Appendix I- Comparison of body condition of adult females in migratory caribou of the Rivière-George and the Rivière-aux-Feuilles herds, Northern Québec and Labrador, Canada, using PC scores.

Objective and methods

We used measurement(s) selected from the multivariate analysis (PC scores) to compare body condition of adult females between the Rivière-George (RG) and the Rivière-aux-Feuilles (RAF) migratory caribou herds in Northern Québec-Labrador, Canada. We expected PC scores to be higher for the RG than for the RAF herd, reflecting the negative impact of high population size on adult female body condition. To assess whether body condition of adult females differed between herds using PC scores (for selected PC axes only), we tested the effect of herd while taking into account year, female age, and all second-degree interactions for calving and weaning separately using multiple regression models (GLM procedure, SAS Institute 9.2). We tested for the effect of age of adult females as a linear and a quadratic variable. All data are presented as means ± SE. A level of α=0.05 was used to determine significance.

Results

In both herds, adult females (calving : PC1 scores : $F_{2,72}$=5.73, P =0.005; weaning PC1 scores : $F_{2,80}$=9.04, P=0.0003) were smaller in 2007 than in 2008 and 2009. There was, however, no herd*year interaction (all P's>0.15), indicating that the effect of herd was similar over the 3-year period. There was no significant effect of age of adult females on PC scores (all P's>0.15).

No adult female of either herd had any rump fat at calving. At weaning, 34 of 48 females (71 %) of the RG had rump fat (average excluding zeros 1.0±0.2 mm), as did 10 of 50 females

(20 %) of the RAF (average 0.4±0.1 mm). RG females had higher body bulkiness scores at calving (PC1 scores: RG=0.51±0.14, RAF=-0.28±0.14, $F_{1,72}$=16.26, P =0.0001; Fig.1b) and weaning (PC1 scores: RG=0.45±0.14, RAF=-0.40 ±0.12, $F_{1,80}$=21.7, P <0.0001; Fig.1d) compared to RAF females. The difference in average total body mass between herds was 5 kg at calving (RG=81.1±1.0, RAF=76.1±0.9) and 8 kg at weaning (RG=100.2±1.1, RAF=92.3±1.1; Table II, Fig. X). RG females also had higher body fat scores at weaning compared to RAF females (PC3 scores: $F_{1,80}$=21.56, P <0.0001; RG=0.50±0.14, RAF=-0.39±0.13; Fig.1d), including a difference of 4% of KFI between herds (RG=12.8±0.9, RAF=8.4±0.9; Table II). We found no significant differences in female body size between herds at calving (PC2 scores: RG=-0.06±0.15, RAF=-0.13±0.15, $F_{1,72}$=0.12, P =0.73; Table II) or at weaning (PC2 scores: RG=0.21±0.16, RAF=-0.11±0.14, $F_{1,80}$=2.34, P =0.13; Table II).

Discussion

Using a body bulkiness index for adult females (PC1) and body mass, we detected differences between herds that may be related to population size. Caribou females from the RAF herd, currently thought to be at relatively high population size, had lower body bulkiness index and body mass at both calving and weaning, and lower kidney fat at weaning than females from the RG herd, which is currently at low population size. Low body condition can reduce adult survival (Cook et al., 2004b) and shorten reproductive life (Langvatn et al., 1996). Negative effects of density on body mass and body size have repeatedly been documented in large herbivores (Bonenfant et al., 2009). At high population size, resource availability and quality may decrease because of competition for food (Côté et al., 2004), affecting the body reserves of adult females (Barboza & Parker, 2008).

In temperate regions, ungulate body mass is partly dependent on winter severity (Cederlund et al., 1991; Gaillard et al., 1996) which may have a more profound impact on body mass dynamics in high-density populations (Gaillard et al., 1996). In our study, snow conditions could affect the costs of traveling during spring migration (Couturier et al., 2009) that coincides with the last trimester of pregnancy. Females of the RAF herd undergo longer spring migrations compared to the RG herd (630±15km vs 280±20km; unpublished data), possibly increasing energy expenses (Couturier et al., 2010). No data, however, are available to compare winter range quality of the RG and RAF herds. Other studies also suggest that previous summer range condition and fall nutrition are the principal factors influencing female body condition during gestation (Couturier et al., 2009), conception rates (Simard et al., 2008) and the probability of calving (Ouellet et al., 1997). Based on the body mass and kidney fat of females at weaning, we expect RG females to have higher probability of calving than RAF females.

