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Short Communication

Experimental reduction of food quality is not compensated with increased food intake in high-arctic muskoxen (*Ovibos moschatus*)

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Abstract

A total of four barren adult female muskoxen (*Ovibos moschatus*) were used over a period of 2 years for the purpose of the present study. During the first year, the natural changes in appetite (*ad libitum* intake of standard pelleted reindeer feed) and body mass were determined in two of the animals. During the second year, the effect of reduced food quality on *ad libitum* food intake was tested in all four animals in July when the appetite had been found to be at a high. We found that the experimentally reduced food quality was not compensated with increased food intake in these large high-Arctic herbivores.

Key words: **Muskoxen *Ovibos moschatus*: Reindeer *Rangifer tarandus*: Climate change: Global warming: Appetite: Mismatch**

It is well established that climate warming is occurring in the Arctic at a rate that is twice that of the global average[1,2], and ecosystems and the biota of the Arctic are thought to be particularly sensitive to the direct and indirect consequences of climate change[1,3].

Plant quality is conspicuously reduced as the concentration of protein and easily digestible carbohydrates decreases and fibre concentration increases throughout the growth season in the Arctic[4–6]. In high-Arctic herbivores, like muskoxen (*Ovibos moschatus*), reindeer (*Rangifer tarandus*) and ptarmigan (*Lagopus* sp.), appetite undergoes conspicuous seasonal changes, with a low in winter–spring and a high in summer–autumn[7–9]. It is also well established that these endogenous rhythms are regulated by photoperiod[10–13]. Further, ovulation will not occur unless a certain body weight and fat content are reached at the rut in the autumn[14,15]. With the ongoing warming of the Arctic, the development of many plant species is starting earlier and proceeding faster and this trend is likely to continue[3]. In one extreme example from Northeast Greenland, plant phenology was advanced by 30 d within a very short growing season of usually about 3 months[16]. This earlier seasonal plant development implies that the nutritional quality of plants may be reduced at the time when the animals give birth and need to support milk production, and in particular in the autumn when appetite also is high to support fat deposition and growth. It further implies that body fattening and hence reproductive rate may be compromised, unless the lowered forage quality is compensated by increased food intake.

In the present study, we show in the muskoxen that reduced food quality is not compensated by increased food intake, but follows instead the normal seasonal changes regardless of food quality.

Methods

Animals

For the purpose of this study, four barren adult captive female muskoxen aged 12–13 years were used. The animals were born to originally wild muskoxen captured in East-Greenland and kept in a herd of about fifteen animals on an island with natural vegetation outside Tromsø (69°40′N; 18°58′E), Norway. While on the island, the animals were roaming freely but were accustomed to ‘control’ pelleted feed (FK Reinfor, Felleskjøpet; Table 1), which they received on occasion to maintain contact with their keepers.

The use of the animals was in accordance with the Norwegian Animal Welfare Act, and the experiments were carried out under permit from the National Animal Research Authority of Norway.

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Table 1. Composition of 'control' and 'experimental' feed, as fed

	Control (%)*	Experimental (%)†
Protein	10·7	7·6
Fat	3·7	2·9
NDF	28·2	44·9
WSC	7·1	4·6

NDF, neutral-detergent fibre; WSC, water-soluble carbohydrates.
* The 'control' feed consists primarily of wheat bran (40 %), barley (15 %), beet pulp (12 %), oat bran (10 %), oats (7 %), molasses (5 %) and rapeseeds (3 %), with addition of minerals and vitamins.
† The 'experimental' feed consists of a 50/50 mixture of the 'control' feed and identical pellets of oat bran (95 %) and molasses (5 %), with addition of minerals and vitamins. DM of 'control' and experimental feed was 90·4 and 92·1 %, respectively.

Experimental protocol

In preparation for the experiment, the animals were moved to a specially prepared outdoor pen at the Department of Arctic Biology in Tromsø, where they were weighed daily and received pelleted ('control') feed (Table 1) and water/snow *ad libitum*, occasionally supplemented with small quantities of high-quality hay for a period of 4 months before any experiment started.

