Climatic changes and caribou abundance in northern Québec over the last century.

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Abstract: The temperature increase observed in the Northern hemisphere during the first half of this century was also detectable in Québec; it affected both summer and winter. In northern Québec, warmer summers stimulated growth and favored range expansion of trees and shurbs. Based on black spruce krummholz height and water level in lakes, the warmer period was also characterized by greater snowfall and deeper snow cover. This period of deep snow coincided with apparent caribou scarcity. Three hypotheses were explored to relate increased temperature with caribou decline: 1) destruction of winter habitat due to high frequency of forest fires, 2) increased energy cost to obtain forage in deep snow and 3) delayed melting of snow on calving grounds that shortened the time to raise calves. The combined effect of the 3 mechanism could explain caribou scarcity, particularly for the Rivière George herd whose calving ground becomes snow free in late June. Ways to test the third hypothesis are proposed.

Keywords: caribou, climate, Québec, *Rangifer*

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Introduction

Various factors have caused continuous changes of earth's climate over geological time (Harrington 1987). The temperature increase obeserved in the Northern Hemisphere during the first half of the 20th century was associated with reduced volcanic activities (Harrington 1987). Vegetation of northern Québec reacted to warm summers during this period: growth of black spruce *(Picea mariana)* was better than during the preceding 5 centuries (Payette et al. 1985), and green alder *(Alnus crispa)*, tamarack *(Larix laricina)* and white spruce *(Picea glauca)* exhibited range expansion at the tree line (Gilbert and Payette 1982; Morin and Payette 1984; Payette and Filion 1985). Such vegetation response must mainly have depended on longer and warmer growing seasons, but temperatute records in southern Québec since 1876 indicate that the warming trend also occured in winter. Warm winters during the first half of the century in Greenland were apparently caused by a displacement of the polar front; they were characterized by greater snowfall and rainfall (Meldgaard 1986). In northern Québec, mean snow depth may have increased by 20 cm during this period (Payette et al. 1985).

Even if quantitative information remains unavailable for most of the period, caribou numbers have fluctuated drastically over the last 100 years. They were seemingly plentiful at the turn of the century but became suddenly scarce until 1950-1960 (Audet 1979). During the following decades, the Rivière George herd increased at an annual rate exceeding 10 percent (Messier et al. 1988), to reach 682 000 (S.E. = 145000; n=81) individuals in 1988 (Crête et al. 1989). Calf production has diminished by 20 percent since 1984 (Messier et al. 1988) and the herd may be leveling off or decreasing (Crête et al. 1989; Hearn et al. in press.). The Rivière aux Feuilles herd, the other herd calving on the Québec tundra, was made up of more than 100 000 individuals in 1986 (Crête et al. 1987); animals are in excellent condition (unpubl.), but the population dynamics of this herd remain unknown. Comparable fluctuations in caribou numbers with peak density by 1900 and in recent decades were also reported for Greenland (Meldgaard 1986). We examined climatic changes over the last 100 years in relation to fluctuation of caribou abundance. We tried to find relationships between temperature warming and caribou scarcity. We investigated the following hypotheses: 1) the incidence of forest fire was higher during the first half of the century, particularly in the north of the boreal forest so that caribou prime winter habitat became limited; 2) snow cover was deeper during this period and incidence of winter rain was higher so that forage was more difficult to obtain; 3) deeper snow cover delayed snow melt in spring so that emergence of green vegetation came later on calving grounds.

Study area and methods

The calving ground of the Rivère George herd is located east of Kuujjuaq on a tundra plateau which ranges in altitude between 500-750 m. (Fig. 1.). Before the mid-seventies, the herd used to spend the snow-free period in the vicinity of the calving area and migrate south and