We found that the difference in body condition of females between herds persisted from calving to weaning, possibly because of differences in forage quality or quantity in the summer ranges. In red deer, reduction in summer forage availability or quality resulted in a lower quality milk produced by females (Landete-Castillejos et al., 2003), in lower females' mass in autumn (Landete-Castillejos et al., 2003) and in reduced fat reserves at the onset of the next breeding season (Clutton-Brock et al., 1997; Clutton-Brock & Coulson, 2002). Differences in body condition of females can also result from delayed density effects of browsing pressure and trampling, leading to range degradation (Crête & Huot, 1993; Côté et al., 2004). Recent studies on white-tailed deer showed that high density (Simard et al., 2010) and long-term chronic browsing (Simard et al., 2008) reduced body condition by limiting fat accumulation of adult females. Interestingly, at the end of the 1980's, when the RG herd was peaking and the RAF herd was still increasing, RAF females were heavier than RG females during summer (Crête & Huot,

1993; Couturier et al., 2010). Since the early 1990's, however, the body mass of RG females has increased, while that of RAF females has declined (Huot, 1989; Couturier et al., 2009; Fig. X). Body mass at weaning was already 7 and 9 kg higher in the RG than in the RAF in 2001 and 2002 respectively (Couturier et al., 2009; Fig. X). These long-term records support the idea of possible long-term degradation of summer ranges in Northern Québec and Labrador.

Literature cited (addition to the main article)

Cederlund, G. N., H. K. G. Sand & A. Pehrson, 1991. Body mass dynamics of moose calves in relation to winter severity. Journal of Wildlife Management, 55: 675-681.

Clutton-Brock, T. H., A. W. Illius, K. Wilson, B. T. Grenfell, A. D. C. MacColl & S. D. Albon, 1997. Stability and instability in ungulate populations : an empirical analysis. American Naturalist, 149: 195-219.

Clutton-Brock, T. H. & J. C. Coulson, 2002. Comparative ungulate dynamics: the devil is in the detail. Philosophical Transactions of the Royal Society of London Series B, 357: 1285-1298.

Cook, J. G., B. K. Johnson, R. C. Cook, R. A. Riggs, T. Delcurto, L. D. Bryant & L. L. Irwin, 2004b. Summer–autumn nutrition and birth date influence on reproduction and survival of elk. Wildlife Monographs, 155: 1-61.

Côté, S. D., T. P. Rooney, J. P. Tremblay, C. Dussault & D. M. Waller, 2004. Ecological impacts of deer overabundance. Annual Review of Ecology, Evolution and Systematics, 35: 13-47.

Gaillard, J.-M., D. Delorme, J. M. Boutin, G. Van Laere & B. Boisaubert, 1996. Body mass of roe deer fawns during winter in 2 contrasting populations. Journal of Wildlife Management, 60: 29-36.

Landete-Castillejos, T., A. Garcia, J. A. Gomez, A. Molina & L. Gallego, 2003. Subspecies and body size allometry affect milk production and composition, and calf growth in red deer: comparison of Cervus elaphus hispanicus and Cervus elaphus scoticus. Physiological and Biochemical Zoology, 76: 594-602.

Langvatn, R., S. D. Albon, T. Burkey & T. H. Clutton-Brock. 1996, Climate, plant phenology and variation in age of first reproduction in a temperate herbivore. Journal of Animal Ecology, 65: 653-670.

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

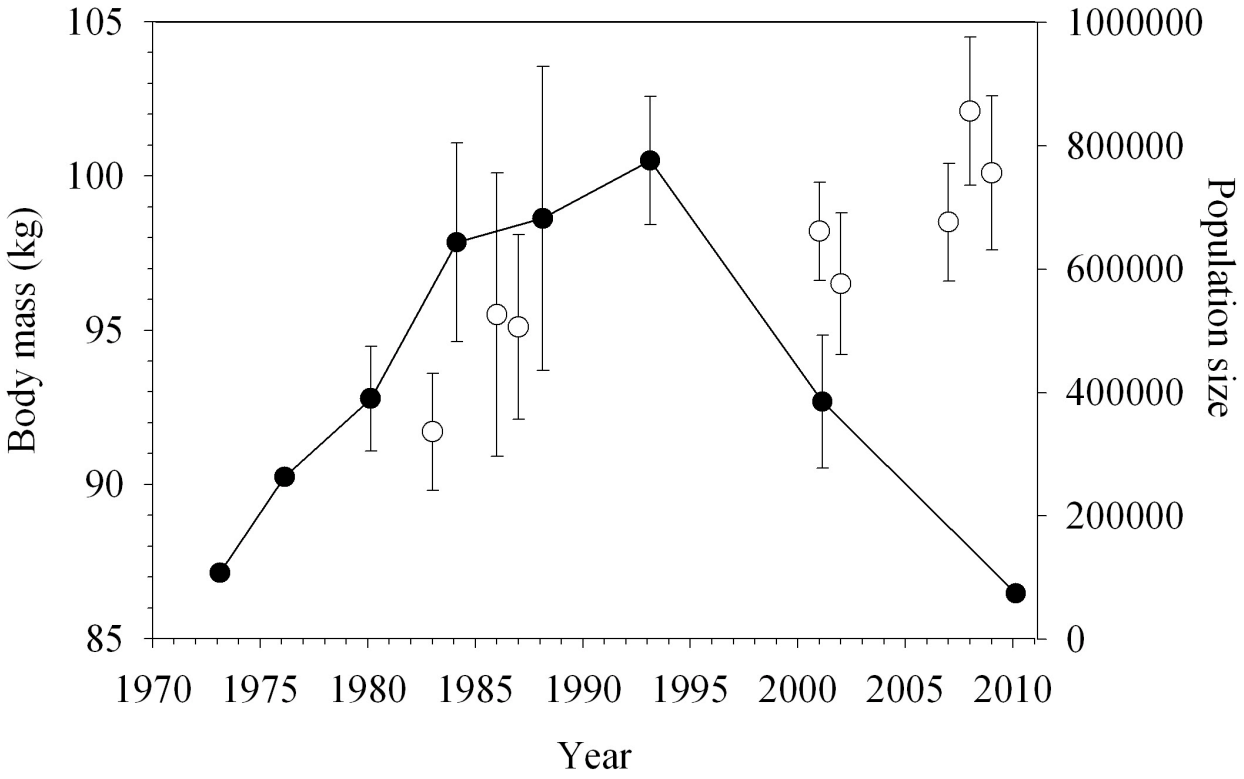
Simard, M.-A., S. D. Côté, R. B. Weladji & J. Huot, 2008. Feedback effects of chronic browsing on life-history traits of a large herbivore. Journal of Animal Ecology, 77: 678-686.

