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Population structure and dynamics in captive muskoxen at the Large Animal Research Station, 1988-1994

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Abstract: The muskox colony at the Large Animal Research Station, started in 1979, totaled 22 individuals before calving in 1988. Between 1988 -1994 cows of breeding age have been maintained on either a high plane (HP) or low plane (LP) of nutrition, and as far as possible, female offspring are kept with their mother's group. During this time the population has increased from 22 to 43 animals (25 females and 18 males). Fifty-four calves were born with an overall sex ratio of 52:48 (male:female). When partitioned between the 2 nutritional planes the sex ratio was HP 45:55 and LP 62:38. The calf/cow ratio was 0.83 in 1988 and 0.86 in 1994. The LP group accounted for most of the variability in pregnancy rate, primarily through delayed puberty and breeding pauses. Calf mortality was due mainly to abortions, stillbirths and neonatal death (n=12), 7 deaths occurred between 2 weeks and 1 year of age. All stillbirths and abortions (n=4) and 6 of 8 neonatal deaths affected calves of HP cows. Thirteen adults died, 4 males were loaned to other facilities and 2 new calves were added.

Key words: herd composition, rate of increase, calf production, yearling recruitment, sex ratio, mortality.

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Introduction

Analysis of captive populations of wild animals are rarely published. Because so many more variables can be measured in captivity, the experience of rearing captive wild animals can add useful insights for studies on natural populations. Inherent controls on growth of captive populations could convey both advantages and disadvantages to analyzing population structure. In captivity, we can collect detailed information on behavior, activity budgets and physiology. We know the age of our animals, the exact number and sex of animals that are born and, in most cases, specific causes of death. We also can control a wide range of variables including group size and composition, diet, breeding season, predation, immigration and emigration. Conversely, captivity constrains population analysis through small sample size, replacement of natural foraging with an artificial diet and feeding regimen, and restricted animal mobility and dispersal. Close contact with humans and/or other species can enhance the potential for injury and disease transmission.

This paper is the demographic analysis of a captive population of a species that responds well to confinement, the muskox (*Ovibos moschatus*). Periodic epidemiologic surveys are part of a management protocol used to evaluate the relative health of our captive muskox population at the

Large Animal Research Station (LARS), University of Alaska Fairbanks. Because epidemiology employs essentially the same tools used in population analysis, we present data in a form for comparison with free-ranging populations. This provides a framework for interpretation of captive information. While it is always imperative to keep in mind the physical differences between captive and wild populations, the similarities and differences among population parameters can provide insights into mechanisms controlling free-ranging populations (*sensu* Hamilton & Blaxter, 1980; Albon *et al.,* 1986; Parker *et al.,* 1990; White *et al*, 1997).

Animals and methods

We extracted data from the herd management records at LARS and from the pathology records at Veterinary Services, Institute of Arctic Biology. For the purposes of this paper, the total of all captive muskoxen at LARS are referred to as the captive population. Within this population, animals maintained in different pens (social units) are referred to as groups. In 1987, 6 female muskoxen of breeding age (2-7 yr.) were placed on either a high (n=3) or low (n=3) nutritional plane. High-plane (HP) animals were allowed to graze pasture (brome grass). They had year-round access to brome-grass hay and were supplemented throughout the year with a pelleted ration. Low-plane (LP) cows were provided similar pastures to HP cows, were allowed year-round access to brome-grass hay but did not receive the pellet supplement. In winter, LP cows had access to hay only. Between mid-August to mid-October a breeding bull was placed with each group. The adult bulls and cows remained separate in the non-breeding season. Healthy calves born to cows within a dietary treatment remained with their dams and were raised on her nutritional treatment until natural weaning occurred. At weaning, males were removed and females remained within the treatment group. Exceptions to this protocol were made if the calf required medical attention. In some cases this necessitated artificially weaning the calf and removing it from the nutritional experiment. A more detailed account of the nutritional experiment can be found in White *et al.* (1997) and Rowell *et al.* (1997). All research protocols were approved by an independent animal welfare committee.