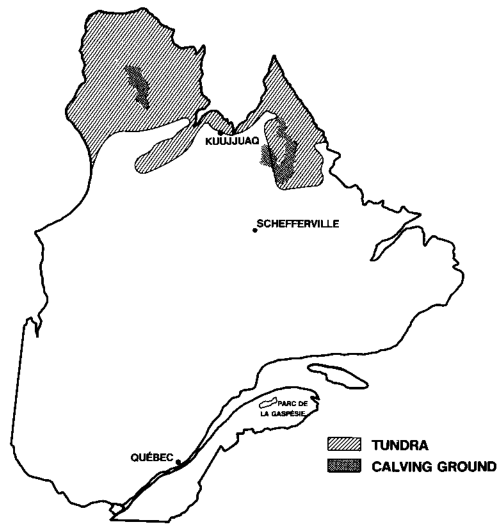

Fig. 1. Location of the 3 weather stations from which meteorogical data were analysed, distribution of the tundra in northern Québec and calving grounds used in 1986 by the Rivière aux Feuilles caribou herd (west) and the Rivière George herd (east).

west in the forest-tundra and the boreal forest during the winter, east of longitude 70°. More recently, the herd has initiated fall migration earlier and has expanded its range west to Hudson Bay, occupying on an annual basis around 600 000 km^2 (Messier et al. 1988). The Rivière aux Feuilles herd calves in the middle of the Ungava peninsula, northwest of Kuujjuaq on a gently rolling plateau averaging 225 m in elevation (Fig. 1). Apparently, it spends the summer north of the tree-line and part of the herd migrates south in winter generally west of longitude 68° - 70°. Recently, winter range of both herds has partly overlapped while common use of the same range has been limited during the calving season and the snow-free period (unpubl.).

Weather records were provided by the Ministère de l'Énergie et des Ressources du Québec for Québec City (1876-1986), Schefferville (1948-1986) and Kuujjuaq (1947-1986) (Fig. 1). Monthly temperature averages and total snowfall and rainfall served as input data. The year was divided into periods, November - April and

Table 1. Pearson correlation coefficient matrix computed with annual winter and summer average temperatures between 3 weather station in Québec, 1946-1948 to 1986. All coefficients significant ($P<0.02$).

	November - April		May - October	
	Shefferville	Kuujjuaq	Shefferville	Kuujjuaq
Québec	0,525 (38[a])	0,402 (38)	0,624 (38)	0,535 (38)
Schefferville	—	0,858 (37)	—	0,879 (36)
Kuujjuaq	0,858 (37)	—	0,879 (38)	—

[a] number of years compared

May - October. In addition NOAA/AVHRR satellite images were used to examine snow cover disappearance between 1980 and 1986 over northern Québec (St-Pierre et al. 1987). In 1984 and 1986, vertical aerial photographs were used to determine percent snow cover during calving (Crête et al. 1987); in 1987, visual estimation was made from an aircraft flying 200-300 m above the ground (Vandal and Couturier 1988).

Results and discussion

Temperature and precipitation trend: 1876-1986

Continuous weather records began in the late forties in northern Québec so that data were not available for most of the warmer period that started at the turn of the century. For Québec City however, observation began in 1876, which covers the complete cycle of warming and cooling trend. For the 1946-1986 period, there was a significant ($P<0.02$) relationship for the average annual winter and summer temperature between Québec City, Schefferville and Kuujjuaq (Table 1). The strength of the relationship was greater for Kuujjuaq and Schefferville that are relatively close, than for Québec City and 2 other areas; the relationship between the 3 weather stations was slightly closer for summer than winter temperature. On the other hand, no significant ($P>0.1$) relationship was found for winter snowfall or rainfall between Québec City and Schefferville or Kuujjuaq. We concluded that the temperature trend in northern Québec during the last century could be extrapolated from Québec City, but not precipitation trends.

A clear tendency for increasing winter temperature between 1880-1950 was apparent

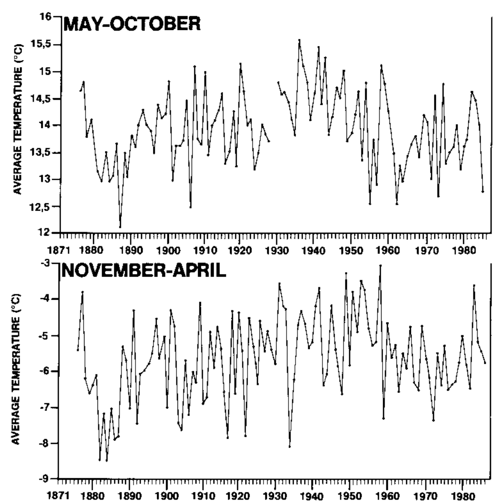

Fig. 2. Average winter (November-April) and summer (May-October) temperature between 1876 and 1986 in Québec City.

in Québec City, while summer temperature may have peaked a decade earlier (Fig. 2). Since 1950, temperature averages decreased by 1-2°C. Summer temperature trends observed in Québec City match well with vegetation growth and range expansion documented in northern Québec between 1900-1950 (Gilbert and Payette 1982; Morin and Payette 1984; Payette and Filion 1985; Payette et al. 1985).

