country. [Rev. note: If the "Endicotts" are the Endicott Mountains of the central Brooks Range and "the Portage country" refers to a Portage Creek either in the lower Kobuk or upper Noatak river valleys, the above described caribou are likely to be a portion of the Western Arctic Herd.] He further stated that today [1946?], the caribou migration north of Fairbanks was practically nonexistent, with only small (100-200 animals) herds occasionally seen. [Rev. note: It was unclear if the general was referring to the Endicott-Portage area or possibly the Steese-Fortymile herd.] His belief was that wolves were the major factor in the decline of caribou, reindeer, sheep and moose. Additionally, the general claimed that in 1939-40, it was not uncommon to see 45,000-50,000 caribou in the Eagle Summit area, while by [1946?] it was the exception to see 200-300 caribou in the area. [Rev. note: This area is a portion of the range of the Steese-Fortymile herd.] Again, wolves were believed by the general to be the major factor in this apparent decline.

Written testimony to these hearings described market hunting in the McKinley Park - northern Alaska Range area. This hunting, primarily to supply Fairbanks with a supply of meat, was directed primarily towards sheep, although the author stated that caribou and moose were likely to be more heavily hunted as sheep in accessible areas became scarce.

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Valkenburg, P., and J.L. Davis. 1985. The reaction of caribou to aircraft: a comparison of two herds. Pages 7-9 in A.M. Martell and D.E. Russell, eds. Proceedings of the first North American caribou workshop, Whitehorse, Y.T., 1983. Can. Wildl. Serv. Spec. Publ., Ottawa. 68 pp.

Results of a study comparing the reactions of caribou of two Alaskan herds to aircraft and ground disturbance between 1979 and 1983 are presented in this report. The Delta Herd (DH) is located in the Interior, south of Fairbanks, and is subjected to a considerable amount of small plane, military, and civilian jet traffic and a minor amount of ground vehicle traffic (primarily snowmachine) compared to the WAH. The use of fixed-wing aircraft is a major mode of hunting. Conversely, the Western Arctic Herd (WAH), in northwestern Alaska, is located in a remote area with comparatively little aircraft traffic, where hunting is primarily from snowmobiles and other small ORVs. Observations of the specific responses (e.g., panic, mild escape, no visual response) to aircraft by groups with radio-collared individuals in both herds, and the authors' general

impressions of the reactions of animals in both herds are reported. Group response data were gathered during flights in winter (October 1-April 30).

Relevant observations and conclusions include the following:

(1) During winter experimental flights, WAH caribou ran from overflying aircraft during 82% of the passes and DH animals during 36% of the passes. During flights over the WAH, the authors could reliably identify cow-calf pairs by flying over the pair, in response to which the calf would run to its mother. Similar responses by DH animals did not reliably occur.

(2) DH caribou appear to have become habituated to aircraft. There was no open season on the DH between 1974 and 1980, and when the season was reopened in 1980-1981, hunters could not take caribou the same day airborne. Conversely, the WAH has not been subjected to a large amount of aircraft activity, during hunting or otherwise. The more extreme reaction to aircraft by WAH could be a result of either not having a sufficient amount of non-threatening aircraft activity to become habituated or, conversely, the animals could be reacting to airplanes as if they were snowmobiles.

(3) In the past, the effects of aircraft disturbance have been overemphasized. The changes in hunting practices that accompanied the widespread use of snowmachines in the 1960's have probably had a more important effect than aircraft.

[Rev. note: See also Davis et al. 1984 for additional information on the DH and man's activities.]

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van Zwoll, W. 1983. Ghosts of the Selkirks. Washington Wildl. 33(2):26-29.

This popular article discusses the current status, basic biology and life cycle, habitat use, and impacts of human development and land use on a small population of woodland caribou (Rangifer tarandus caribou) found in the Selkirk Mountains of extreme northeastern Washington. This small population, known as the Selkirk Herd, currently numbers roughly 20 animals and is the only woodland caribou herd within the United States.

