Goose droppings as food for reindeer

René van der Wal and Maarten J.J.E. Loonen

Abstract: Feeding conditions for Svalbard reindeer, *Rangifer tarandus platyrhynchus,* on Spitsbergen are generally poor, owing to low availability of forage. We report on coprophagy: the use of goose faeces as an alternative food source for reindeer. Fresh droppings from Barnacle Geese, *Branta leucopsis,* placed in a field were readily used as food by reindeer. The majority of reindeer visiting the research area were feeding on droppings instead of plants. Moreover, experiments revealed that reindeer were highly selective, favoring droppings containing grass fragments over those containing moss fragments. This preference could hardly have been based on differences in mineral content (nitrogen, phosphorus, magnesium, calcium, sodium, potassium) or energy content. However, fibre content was found to correlate negatively with the percentage of moss in droppings. Selecting grass-containing droppings would therefore provide more digestible bites. The rate of intake of droppings easily outweighed the intake rate of forage. In total, 36% of all goose droppings in the research area were removed by reindeer. We calculated that the goose droppings eaten met the entire daily energy requirements of 6–8 reindeer.

Résumé : Les conditions alimentaires du Renne de Svalbard, *Rangifer tarandus platyrhynchus,* dans le Spitsberg sont généralement mauvaises en raison de la rareté du brout. Nous avons observé de la coprophagie, soit l'utilisation des fientes de bernaches comme nourriture de rechange chez les rennes. Des fientes fraîches de la Bernache nonnette, *Branta leucopsis*, déposées sur le terrain ont été vite consommées par les rennes. La majorité des rennes dans l'aire d'étude ont mangé les fientes plutôt que des plantes. De plus, des expériences ont démontré que les rennes étaient très sélectifs et préféraient les fientes contenant des fragments d'herbes aux fientes contenant des fragments de mousses, une préférence fort peu probablement basée sur le contenu en minéraux (N, P, Mg, Ca, Na, K) ou sur le contenu énergétique. Nous avons cependant constaté que le contenu en fibres était en corrélation négative avec le pourcentage de mousses dans les fientes. Les fientes contenant des herbes semblent donc offrir des bouchées plus facilement digestibles. Le taux de consommation des fientes, chez les rennes étudiés, dépassait de fait le taux de consommation de brout. Au total, 36% des fientes de bernaches dans l'aire d'étude ont été consommées par les rennes. Nous avons calculé que la quantité de fientes consommées par les rennes pouvait satisfaire tous les besoins énergétiques quotidiens de 6–8 rennes.
[Traduit par la Rédaction]

Introduction

Svalbard reindeer, *Rangifer tarandus platyrhynchus*, on Spitsbergen must survive in one of the most inhospitable natural environments in the world (Orphin et al. 1985), where they are restricted in their movements by glaciers and open water. During the 8 months of winter, 70–90% of their daily energy requirement is supplied by a sparse covering of low-quality fibrous plants such as mosses and herbs (Reimers 1977). For the rest of their energy requirements in winter, they rely on fat reserves (Orphin et al. 1985).

During the short Arctic summer, reindeer have to recover from the effects of the past winter and build up new fat reserves for the following one. Their winter survival is largely dependent on these fat reserves, and the relatively rich food supply in summer has to be exploited in order to gain mass. In summer the food supply is highly diverse, with plants varying in quality (Klein 1990). Reindeer are known to be highly selective feeders, preferring lichens over grasses, but preferring grasses over mosses (Danell et al. 1994). These preferences might reflect special nutritional needs. Several authors have focused on selection of certain nutrients, mainly on the basis of correlative data (e.g., Staaland et al. 1983; Leader-Williams 1988).

Plant biomass on Spitsbergen is low. In our study area, lichens are scarce, partly because of reindeer grazing. There are only a few rich spots that offer a variety of grasses and forbs. These spots are near bird cliffs or lake shores, where the vegetation is fertilized by faeces of seabirds and waterfowl.

Our study was performed along one of these lake shores. During summer, reindeer are not the only herbivores present. About 600 adult Barnacle Geese, *Branta leucopsis*, raise their young and spend the flightless period during wing molt in close proximity to the lake. They remove almost all harvestable biomass of grasses and also feed on mosses. They therefore produce many droppings.