It is difficult to reach any conclusions concerning the impact of warmer winter on snow cover in northern Québec because no historical data in snow preciptitation or depth are available. Based in black spruce krummholz (stunted trees) height close to the tree line, snow depth could have been 20 cm greater during the warming period than before (Payette et al. 1985). The same conclusion can be reached when considering water level in a lake of the same area that raised to a maximum height in the 20th century (Begin and Payette 1988). Water level in lakes is mostly determined by snow cover at the tree line in northern Québec. Increased snow depth during the first half of the century concurs with what probably occured in Greenland where the polar front may have moved north at that time (Meldgaard 1986). The trajectory of major snow storms that currently often follows the Atlantic coast in northeastern North-America may have moved north during the first half of the century if the polar front slightly retreated; that would explain the increased snowfall.

Incidence of fire in the boreal forest during the last century

Age and size of detectable fires were recently mapped in a 54 000 km^2 strip of land of northwestern Québec between latitude 55°and 59° (Payette et al. 1989); it incompasses part of the boreal forest, the forest tundra and the tundra (Payette 1983). Fire rotation was estimated at 7 300 years, 200-1 200 years and 100 years for the tundra, forest tundra and boreal forest respectively. In the prime winter caribou habitat - the fringe of the boreal forest - approximately 50 percent to the study area burnt over between 1920 and 1940. Moreover a similar proportion of land was affected by fire during decades 20s, 30s and 50s in the south of the forest tundra. It is difficult to determine if the incidence of fires increased during the warmer summers of the first half of the century because it is often impossible to know the history a site previous to a fire. However stands containing enough fuel to allow large fires to develop were present at the beginning of the twenties. Warmer summers obviously had a limited impact on fires in the tundra and the north of the forest tundra; however fires reduced by more than 50 percent prime winter habitat of caribou. In the worst situation, assuming no forage production for a few decades after fire, the carrying capacity of the boreal forest would hav decreased by more than 50 percent between 1920 and 1960. No precise data on fire history are available for the boreal forest and the forest tundra around Schefferville, which served as the winter range of the Rivière George herd in the sixties and the seventies. Fire rotation may have been longer there than further west due to greater precipitations and numerous fire breaks (Foster 1983).

Increased difficulty of obtaining winter forage

Cost of locomotion increases exponentially with snow depth in cervids (Mattfeld 1973; Fancy 1986) as is the energy spent by caribou digging in the snow to reach forage (Fancy 1986). In particular, the presence of ice crust may be very detrimental. Increased snow depth during the first half of the century certainly inflated the annual energy budget of caribou. No massive caribou die-off was reported during winter in northern Québec for this period, but it could have gone unnoticed in this vast and unaccessible area. Caribou of the Rivière George herd, particularly lactating females, actually enter the winter with limited fat reserve (Huot 1989) due to poor summer range (unpubl.);

however they do not exhaust their fat store in winter because of a good winter range (Huot 1989). Increased energy demand for winter foraging would be actually detrimental to the herd productivity.