(1) Historical distribution - Woodland caribou were scattered throughout Maine, New Hampshire, Vermont, Michigan, Wisconsin, Minnesota, possibly New York, as well as Washington, Idaho, and Montana. Habitat destruction by logging and agriculture are stated to have gradually driven the caribou from the US. Parasitic roundworms [Parelaphostrongylus tenuis] from white-tailed deer are also believed to have contributed to the demise of the caribou in the Northeast. Caribou disappeared from New England by 1908, from the Great Lakes region by 1940, and from Montana sometime prior to 1960.

(2) Impacts of development - The Trans-Canada Highway, built in 1963, bisected the range of the Selkirk caribou. Several caribou were hit by cars. Additional caribou were killed or crippled by poachers. Snowberms along the highway hampered caribou travel. Powerline access roads and rights-of-way, as well as logging trails, created problems in some areas [no elaboration was presented as to what these problems were].

(3) Potential impacts - A US Forest Service proposal to salvage insect-killed timber, which could still support arboreal lichens for up to 15 yr, is planned and would eliminate these lichens in a portion of prime caribou habitat.

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Vershinin, A.A., A.D. Kleimenov, P.S. Vyatkin, and V.I. Fil'. 1984. Wild reindeer of Kamchatka. Pages 209-216 in E.E. Syroechovskii, ed. Wild Reindeer of the Soviet Union. Proceedings of the first interdepartmental conference on preservation and rational utilization of wild reindeer, 1974 (Transl. from Russian). Amerind Publ. Co., New Delhi. 309 pp.

This report summarizes historical and current [as of 1974] distribution of wild reindeer on Kamchatka Peninsula and the adjacent Penzhiina region of the USSR.

Relevant observations and conclusions include the following:

(1) Caribou numbers on Kamchatka Peninsula have never been large; however, the geographic distribution in early historical times encompassed the entire region. Density of caribou in the birch forest zone of the region was never great, because of the heavy snow accumulation there.

(2) Reindeer husbandry by the native Koryak people predated Russian occupation. As a result, even by the 17th century, when Russians colonized the area, caribou were already scarce in the northern portion of Kamchatka. Other Native subsistence hunting and fishing groups lived along the coast and rarely hunted caribou in the mountainous regions; therefore, caribou became most common in the remote areas of the peninsula. As the region became settled by more domestic reindeer herders and as furfarming (especially sable) became an important industry, more caribou were harvested in order to reduce competition with domestic reindeer and to provide food for the fur farming industry. By the late 1800's, caribou populations were depleted, and their range restricted to three "centers."

(3) The current caribou population estimate for the Kamchatka region is 10,000 animals. The domestic reindeer population decreased from a high of 257,000 in the 1920's to 170,000 in 1969.

(4) As a result of the restriction of caribou to widely separated refugia, they no longer undergo lengthy seasonal migrations but do undertake

short altitudinal migrations. The authors expressed concern that the high predator (wolf, brown bear, wolverine) population on the island could seriously reduce such a sedentary population. [Rev. note: In another portion of the article, the authors mention that a successful poisoning and shooting campaign had "significantly reduced" predators in the major caribou areas.]

(5) The authors pointed out that due to the restricted habitat, presence of predators, and the current [as of 1974] harvest rate of 7-8% by poachers and reindeer herders, plans for commercial harvest of caribou in the Kamchatka region are premature unless poaching and predation can be reduced and accurate estimates of caribou and domestic reindeer carrying capacity determined.

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Villmo, L. 1975. Plenary session: Potential impact of accelerated northern development on caribou and reindeer populations and ecology - The Scandinavian viewpoint. Proceedings of the first international reindeer/caribou symposium, Fairbanks Alaska, 1972. Biol. Paper Univ. Alaska, Special Rept. No. 1. 551 pp.

The author presents a number of general accounts of impacts to reindeer from a variety of development sources prior to 1972. These accounts were acquired through conversations with reindeer herders in Norway and Sweden and through the author's own observations in the 12 yr preceeding his presentation. Among the many impacts that the author identifies as important are the following:

(1) Roads and traffic create visual barriers to movement, cause disturbance and road-kill accidents, facilitate access by humans and domestic dogs, and result in an incremental loss of habitat.

(2) Mining operations create obstructions and disturbance leading to changes in traditional migration routes or modification of grazing habits.