Barnacle Geese have a simple digestive tract. Most of the food passes through the intestine within 2–4 h and digestibility of cellulose is low (Prop and Vulink 1992). Digestibility of organic matter ranges from 38 to 54%. Every 3–8 min geese produce a dropping, consisting mainly of cell walls (Prop and Vulink 1992). Casual observations had shown that reindeer eat goose droppings. Reindeer are able to digest cellulose with help of microorganisms living in the rumen (Van Soest 1982; Orphin et al. 1985). The proportion of plant

Received July 18, 1997. Accepted January 14, 1998.

R. van der Wal[1] and M.J.J.E. Loonen.[2] Zoological Laboratory, University of Groningen, P.O. Box 14, 9750 AA Haren, the Netherlands.

[1] Present address: Institute of Terrestrial Ecology, Banchory Research Station, Hill of Brathens, Glassel, Banchory, Kincardineshire AB31 4BY, Scotland (e-mail: rvdw@ite.ac.uk).
[2] Author to whom all correspondence should be addressed (e-mail: m.j.j.e.loonen@biol.rug.nl).

 © 1998 NRC Canada

Table 1. Time periods during which droppings placed for reindeer disappeared.

	No. of cases
Droppings disappeared within:	
2 days	4
3 days	4
4 days	1
5 days	1
Total no. disappeared	10

Note: When droppings disappeared from a plot, a maximum of 4 out of the 25 droppings initially placed there were still present. In total, 14 plots with droppings were established.

Table 2. Numbers of droppings containing either grass or moss fragments eaten by reindeer.

	No. of moss droppings	No. of grass droppings
26 July	0	43
31 July	0	23[a]
31 July	0	41
8 Aug.	0	47
Total no. disappeared	0	154
Total no. spread	200	200

Note: On each day, two squares with 25 moss droppings each and two with 25 grass droppings each were spread in the field in a 1-m^2 matrix.
[a]Grass droppings in only one of the two squares were eaten; the other square was untouched.

organic matter that they digest ranges from 74 to 87%, far higher than in geese (Aagnes et al. 1996).

In our study area, where the food supply for reindeer was low because of high goose grazing pressure, we report on the use of goose droppings as an alternative food source for Svalbard reindeer. Fresh goose droppings were placed in a field to see whether reindeer would accept them as food. At the end of previous summers, an accumulation of droppings containing moss fragments was observed along the lake shore. Selective removal of grass-containing droppings by reindeer was tested with droppings containing either grass or moss fragments. Several nutritional parameters of droppings and forage plants were compared.

Site description

The experiments were performed in Ny-Ålesund, Spitsbergen (79°56′N, 11°57′E). This research village with about 100 summer inhabitants has become an important foraging area for Barnacle Geese. The vegetated areas in the village are dominated by tussocks of *Deschampsia alpina*. Geese grazing in these dry areas focused on *Poa arctica* growing between these tussocks. The wet areas are covered by a dense carpet of mosses (mainly *Calliergon richardsonii*) with a low cover of grasses (*Poa* sp.). Outside the village a typical dry Arctic tundra vegetation is found, with *Dryas octopetala*, *Salix polaris*, and *Saxifraga oppositifolia*. *Sanionia unicata* is the most common moss species in these dry areas.

The local goose population increased from 13 nesting pairs in 1985 to 255 in 1993 (Loonen et al. 1997). After hatch, parents took their young to the village and surrounding area, where they grazed for about 1½ months. All geese started to feed in early July on grasses protruding from the moss carpet around the shore of Lake Solvatnet. When grasses on the lake shores became depleted over time, goose families switched to drier areas in the village in search of grasses. A flock of 150 nonbreeders and failed breeders continued feeding on mosses along the lake shore. Over the 24-h daylight period, geese alternated feeding with resting (Prop et al. 1980). Goose families usually returned to the lake shore to rest, where defecation continued. As a consequence, lake shores were covered with droppings. Moss-containing droppings (hereafter moss droppings) originated from failed breeders or nonbreeders, while grass-containing droppings (hereafter grass droppings) were brought in by families. In the dry areas, droppings originated from goose families and contained mainly grasses.