Effect of delayed snow melting on calving grounds

Actually, caribou from northern Québec appear to find enough energy in their forage during winter, wich however is deficient in protein (Huot 1989). Forage rich in protein is necessary to complete gestation and to nurse calves in cervids (Smith et al. 1975; Sadleir 1980). New graminoid shoots represent the first green vegetation found in rumens during spring and are consumed in early June by females on both calving grounds (Gauthier et al. 1989). Their emergence depends certainly on snow melt. Increased snowfall in winter, if not compensated by warmer weather and greater rainfall in spring, might reduce forage availability on calving ground. The Rivière George calving area is particularly vulnerable to such a phenomenon. By June 15, percent snow cover was 45, 44 and < 20 in 1984, 1986 and 1987 respectively (Crête et al. 1987; Vandal and Couturier 1988). At the Rivière aux Feuilles calving ground, snow covered 34 percent of the ground on June 3, 1986 (Crête et al. 1987). In general, snow melts more rapidly on the Ungava peninsula than along the Rivière George as illustrated satellite images taken in late June 1985 and 1986 (Fig. 3). Greater snowfall in the past could have resulted in complete snow cover on the Rivière George calving area until late June and early July, which would leave too short a period for females to successfully complete an annual cycle there.

Conclusion

Overgrazing, habitat destruction, overhunting, predation, disease, and climatic changes all constitute possible explantions for the decline of caribou observed in northern Québec during

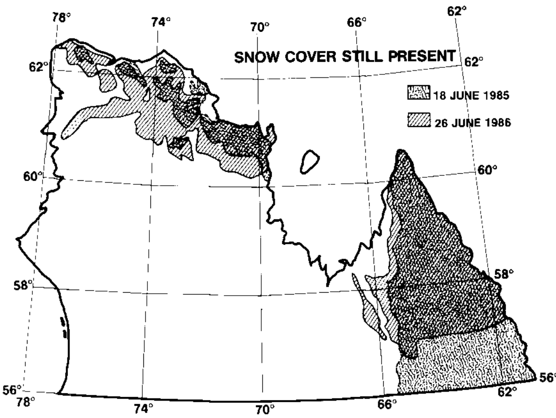

Fig. 3. Distribution of the remaining snow cover in northern Québec on June 18, 1985 and June 26, 1986 according to visual interpretation of NOAA/AVHRR satellite image (St-Pierre et al. 1987).

the first half of this century. Of all, climatic changes possess the greatest potential of affecting equally all animals over vast areas. As pointed by Meldgaard (1986), their effect may be subtle and slow, making them difficult to measure. Moreover, climate could have a carry over effect in cervids throughout their life (Peterson et al. 1988), which further complicates the study of its consequences.

Warmer winters during the first half of the century were associated with greater snowfall and deeper snow cover. This period coincided with great scarcity of caribou. It will never be possible to determine if climatic changes caused caribou rarity. However it is possible to partly test the hypothesis that delayed access to green vegatation in spring, coupled with greater energy expenses during period of snowy winters, would have prevented caribou from completing their annual cycle in some parts of their actual range. Parturition should occur earlier where snow melt is earlier. This can be observed currently in northern Québec, where, for comparable latitude, calving has occured 7-10 days earlier in recent years on the Rivière-aux-Feuilles calving ground than in the Rivière George area (Crête et al. 1987). In southern

Québec, most calves are born by the beginning of June for the Gaspésie Park herd (Fig. 1; unpubl.). Manipulation of forage protein content in spring for captive caribou would be the best way to test the hypothesis.

Our analysis could not explain caribou fluctuations over the last century. However it may point out important aspects of the environment that have been overlooked in Québec, i.e pattern and timing of snow melt in spring, snow depth in winter and frequency of forest fires. As human activity on the earth risks provoking increased temperature during the coming decades (Harrington 1987), conditions observed during the first half of the century may reappear. Caribou managers should monitor closely climate changes.

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References

Audet, R. 1979. Histoire du caribou du Québec-Labrador et évolution des population. - *Rech. amérindiennes au Québec* 9:17-27

Bégin, Y. and **S. Payette.** 1988. Dendroecological evidence of subarctic lake level changes during the last three centuries. - *Quaternary Res.* : in press.

Crête, M.,D. Le Hénaff, R. Nault, D. Vandal, and **N. Lizotte.** 1987. Estimation du nombre de caribous associés aux aires de mise bas de la Rivière aux Feuilles et de la Rivière George en 1986. - *Min. Loisir, Chasse et Pêche, dir. faune terrestre and dir. rég. Nouveau-Québec,* 31 pp.