The total LARS population was 22 individuals before the 1988 calving season and it increased to 43 by the end of 1994. Within any pen we controlled the group or harem size and age/sex composition in a manner that ensured all healthy cows ≥ 2.5 years old were provided the opportunity to mate with a mature bull. Emigration (4 males were loaned to other facilities) and immigration (2 zoo-born calves were donated in 1994) were limited. Annual population size and yearling recruitment were based on counts made prior to calving. Data were log transformed and regressed against yeat. Calf production was calculated as % of population size and as % of cows of breeding age (≥ 3 years). To examine the effect of diet on calf production, the data between 1988-1994 were pooled by nutritional group (HP or LP).

Results and discussion

Population composition and annual rate of increase

Changes in age and sex ratio of the captive population over 7 years are depicted in (Figs. 1a, b). This includes emigration (4 bulls loaned to another facility) and immigration (2 calves donated to LARS). These graphs show a marked increase in the younger cohorts and a disproportionately higher death rate among males.

The slope of the regression for population size over time gave an average exponential rate of 8% (y= 2.99+ [0.0798x], s.e. slope = 0.0174, r^2 = 0.777, P=0.0038). Estimates of annual rate of increase from the wild range from a low of 2% in south eastern Greenland (Ferns, 1977) to 16-17% for newly introduced populations in Alaska (Spencer & Lensink, 1970; Jingfors & Klein, 1982) to a high of 20-25% for expanding populations in the Canadian Arctic (Vincent & Gunn, 1981; Gunn *et al.,* 1984; McLaren & Green, 1985) and highly productive ateas in Alaska (Jingfors & Klein, 1982). The relatively low rate of increase identified in our captive population has been attributed to the nutritional treatment and high calf mortality and will be discussed in more detail in the following sections.

Calf production

In 1988 calf production was 23% of the population or a calf/cow ratio of 0.83. In 1994 calf production was 36% for the population with a calf/cow ratio 0.86 (Fig. 2).

Dietary treatment had an effect on calving rate (Fig. 2). Over the 7 year period, calf production per HP cow was 0.94. This was similar to estimates from expanding and reintroduced populations in

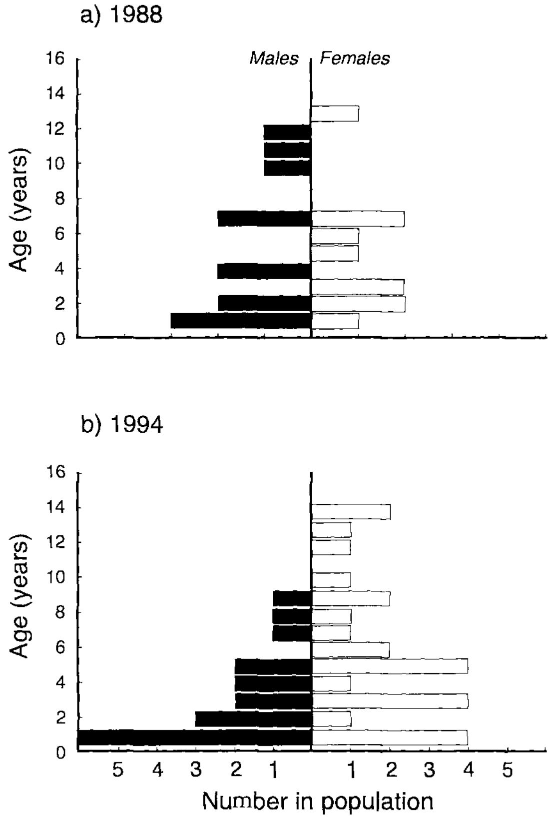

Fig. 1. Age and sex composition in 1988 (a) and 1994 (b) for a captive population of muskoxen (≥ 1 year-old) at the Large Animal Research Station, Fairbanks. The population was allowed to increase from 22 individuals in 1988 to 43 individuals in 1994.