Subsequently, two of the animals were studied for 9 months (March–November) to determine the natural seasonal changes in body mass and appetite (*ad libitum* intake of 'control' feed; Table 1).

The pelleted feed was offered in specially designed troughs, from which the food uptake for each individual animal was recorded daily for a period of 6 d every month, while body mass was recorded by the use of a platform scale (LF-211/Flintec SB4; Sartorius Combics 2) which was in place in front of the trough, alternating every second day between the two animals. Thus, body mass was recorded every time an animal approached the trough.

During the following year, the effect of offering low-quality 'experimental' pelleted feed (Table 1), simulating late-season plant material, on food uptake was tested for a period of 8 d in July when appetite is at a high (Fig. 1(b)). The 'experimental' pelleted feed that had the same size and shape as the 'control' feed was produced by the Center for Feed Technology, Norwegian University of Life Sciences, Ås, Norway. At this time, all four animals were kept together in a group and food uptake recorded every day for all four animals together, while each animal was identified by the use of a video camera, when on the scale. Compositional analyses of both 'control' and 'experimental' feed were performed for crude protein[17], fat[18], neutral-detergent fibre[19] and water-soluble carbohydrates[20] by accredited laboratory Eurofins Norsk Matanalyse AS, Moss, Norway. Results are given as averages and standard deviations. A two-tailed unpaired t test was used to test differences in food intake; a P value of 0·05 being considered significant. The relationship between body mass and food intake during the growth season (June–October) was examined by linear regression analysis.

Results

The seasonal changes in body mass in the two barren females were large (Fig. 1(a)). The seasonal changes in intake of 'control' feed show a range of 1·2–3 kg/animal per d, with a minimum in April and November and a peak in June (Fig. 1(b)), which coincide with previously recorded changes in rumen fill[21]. Moreover, the body mass and food intake of these animals developed linearly, but inversely from June to October