In 1978, fifteen reindeer were introduced on Brøggerhalvøya, the peninsula on which Ny-Ålesund is situated (Mehlum 1990). The area is enclosed by glaciers, and the unhunted population of reindeer increased to 360 individuals in 1993 (N. Øritsland, personal communication). Male reindeer visited the village and fringes of the lake mostly at night or in the early morning. The geese were also most active at that time, while human activity was low. At any given moment, up to 10 male reindeer could be observed in the village.

Methods

Two small-scale experiments were performed in July and August 1993. In the first experiment we spread 25 fresh goose droppings in squares of 0.5 × 0.5 m after removing old droppings. The fresh droppings were collected in grassy spots in the village and placed on sites that were used by geese. This experiment was repeated 14 times at different locations in the village. Over a period of 5 days we checked twice a day whether the goose droppings were still present or had disappeared. Every time a reindeer was observed in the village we recorded whether it was grazing or feeding on goose droppings.

In the second experiment, fresh goose droppings containing either moss or grass fragments were collected. Again 25 droppings of each type were spread in a 2 × 2 matrix with an area of 1 m^2, with the different types of droppings placed in adjacent parts of the matrix. This experiment was repeated 4 times; all plots were checked twice a day. From every sample we placed, a subsample was stored for later analysis. In the field, we had discriminated dropping types on the basis of color, grass droppings being far greener than moss droppings. However, some of the "grass droppings" contained rather large amounts of moss fragments and were therefore analyzed separately in the chemical analyses ("mixed droppings" in Table 3). We collected leaves of *P. arctica* and sampled the live upper parts of the most common moss species (*C. richardsonii*). Some samples were taken in the year before or after we carried out the dropping experiments. The plant material was sorted into live parts only. Plant material and droppings were dried at 70°C and subsequently ground to pass through a 0.5 mm mesh sieve in a Wiley Mill. We measured Kjeldahl nitrogen, phosphorus, calcium, magnesium, potassium, and sodium in both forage and droppings following standard procedures (Allen 1989). Energy content was determined using an adiabatic bomb calorimeter (Allen 1989); neutral detergent fibre (NDF) and acid detergent fibre (ADF) were measured following Van Soest (1982). We did not correct for sand in

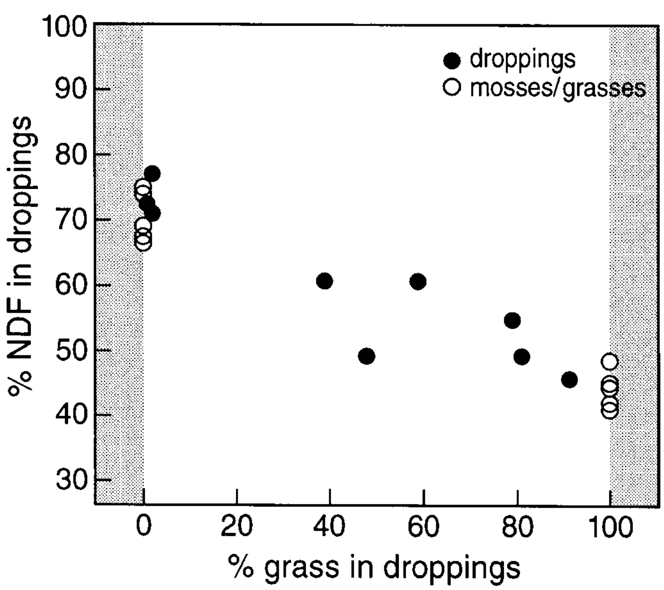
© 1998 NRC Canada

Table 3. Chemical composition of plants and goose droppings.