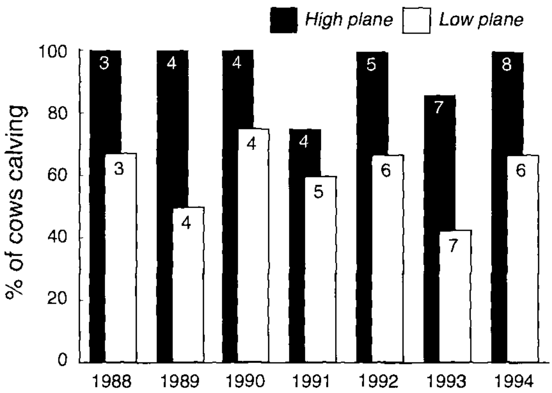

Fig. 2. Annual muskox calf production for muskox cows on a high (HP) and a low (LP) nutritional plane. Data are presented as a % of cows ≥ 3 years-old calving. Numbers on the bars indicate the number of cows of breeding age for each group.

the wild; Banks Island, 0.83 (Latour, 1987), West Greenland, 0.90-1.0 (Olesen, 1993), Nunivak Island, 0.80 (Smith, 1984) Northern Quebec, 0.86-0.97 (Le Henaff & Crête, 1989) and Northeast Alaska, 0.89 (Jingfors & Klein, 1982). Calf production among the LP cows was 0.60, consistent with estimates from less productive populations; NE Gteenland, 0.39-0.57 (Thing *et al.*, 1987) and 0.58-0.63 (Lassen, 1984). Among the LP cows, lowered calf production was a function of delayed onset of first breeding and breeding pauses in parous cows (Rowell *et al*, 1997). A more detailed discussion of the effect of dietary tteatment on breeding success can be found in White *et al.* (1997).

Also of interest is the association of diet and calving date (Fig. 3). While the sample size was too low

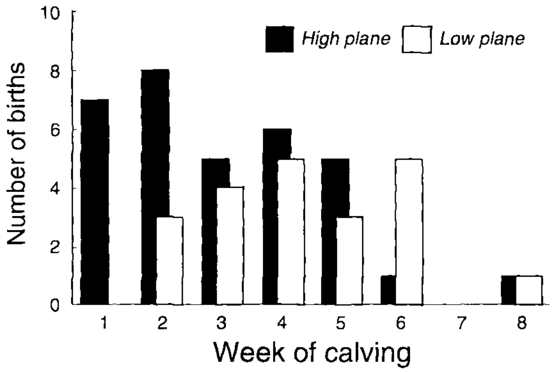

Fig. 3. Maternal plane of nutrition and timing of calving among captive muskoxen, 1988-1994. Week 1 begins on April 23 and week 8 ends on June 19.

to detect significant differences, the majority of HP cows calved earlier than LP cows. Mating behavior was consistently observed earlier among HP cows (Rowell, unpubl. observ.). Early born calves have the potential to gain more weight before the first winter, thus enhancing survival. In Fairbanks, early born calves usually avoid high ambient temperatures during the vulnerable neonatal period. Yet, in the captive population, the majority of neonatal mortalities occurred among HP cows, obscuring any positive effect of early birth. Neonatal mortality is discussed in a separate section.

