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

Michel Crête and Serge Payette

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 shrubs. 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

Introduction

Various factors have caused continuous changes of earth’s climate over geological time (Harrington 1987). The temperature increase observed 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 temperature records in southern Québec since 1876 indicate that the warming trend also occurred 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. = 145,000; 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 Rivière 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 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 km² (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).

<table>
<thead>
<tr>
<th></th>
<th>November - April</th>
<th>May - October</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Shefferville</td>
<td>Kuujjuaq</td>
</tr>
<tr>
<td>Québec</td>
<td>0.525 (38&lt;sup&gt;a&lt;/sup&gt;)</td>
<td>0.402 (38)</td>
</tr>
<tr>
<td>Schefferville</td>
<td>—</td>
<td>0.858 (37)</td>
</tr>
<tr>
<td>Kuujjuaq</td>
<td>0.858 (37)</td>
<td>—</td>
</tr>
</tbody>
</table>

<sup>a</sup> 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.](image-url)
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;
It is difficult to reach any conclusions concerning the impact of warmer winter on snow cov­
er in northern Québec because no historical data in snow precipitation or depth are avail­
able. 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 occ­
curred 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 km² strip of land of north­
western Québec between latitude 55° and 59° (Payette et al. 1989); it encompasses 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 re­
spectively. 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 sit­
uation, 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 precipita­
tions 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 in­
flated 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 Geor­
ge 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, which 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 explanations for the decline of caribou observed in northern Québec during 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 vegetation 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 occurred 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

Rangifer, Special Issue No. 3, 1990.
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.

Acknowledgements
This paper was prompted by a stimulating discussion with Ann Gunn who kindly brought to our attention Meldgaard’s article in addition to providing an unpublished manuscript. René Nault and Réhaume Courtois helped with the preparation of the meteorological data. Jean Berthiaume prepared the figures.

References