	Grass	Mosses	Grass droppings	Mixed droppings	Moss droppings	Analysis
N	27.1*bc* (7.9)	15.3*a* (2.4)	19.8*ab* (6.7)	30.1*c* (10.3)	21.5*abc* (2.0)	One-way ANOVA
P	94.5*a* (32.7)	67.5*a* (22.7)	74.9*a* (19.0)	108.9*a* (45.8)	117.1*a* (38.5)	One-way ANOVA
Mg	5.2*a* (1.3)	10.2*bc* (2.3)	8.2*b* (0.8)	10.5*bc* (0.5)	12.1*c* (1.0)	One-way ANOVA
Ca	10.0*a* (2.8)	19.5*b* (6.4)	20.4*b* (7.2)	19.3*b* (8.7)	22.8*b* (7.9)	One-way ANOVA
Na	0.32*a* (0.25)	0.87*b* (0.48)	0.27*a* (0.16)	0.82*ab* (0.55)	1.49*c* (0.32)	One-way ANOVA
K	11.8*b* (1.9)	8.5*a* (1.6)	17.5*c* (2.4)	19.3*c* (3.5)	12.1*b* (3.0)	One-way ANOVA
NDF	47*a* (3)	72*c* (4)	53*ab* (5)	59*b* (8)	75*c* (4)	One-way ANOVA
ADF	19*a* (3)	42*cd* (4)	31*b* (4)	37*bc* (7)	47*d* (6)	One-way ANOVA
Energy	19.2**a* (0.2)	17.3*b* (0.7)	16.3***b* (0.5)	15.0***b* (0.4)	15.7*b* (1.3)	Kruskal–Wallis test
% grass	—	—	84*a* (7)	49*a* (10)	2*b* (1)	Kruskal–Wallis test

Note: Concentrations are given in milligrams per gram dry mass and energy content is given in kilojoules per gram dry mass. Values followed by the same letter differ significantly between food items. Numbers in parentheses show the standard error. The percentage of grass fragments in droppings is also given. $n = 5$ for grass and moss and $n = 3$ for all types of droppings except where indicated by * ($n = 6$) and ** ($n = 2$).

Fig. 1. Relationship between percent NDF and the percentage of grass in droppings. NDF values for mosses (0% grass) and grasses (100%) are also given. The correlation coefficient was calculated on data for droppings only ($r_s = -0.92$; $n = 9$, $P < 0.001$).



droppings, since it would also be ingested by reindeer. We determined plant composition microscopically for every dropping sample used in the above-described analyses.

In the statistical analyses, we used analysis of variance (ANOVA) with least square difference contrasts, since samples were small. Percentages were arcsine square root transformed. Data were transformed to satisfy the underlying assumptions of the tests used. If we could not meet the assumptions of ANOVA, a Kruskal–Wallis test was used instead.

Results

In 10 out of 14 cases, the majority (86–100%) of droppings spread for reindeer in the plots disappeared, mostly within 3 days (Table 1). We observed a striking difference in the way reindeer foraged on either Arctic plants or goose droppings. When foraging on goose droppings, reindeer acted like a vacuum cleaner, swinging their head from side to side with the mouth held just above the ground. The reindeer walked at a slow but steady pace while swallowing the droppings. When they were grazing, distinct bites were taken with small tugs and no swinging movement of the head occurred.

Reindeer in the village foraged mainly on goose droppings instead of grasses or herbs. In 34 out of 48 cases, reindeer were recorded eating droppings (71%). In 8% of cases, grazing was combined with eating droppings. Only grazing was observed in the remaining 21% of cases.

We repeated a cafeteria experiment 4 times, in which reindeer could choose between fresh droppings containing either grass or moss. In all cases grass droppings were eaten, while moss droppings were refused (Table 2). On average, 77% of the grass droppings were removed, but none of the moss droppings. Droppings labelled “grass droppings” contained 66% grass fragments (range 39–91%), whereas in “moss droppings” only 2% grass fragments were found.

To understand the strong preference of reindeer for grass droppings over moss droppings, we examined several parameters (Table 3). Fibre content was measured as both NDF and ADF, the latter containing most fibre elements resistant to digestion. Analysis revealed that NDF decreased with increasing percentage of grass fragments in the droppings (Fig. 1; $r_s = -0.92$; $n = 9$, $P < 0.001$). The same trend was observed for ADF in droppings ($r_s = -0.73$; $n = 9$, $P < 0.01$). Both NDF and ADF are negatively correlated with food digestibility (van Soest 1982; Robbins 1993). Therefore, the high NDF and ADF contents in moss droppings indicate poor digestibility relative to grass droppings. Droppings containing almost all moss or grass fragments had NDF contents only slightly higher than the respective forage (Fig. 1). Therefore, no large difference in digestibility between goose droppings and plant material was expected.