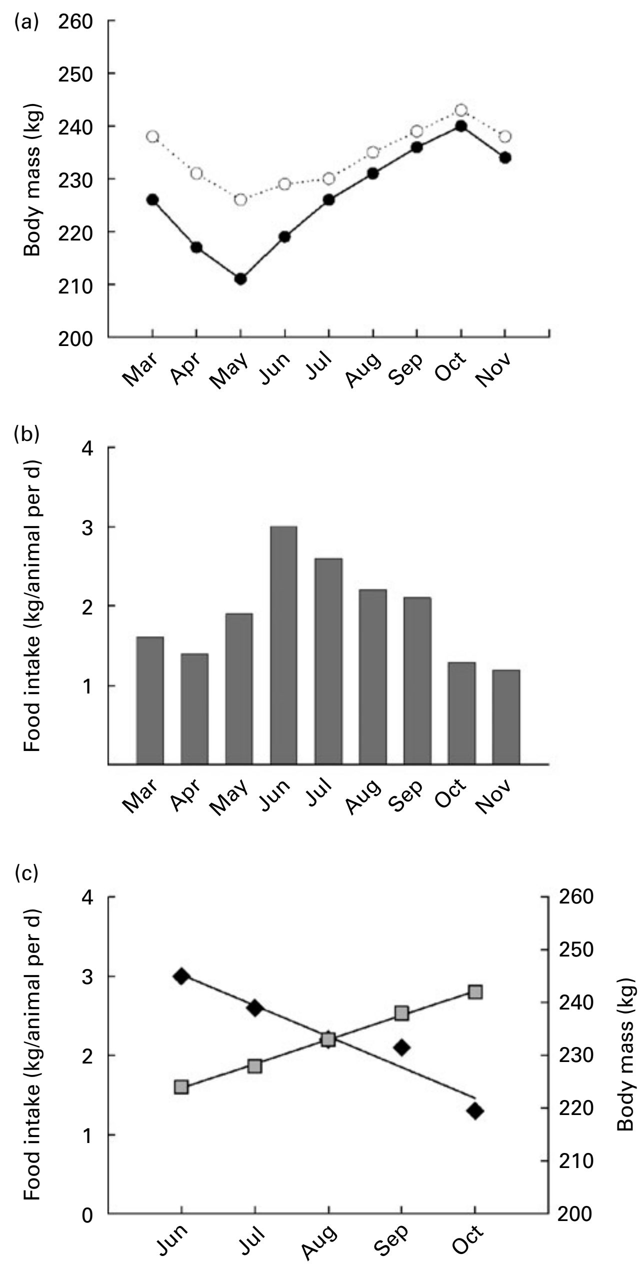

Fig. 1. Seasonal changes in two barren female muskoxen (*Ovibos moschatus*) under natural day-length conditions: (a) monthly changes in individual body mass (kg) throughout the year. (b) Concomitant changes in average *ad libitum* intake (kg/animal per d) of high-quality 'control' feed. (c) Inverse relationship between average body mass (■; kg) and average food intake (◆; kg/animal per d) during the 'growth' season June–October.

(body mass: regression coefficient 2·2, SE 0·16, $P=0·001$; food intake: regression coefficient −0·38, SE 0·06, $P=0·008$; Fig. 1(c)).

The change from 'control' feed to 'experimental' feed for 8 d and *vice versa* in our four barren females in July the following year resulted in a 0·4–0·9 % increase in body mass, which is well within the 2 % daily variation in these animals, but did not result in a significant change in food intake. The values for all four non-pregnant, non-lactating animals combined were 13·3 (SD 0·2), 13·2 (SD 0·8) and 12·8 (SD 1·8) kg/d, before, during and after the change to experimental food, respectively. It follows, that the average daily food intake per animal while eating experimental food was 3·3 kg, which is much lower than the highest (5·0 (SD 0·3) kg) daily food intake of one of the, then nursing, females in July the previous year (A. S. Blix, unpublished results).

Discussion

The large seasonal changes in body mass in our animals (Fig. 1(a)) are consistent with the seasonal changes in wild muskoxen[22].

Our findings on food intake suggest that even though our muskoxen have the capacity for a daily food intake of at least 5 kg, they did not increase their daily food intake above the 3 kg, typical of that time of the year (Fig. 1(b)), in response to the reduction in the nutritional quality of the food. This indicates that the seasonal cycle of food intake is under strong endogenous control in muskoxen. Moreover, as shown before in other high-Arctic species[7–9], an increase in body mass may not follow an increase in food intake, which would otherwise be expected. In fact, we have shown here (Fig. 1(c)) that food intake declines with increasing body mass during the 'growth' season in summer–autumn, probably caused by concomitant changes in locomotor activity, since major changes in digestive efficiency are unlikely[23]. Mammals generally use the annual changes in the photoperiod to drive rhythmic production of melatonin from the pineal gland, providing a critical cue to time seasonal events[24]. In reindeer, these mechanisms are well described, showing unique modifications that may reflect the Arctic photoperiodic condition[25]. Since the photoperiod at our location is representative for the wild and endemic population in East-Greenland from which our animals originated, it seems reasonable to assume that our results reflect the natural situation for this species. If this pattern also applies to our non-pregnant, non-lactating animals, it would suggest that muskoxen are slaves of their photoperiod-controlled seasonal rhythms. This would imply that unless physiological changes resulting from pregnancy, lactation or rut affect adjustments of the seasonal pattern, these animals fill their rumen to an extent which is pre-determined, regardless of the quality of the food. This is a notion that deserves further attention.

While our observations are derived from an experiment on muskoxen, they may also relate to reindeer. However, reindeer are much less amenable to this kind of experimentation, since unlike muskoxen, they usually go off their feed for a variable period of time in response to experimental changes in diet (personal observations). This, for once, seems to make the muskox an ideal experimental animal.

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