Sex ratio

The sex ratio for 54 calves born between 1988-1994 was 52:48 (M:F) and did not differ significantly from 1:1 (Fig. 4), consistent with sex ratios identified in the field (Spencer & Lensink, 1970; Latour,

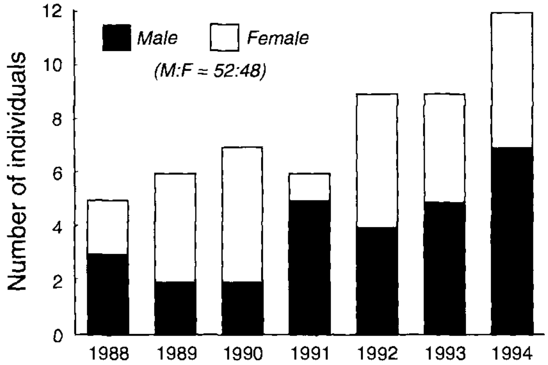

Fig. 4 Sex ratio of 54 muskox calves born ar the Large Animal Research Station between 1988-1994. The ratio of males to females did not differ significantly from 1:1.

1987). Sex ratios within the two treatment groups were 45:55 for the HP and 62:38 in the LP group (Figs. 5a, b) but these ratios were not significantly different (P=0.348), possibly due to small sample size. While these data are interesting, the small sample size and lack of experimental design to specifically evaluate the effect of diet on sex ratio make it premature to draw conclusions.

Yearling recruitment

Yearling recruitment in 1994 was 12% with a yearling/cow ratio of 0.25, a reflection of high calf losses. Between 1988-1994 death during the first year of life in the captive population averaged 30%. In wild populations yearling recruitment is a reflection of both calf production and calf survival. Estimates of proportion of yearlings vary from lows of 6.8-8.7% in parts of the Canadian Arctic (Gunn *et al.*, 1989) to 10-16% for more productive populations of the Canadian arctic (Gunn *et al.*, 1989), Greenland (Thing *et al*, 1987) and Nunivak Island (Spencer & Lensink, 1970) to highs of 24% or 0.62 yearlings/cow on Banks Island (Latour, 1987).

Adult mortality (> 1 year)

Over the 7 years, 11 males and 2 adult females died (Fig. 6; Table 1). Almost half (n=5) of the male deaths were attributable to a nutritional problem that occurred during the winter and spring of 1990-1991. All 5 males were housed with 15 other animals in a pasture suspected to be of poorer quality compared to other areas of LARS and they did not receive a pelleted supplement. Only 2 of the 5 were available for necropsy. Three males died during heavy snows mid-winter and the carcasses, found in

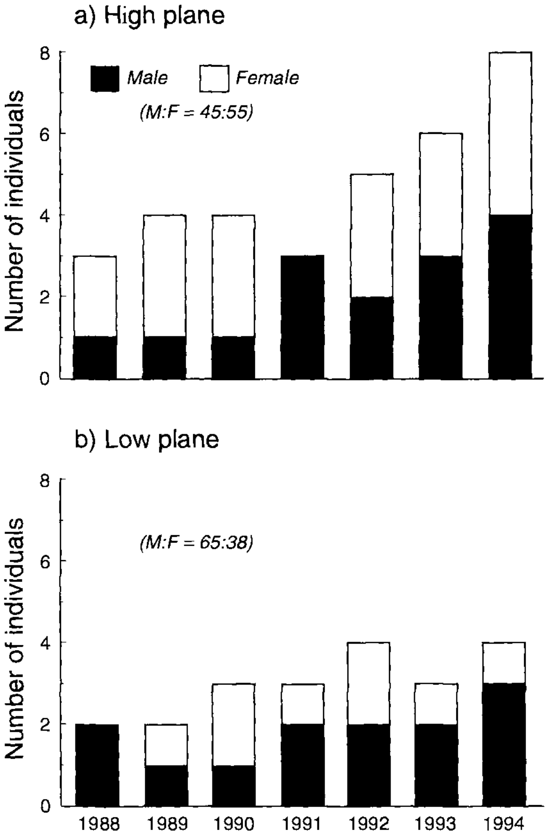

Fig. 5. Maternal nutritional plane and calf sex ratio. (a) sex ratio of calves born to muskox cows maintained on a high (HP) plane and (b) a low (LP) plane of nutrition.