Among minerals, magnesium and sodium contents decreased significantly with increasing percentage of grass in the droppings ($r_s = -0.86$ and -0.91, respectively; $n = 9$, $P < 0.01$), while a slight but significant increase in potassium content was found ($r_s = 0.66$; $n = 9$, $P < 0.05$). No such correlation was found for phosphorus or calcium content ($r_s = -0.49$ and -0.13, respectively; $n = 9$, ns). If reindeer selected their food in order to obtain specific minerals, only selection of

© 1998 NRC Canada

Fig. 2. A male reindeer chases young Barnacle Geese in order to consume the fresh pile of droppings produced while the geese were resting.

potassium or avoidance of magnesium and sodium could explain the observed preference for grass droppings over moss droppings.

No correlation was found between nitrogen or energy content and the amount of grass in droppings (r_s = 0.04 and 0.26, respectively; n = 9, ns). Nitrogen content was highest in the mixed droppings, while energy content did not vary among dropping types (Table 3). Nitrogen and energy contents, therefore, do not explain the preference for grass droppings.

If reindeer prefer grass droppings over moss droppings because grass droppings contained less fibre, grasses should be preferred to grass droppings. Grasses contained the lowest amount of fibre. However, grasses were heavily grazed by Barnacle Geese and biomass was only 7.8 ± 1.4 g dry mass · m^{-2} (average ± SE of live biomass of vascular plants on 6 turves of 10 × 10 cm). Mosses were still abundant in the areas where the geese grazed (88.6 ± 24.9 g dry mass · m^{-2}). Mosses contained more fibre and sodium but less potassium than grass droppings. Earlier we showed that such a difference could explain the rejection of moss droppings by the reindeer. According to this argument, reindeer should prefer grass droppings over moss plants.

Discussion

Goose droppings lack the well-known penetrating odor of, for instance, most carnivore faeces. Several herbivores have been reported to use goose droppings as a food source. Cattle, sheep, horses, and donkeys have all been observed eating goose droppings (Ingram 1933; Kear 1963; Rochard and Kear 1968; Marriott 1973; Summers and Grieve 1982). These observations come from several countries and the droppings were produced by several goose species. The present study is the first dealing with a wild herbivorous species eating goose droppings.

Why do these herbivores show this coprophagous behavior? It has been argued that in this way trace elements are more easily obtained (Kear 1963) or the diet is enriched by urea, which could facilitate the digestive process (Marriott 1973; Summers and Grieve 1982). Droppings consist of not only plant material but also microorganisms and uric acid (Prins 1977; Van Soest 1982). This could favor the use of droppings as a food source.

In the present study we have shown that chemical elements could play a role in explaining the preference of reindeer for grass droppings. Positive selection of potassium or avoidance of high concentrations of sodium and magnesium could result in a preference for grass droppings or grasses. We have not found any data in the literature that would be consistent with such selection by reindeer. Summers and Grieve (1982) suggested that eating droppings enhanced the intake of phosphorus, nitrogen, and energy. In our study, the levels of none of these explain the observed preference for grass droppings over moss droppings. However, fibre content was far lower in grass droppings than in moss droppings. Danell et al. (1994) showed that the food preference of reindeer was negatively correlated with ADF content. ADF content correlated negatively with digestibility, as has been found in many other studies of ruminants, hindgut fermenters, and geese (Van Soest 1982; Duncan 1992; Gadallah and Jefferies 1995).

In feeding trials with Svalbard reindeer, the low digestibility of mosses compared with grasses was demonstrated by

© 1998 NRC Canada

Ekern and Kildemo (1978, cited in Prins 1982)[3]. The maximum net energy gain from the moss *Polytrichium alpinum* was only 0.3 $kJ \cdot g^{-1}$, while the energy gain from the grass *Alopecurus alpinus* was 5.4 $kJ \cdot g^{-1}$. If the difference between grass droppings and moss droppings is a reflection of the difference between grass and moss plants (Table 3), the net energy gain by reindeer feeding on grass droppings will be greater.

Not only does diet selection depend on nutrient content, but intake rate is also important (Hanley 1997). In our study area, forage availability is low, owing to intense goose grazing. Measurements on reindeer in the Canadian Arctic revealed that short-term food intake was 4–5 g dry matter $\cdot$ min^{-1} on grasses and vascular plants of low stature (Trudell and White 1981). When reindeer consume more than 5 droppings/min, this already equals the rate of intake of grasses. Although no data on intake rate were collected, based on our own observations we conclude that this would be fairly easy to do. Anecdotically, an Irish farmer observed an intake of 100 goose droppings/5 min by his cows (Ingram 1933). This record is close to the ad libitum maximum intake of 26.6 $g \cdot min^{-1}$ by Canadian reindeer fed hand-picked lichens (Trudell and White 1981).