(3) Hydroelectric impoundments influence the ecology of connecting watercourses so that they either facilitate or prevent migratory movement, result in extensive icing along river banks, or modify adjacent vegetation types.

(4) Pipelines present a physical barrier to movement.

(5) Electric powerlines damage or change the vegetation and create an auditory barrier to unrestricted reindeer movement.

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Watson, A. 1979. Bird and mammal numbers in relation to human impact at ski lifts on Scottish hills. J. Applied Ecol. 16:753-764.

This field study, conducted at Cairn Gorm and Cairnwell, Scotland, from 1967 to 1978, set out to examine bird and mammal numbers in disturbed vegetation areas at Scottish skiing areas and compare them with nearby undisturbed areas. Ptarmigan and red grouse were the main species studied, although reindeer, sheep, dogs, crows, gulls, and other birds were also studied to a limited extent.

Reindeer densities were significantly higher on areas of disturbed (and subsequently revegetated) land than on undisturbed areas, with greater than 90% of the reindeer observed on patches of fertilized, re-seeded grass.

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White, R.G., F.L. Bunnell, E. Gaare, T. Skogland, and B. Hubert. 1981. Ungulates on arctic ranges. Pages 397-483 in L.C. Bliss, O.W. Heal, and J.J. Moore, eds. Tundra ecosystems: a comparative analysis. Internatl. Biol. Progr. No. 25. Cambridge: Cambridge Univ. Press. 813 pp.

This report is a synthesis of research conducted on caribou/reindeer, muskox, and Dall and snow sheep as part of the International Biological Programme's (IBP) Tundra Biome project. Results from Arctic and alpine tundra sites throughout the Northern Hemisphere were reported.

Relevant results and conclusions include the following:

(1) Of all the species mentioned above, Rangifer shows the greatest niche breadth, inhabiting the polar deserts of High Arctic islands of northern Canada, to dense boreal forest of Canada and the Old World. Caribou/reindeer are at various times both grazers and browsers.

(2) Both internal and external factors affect Rangifer natality. Although the age at first conception is the most plastic component of natality, it appears that for wild reindeer and caribou populations, first conception occurs at three years of age. Domestic reindeer have shown the ability for yearlings to breed; pregnancy rates of 50% for 2-yer olds have been reported. For female Rangifer older than 2-yr, pregnancy rates of 80-95% are the rule. Although conception has been shown to be highly correlated with fall age-specific body weight in Norwegian reindeer, there is little unequivocal evidence to suggest that natality of Rangifer is dependent on range quality.

(3) Mortality rates and patterns are highly variable, ranging from biotic factors, such as harvest by humans and wolves, to abiotic factors such as severe weather during calving, drowning during river crossings, or ice storms during the winter. Abiotic mortality factors appear to be especially important for controlling Peary caribou and Svalbard reindeer.

(4) The effects of individual growth rates and dynamics of the population as a whole were reviewed. Young Rangifer are capable of a high growth rate during the first summer, and this growth rate may be important to overwinter survival. The energy costs of walking are inversely correlated with body size; therefore, a rapid increase in body size should minimize the energy costs associated with migration and predator [or other harassment] avoidance. Because Rangifer has physiologically adapted to a period of relative growth dormancy during winter, calves have only the short summer period to maximize body growth. Because the calf relies heavily on milk for the first two months of life, the nutritional composition and availability (i.e. female's milk production and available time to nurse) of milk is important. Milk nutritional composition is dependent on the female's nutritional plane at calving, which is in turn dependent on fall and winter nutritional condition. Milk availability is dependent on forage quality during summer, and on the amount of external stimuli (e.g. harassment by insect predators, and/or humans) that interfere with nursing.

(5) Critical to the understanding of Rangifer range relationships is the nature of the grazing process. Foraging time, forage selection mechanisms, and the quality and quantity of forage available are important components. Foraging time appears to be a function of forage quality/quantity, the nutritional state of the individual, physical distention of the rumen, and external stimuli (e.g., harassment). Animals in a poorer nutritional state (e.g., pregnant cows, adult bulls immediately after the rut) spend more time foraging than those in better nutritional condition. Daily foraging time is inversely correlated with forage biomass - Rangifer on good-quality range spent less time foraging each day than those on poorer-quality range. All Rangifer studied have spent more time foraging in summer than in winter; conversely, less time was spent resting in summer than in winter.