Figure caption

Figure X. Body mass of lactating females (mean ± SE; empty symbols) and population size (mean ± 90% conf. interval; filled symbols and plain line) in two migratory caribou herds in Northern Québec and Labrador, Canada: (a) Rivière-George herd and (b) Rivière-aux-Feuilles herd. Body mass was collected on female-calf pairs from late October to early November of 2007 to 2009 (this study), 2001-2002 and 1985-1987 (Couturier et al., 2009), and 1983-1984 (Huot, 1989). Population size was estimated from aerial counts. Because of the poor precision of the aerial count in 2001, only the value of the lower confidence limit of herd size is shown for the Rivière-aux-Feuilles herd (see Couturier et al., 2004).

Figure X.

a)


105
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Body mass (kg)
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Population size
1970 1975 1980 1985 1990 1995 2000 2005 2010
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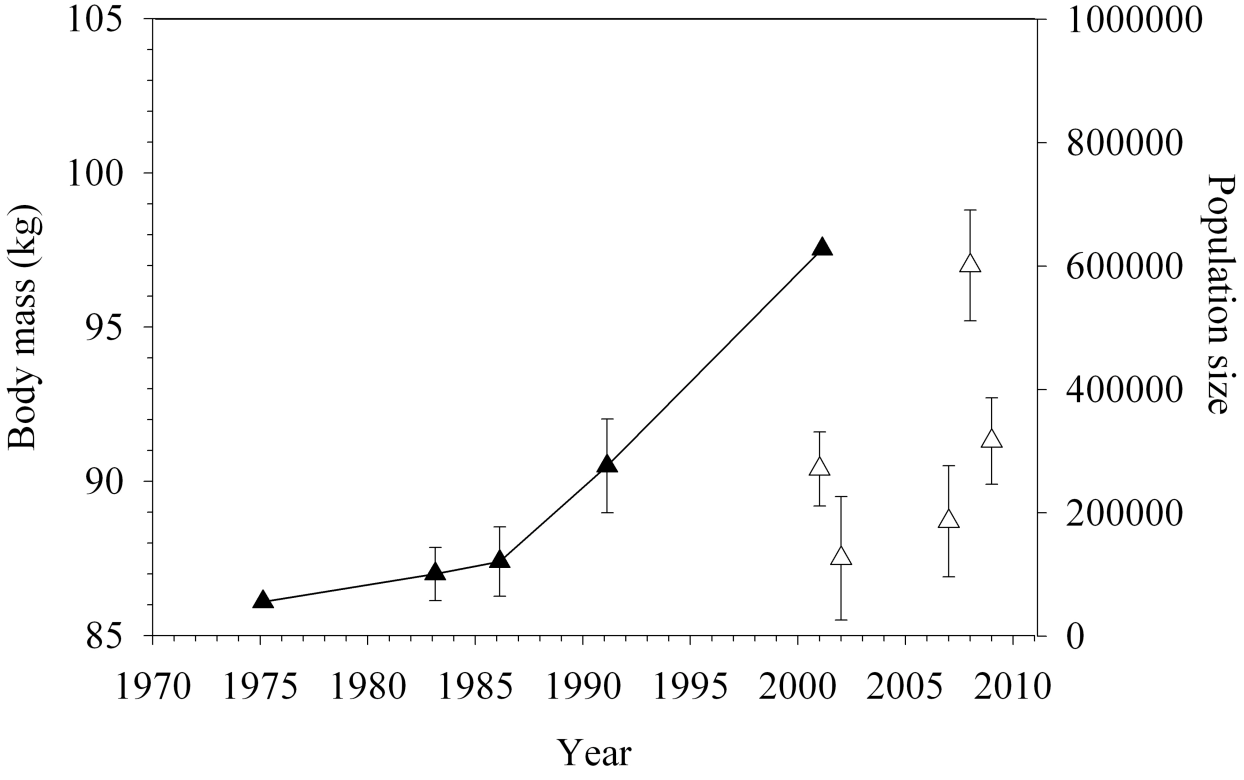
b)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Body mass (kg)
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Population size
1970 1975 1980 1985 1990 1995 2000 2005 2010
Year