The density of droppings in our research area was high. During regular periods of sleeping, the geese produced piles of 6–8 droppings (Fig. 2). Several times we observed reindeer chasing away the sleeping geese in order to eat the piles of droppings. In such a situation, eating droppings would pay in terms of dry matter and energy intake rates. Together with an accelerated dry matter intake, nutrient intake will also be enhanced.

Wallis-de-Vries (1996) observed frequent consumption of rabbit faeces by cattle feeding on heathland in the Netherlands. During winter, faecal pellet intake contributed 3.1% of the average dry matter intake. The nutritive value of rabbit faeces was not much higher than that of the average diet, but the rate of intake of faecal pellets was substantially higher than that of winter grasses. The faecal pellet intake rate dropped radically with the onset of grass growth in spring.

At the end of each season, the density of droppings around Lake Solvatnet is high. However, it would be even higher in the absence of reindeer. In 1992, the mean dropping density was about $18/m^2$. We calculated, on basis of plant production data, that in the absence of reindeer, the density should be around 28 droppings/m^2 (Loonen 1997); 36% of all droppings were therefore removed by reindeer. In dry grassy areas, where most "high-quality" droppings are found, an even larger proportion of droppings disappeared. As a rough estimate, about 6–8 reindeer could live on goose faeces during the 2-month period when geese are present (Appendix). Goose faeces, therefore, can contribute a significant amount of additional food for a small number of reindeer.

Acknowledgements

We thank the Norwegian Polar Institute, Kings Bay Kull Compagnie A/S, and the Plancius Foundation for technical and logistic support during fieldwork. Rudi Drent assisted during fieldwork and commented on the manuscript. Bert Venema, Nellie Eck, and Willem van Hal assisted during chemical analysis. Dick Visser prepared the figures and Nick Tyler provided an estimate for daily energy requirement of Svalbard reindeer. R.v.d.W. was supported by a VSB Bank travel grant.

[3] K. Ekern and K. Kildemo. 1978. Svalbard-Reinens ernæring (*Rangifer tarandus platyrhynchus* Vrolik). Internal publication, Institutt Naturforvaltning/Zoologisk Institutt, Norges Landbrukhøgskole, Oslo.

References

Allen, S.E. 1989. Chemical analysis of ecological materials. 2nd ed. Blackwell Scientific Publishers, Oxford.

Aagnes, T.H., Blix, A.S., and Mathiesen, S.D. 1996. Food intake, digestibility and rumen fermentation in reindeer fed baled timothy silage in summer and winter. J. Agric. Sci. **127**: 517–523.

Danell, K., Utsi, P.M., Palo, R.T., and Eriksson, O. 1994. Food plant selection by reindeer during winter in relation to plant quality. Ecography, **17**: 153–158.

Duncan, P. 1992. Horses and grasses: the nutritional ecology of equids and their impact on the Camargue. Springer-Verlag, New York.

Gadallah, F.L., and Jefferies, R.L. 1995. Forage quality in brood rearing areas of the lesser snow goose and the growth of captive goslings. J. Appl. Ecol. **32**: 276–287.

Hanley, T.A. 1997. A nutritional view of understanding and complexity in the problem of diet selection by deer (Cervidae). Oikos, **79**: 209–218.

Ingram, C. 1933. Cattle feeding on goose droppings. Br. Birds, **26**: 309–310.

Kear, J. 1963. The agricultural importance of wild goose droppings. Annual Report No. 14, Wildfowl Trust, Slimbridge, U.K. pp. 72–77.

Klein, D.R. 1990. Variation in quality of caribou and reindeer forage plants associated with season, plant part, and phenology. Rangifer, **3**: 123–130.

Leader-Williams, N. 1988. Reindeer on South Georgia: the ecology of an introduced population. Cambridge University Press, Cambridge.

Loonen, M.J.J.E. 1997. Goose breeding ecology: overcoming successive hurdles to raise goslings. Ph.D. thesis, University of Groningen, the Netherlands.

Loonen, M.J.J.E., Oosterbeek, K., and Drent, R.H. 1997. Variation in growth of young and adult size in Barnacle Geese *Branta leucopsis*: evidence for density dependence. Ardea, **85**: 177–192.