Crête, M., D. Le Hénaff, R. Nault, L.-P. Rivest and **S. Luttich.** 1989. Estimation du nombre de caribous associés à l'aire de mise bas de la rivière George en 1988 et révision des estimations antérieures. - *Qué. Min. Loisir, Chasse et Pêche,* SP1555-03-89.

Dauphiné, T.C. Jr. 1976: Biology of the Kaminuriak population of barren-ground caribou. Part 4: Growth, reproduction and energy reserves. - *Can. Wildl. Serv. Rep.* Series 38, 71 pp.

Fancy, S. G. 1986. *Daily energy budgets of caribou: a simualation approach.* Ph. D. thesis, Univ. Alaska, 226 pp.

Foster, D.R. 1983. The history and pattern of fire in the boeral forest of southeastern Labrador. - *Can. J. Bot.* 61:2459-2471.

Gauthier, L., R. Nault, and **M. Crête.** 1989. Variations saisonnières de régime alimentaire des caribous du nord du Québec. - *Naturaliste Can. (in press).*

Gilbert, H., and **S. Payette.** 1982. Écologie des populations d'aulne vert *(Alnus crispa* (Ait.) Pursh) à la limite des forêts, Quebec nordique. - *Géog. phys. Quaternaire* XXXVI: 109-124.

Harrington, J.B. 1987. Climatic change: a review of causes. - *Can. J. For. Res.* 17: 1313-1339.

Hearn, B.J., S.N Luttich, M. Crête and **M.B. Berger.** In press. Survival of radio-tagged caribou (Rangifer tarandus caribou) from the George River Herd, Nouveau-Québec - Labrador. - *Can. J. Zool. 68.*

Huot, J. 1989. Body composition of the George River caribou *(Rangifer tarandus caribou)* in fall and late winter. - *Can. J. Zool.* 67:103-107

Mattfeld, G.F. 1973. The effect of snow on the energy expenditure of walking white-tailed deer. - *Trans. Northeast Fish Wildl. Conf* 30:327-343.

Meldgaard, M. 1986. The Greenland caribou - zoogeographes, taxonomy and population dynamics. - *Meddelelser om Grønland, Bioscience* 20:1-88.

Messier, F., J. Huot, D. Le Hénaff and **S. Luttich.** 1988. Demography of the George River caribou herd: evidence of population negulation by forage exploitaion and range expansion - *Arctic:* 41:279-287.

Morin, A., and **S. Payette.** 1984. Expansion récente du mélèze à la limite des forêts (Québec nordique). - *Can. J. Bot. 62:1404-1408.*

Payette, S. 1983. The forest tundra ans the present treelines of the northern Québec-Labrador peninsula. In P. Morisset and S. Payette *(eds.),* Tree-lines ecology. - *In: Proceedings of the Northern Québec tree-line Conference.* Nordicana 47:3-23.

Payette, S., and **L. Filion.** 1985. White spruce expansion at the treeline and recent climatic change. - *Can. J. For. Res.* 15:241-251.

Payette, S., L. Filion, L. Gauthier and **Y. Boutin.** 1985. Secular climate change in old-growth tree-line vegetation of northern Québec. - *Nature* 315:135-138.

Payette, S.,C. Mouneau, L. Sirois and **M. Desponts,** 1989. Recent fire history of the northern Québec biomes. - *Ecology* 70: 656-673.

Sadleir, R.M.F.S. 1980. Energy and protein intake in relation to growth of suckling black-tailed deer fawns. - *Can. J. Zool.* 58:1347-1354.

Smith, S.H., J.B. Holter, H.H. Hayes and **H. Silver.** 1975. Protein requirement of white-tailed deer fawns. - *J. Wildl. Manage.* 39:582-589.

St-Pierre, L., M. Pinsonnault and **J.-M. Dubois.** 1987. La télédétecton: outil de gestion du caribou du Nouveau-Québec. Exemple de la cartographie multitemporelle du couvert neigeux et perspectives de développement. - *Québec, dir. faune terrestre* **SP** 1228-05-87.

Vandal, D. and **S. Couturier.**1988. Delimitation de l'aire de mise bas du troupeau de caribous de la Rivière George en juin 1987. - *Min. Loisir, Chasse Pêche, dir. rég. Nouveau-Québec,* 20 pp.