(6) Studies have shown that, in general, lichens are taken in winter in proportion to availability, whereas there may be a preference for them in late summer. In general, herbaceous plants, graminoids, and salices are preferred vegetation types. There is no unequivocal evidence that caribou can fatten on a lichen-rich diet [Rev. note: for a contrary opinion, see Klein (1982)], although calculations suggest that under ideal snow conditions, caribou could meet their daily energy demands with lichens, and any nonlichen forage obtained during the same period could possibly result in a positive energy balance.

(7) Calculations for arctic and alpine Rangifer at IBP sites throughout the world indicate that the mean live biomass of Rangifer was highly correlated ($r = 0.97$, P less than 0.01) with live vascular plant biomass. In other words, Rangifer population productivity is as dependent on summer range quality as on winter range quality. Therefore, not only is individual body size dependent on summer range quality (cf. Klein 1970) but also total population size. On summer ranges that are less productive (e.g., Prudhoe Bay), caribou population productivity may be more affected by effects on grazing time (e.g., harassment by insects or humans) than population productivity on more productive ranges.

(8) Social behavior may also influence foraging ecology, In winter, antlered females and their calves can displace adult males (which shed their antlers soon after the rut) from feeding craters the males started. Aggregations of Arctic caribou during winter appear to be advantageous because a larger contiguous area can be cratered, resulting in more forage available to each individual. Aggregations during mosquito harassment may minimize the direct effect of blood loss on each individual; however, if aggregations become too large (2000+) there may be interference with a return to foraging after mosquito harassment dies down.

(9) Nursery groups [females with calves, and ancillary nonreproductive females] and post-calving aggregations may be predator responses. Evidence from Norway indicates that size of nursery groups was linearly correlated with the number of calves born and that this formation was enhanced by external disturbances such as man or predators. Conversely, on Svalbard (where there are no predators and few humans) no nursery herds were formed.

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Zagorodskii, E.E., and N.F. Reimers. 1984. Wild reindeer of the Sakhalin Region. Pages 217-222 in E.E. Syroechkovskii, ed. Wild Reindeer of the Soviet Union. Proceedings of the first interdepartmental conference on preservation and rational utilization of wild reindeer resources, 1974 (Transl. from Russia). Amerind Publ. Co., New Delhi. 309 pp.

The historic and current [as of 1974] status of wild reindeer on Sakhalin Island [just north of Japan] is reviewed in this article. The subspecies of reindeer, Okhotsk reindeer, on the island is the largest Palearctic subspecies [Rev. note: scientific name was not provided - may be Rangifer tarundus arcticus (?)]. This small population of wild reindeer winters in mountain forests, primarily in larch groves and open fir forests, and moves to lowlands, including seashore and river areas, in the summer. Although the current [as of 1974] population estimate is ca. 1,500-1,700 animals, the historic population could have been up to 10,000. [Rev. note: This estimate was based on habitat availability rather than on a count of numbers of animals. Although actual numbers for the historic populations were not provided, the authors do present evidence that major contractions of range occurred and that, based on comments by residents of the island and historic literature accounts, there indeed has been a severe population decline since the early 1900's.] Several reasons for the shrinkage in distribution, and decline in population were discussed. These included the following:

(1) Commercial hunting. In some regions, reindeer have been locally extirpated because of overhunting in combination with habitat destruction. Densities of reindeer in areas where hunting has not occurred are up to 23 times as high as those where hunting has occurred. The current harvest of 300 animals would continue the decline of the herd even in the absence of further habitat destruction.

(2) Habitat destruction. Approximately 1% of the winter habitat has been destroyed each year for the past 20 yr. This is primarily due to the destruction of forested areas by logging, construction of defense facilities (airbases and artillery ranges), and replacement of native forests with bamboo plantations.

(3) Competition with domestic reindeer. The domestic reindeer industry has been developed in the same regions as wild reindeer are found; therefore, they are in direct competition for the same limited range.