Marriott, R.W. 1973. The manurial effect of Cape Barren Goose droppings. Wildfowl, **24**: 131–133.

Mehlum, F. 1990. The birds and mammals of Svalbard. Polarhåndbok No. 5, Norsk Polarinstituttt, Oslo.

Orphin, C.G., Mathiesen, S.D., Greenwood, Y., and Blix, A.S. 1985. Seasonal changes in the ruminal microflora of the high-arctic Svalbard reindeer (*Rangifer tarandus platyrhynchus*). Appl. Environ. Microbiol. **50**: 144–151.

Prins, H.H.Th. 1981. Why are mosses eaten in cold environments only? Oikos, **38**: 374–380.

Prins, R.A. 1977. Biochemical activities of gut micro-organisms. *In* Microbial ecology of the gut. *Edited by* R.T.J. Clarke and T. Bauchop. Academic Press, London. pp. 73–183.

Prop, J., Eerden, M.R. van, Daan, S., Drent, R.H., Tinbergen, J.M., and St. Joseph, A.M. 1980. Ecology of the Barnacle Goose (*Branta leucopsis*) during the breeding season: preliminary results from expeditions to Spitsbergen in 1977 and 1978. *In* Proceedings of the Norwegian–Netherlands Symposium on Svalbard, November 1978. *Edited by* A.G.F. van Holk, van H.K. s'Jacob, and E.H. Liefferink. Arctic Centre, University of Groningen, Groningen. pp. 50–112.

© 1998 NRC Canada

Prop, J., and Vulink, T. 1992. Digestion by barnacle geese in the annual cycle: the interplay between retention time and food quality. Funct. Ecol. **6**: 180–189.

Reimers, E. 1977. Population dynamics in two subpopulations of the Svalbard reindeer. Arct. Alp. Res. **9**: 369–381.

Robbins, C.T. 1993. Wildlife feeding and nutrition. 2nd ed. Academic Press, San Diego.

Rochard, J.B.A., and Kear, J. 1968. A trial to investigate the reactions of sheep to goose droppings on grass. Wildfowl, **19**: 117–119.

Staaland, H., Brattbakk, I., Ekern, K., and Kildemo, K. 1983. Chemical composition of reindeer forage plants in Svalbard and Norway. Holarct. Ecol. **6**: 109–122.

Summers, R.W., and Grieve, A. 1982. Diet, feeding behaviour and food intake of the upland goose (*Chloëphaga picta*) and ruddy-headed goose (*C. rubidiceps*) in the Falkland Islands. J. Appl. Ecol. **19**: 783–804.

Trudell, J., and White, R.G. 1981. The effect of forage structure and availability on food intake, biting rate, bite size and daily eating time of reindeer. J. Appl. Ecol. **18**: 63–81.

Van Soest, P.J. 1982. Nutritional ecology of the ruminant. O. and B. Books, Corvallis, Oreg.

Wallis-de-Vries, M.F. 1996. Nutritional limitations of free-ranging cattle: the importance of habitat quality. J. Appl. Ecol. **33**: 688–702.

Appendix

Estimate of the number of reindeer that could meet their daily energy requirements by eating goose droppings only

Geese foraged for 10 h per day and produced a dropping every 8.2 min (Prop and Vulink 1992). Each goose therefore produced 73.2 droppings per day.

In 1993 there were 598 adult Barnacle Geese and 374 goslings (Loonen 1997) in the fjord where Ny-Ålesund is situated. A dropping from an adult goose weighed 0.952 ± 0.413 g (mean ± SD) dry mass (n = 1624), while the dry mass of a gosling dropping was 0.568 ± 0.315 g (n = 1125). Total daily production of faeces by these geese was (598 × 0.952 × 73.2) + (374 × 0.568 × 73.2) = 57.22 kg.

Reindeer removed 36% of the droppings (20.60 kg). The mean energy content of goose droppings was 15.7 $kJ \cdot g^{-1}$. We assume the digestibility goose droppings to be 40–70% and the daily energy requirement of Svalbard reindeer in summer 21–28 × 10^3 $kJ \cdot d^{-1}$ (N. Tyler, personal communication). Goose droppings provided a daily ration for 6.2–8.1 reindeer.

© 1998 NRC Canada