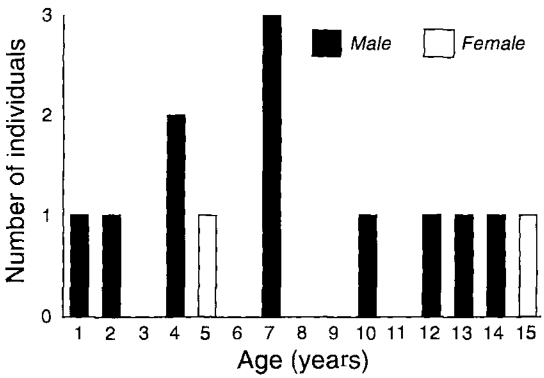

Fig. 6. Age specific mortality among male and female captive muskoxen ≥ 1 year-old, 1988-1994. Causes of mortality are listed in Table 1.

the spring, were too autolysed to examine. However, all three had abundant body fat suggesting a problem similar to the fatty liver, copper deficiency seen in the other two. There is very little information on muskox trace mineral status or trace

Table 1. Description of adult muskox mortality (≥1 year old) at the Large Animal Research Station, 1988–1994.

Category	Diagnosis	Individuals involved
Intraspecific Conflict	1) Skull fracture / cerebral hematoma	1 male
	2) Broken ribs / lung bruising / renal failure	1 male
Foreign Body Ingestion	1) Chronic peritonitis	1 male castrate
	2) Brain abscess secondary to thoracic abscess	1 male castrate
Metabolic Disorder	Fatty Liver Syndrome / copper deficiency. Spring 1991	2 male castrates
Immobilization Problem	1) Hyperthermia under etorphine / xylazine	1 male
	2) Aspiration pneumonia following etorphine / xylazine	1 female
Calving Problem	Emphysematous fetus / metritis and septicemia	1 female
Miscellaneous	Meningitis secondary to tooth abscess	1 male
Unknown	Lost in woods during heavy snow winter of '90-91; found in spring Severe autolysis but all had abundant body fat Suspect Fatty Liver Syndrome / copper deficiency	3 males

mineral requirements, although instances of muskoxen using natural mineral licks have been documented (Thing *et al.*, 1987). The importance of copper, molybdomen, zinc and cobalt in captive muskox diets has been underestimated and the role of these minerals in wild muskox diets is unknown.

In captivity, death from starvation or predation did not occur. Trauma resulting from intraspecific conflict and meningitis from a tooth abscess are both conditions encountered in the wild. The ingestion of foreign objects is a ubiquitous problem, and a higher risk for animals that frequent areas disturbed by humans. It is a recognized source of accidental death in captivity but almost impossible to measure in the wild.

Due to the primary focus of our research programs, females are handled more often, therefore, inconspicuous clinical problems are recognized early and appropriately treated. Both female deaths are considered incidental. One died due to systemic infection following the death *in utero* and maceration of her term fetus. Sporadic losses due to calving problems such as this also occur in free-ranging muskoxen (Norment, 1980; Blake, pers. comm.). The other female died following aspiration of rumen contents during immobilization with etorphine/xylazine.

Regardless of the cause of death, mortalities were much higher among males than females. This also is a finding among many free-ranging populations (Parker *et al.*, 1975; Smith, 1984; Thing *et al.*, 1987; Gunn *et al.*, 1989). Disease investigations of free-ranging muskoxen on Banks Island identified a summer mortality caused by yersiniosis that produced a significantly highet mortality rate in mature, well conditioned males than in any other age ot sex class (Blake *et al.*, 1991). It has been hypothesized that stressors imposed upon the males during and after the rut may predispose them to a higher prevalence of disease (Blake *et al*, 1991) and/or nutritional problems (Gunn *et al*, 1989). Male behavior in general (intraspecific competition, solitary movements) places them at greater risk for accidents, injury and predation.

Calf mortality

Calf mortality was high, despite medical intervention. We divided calf mortality into age categories: (a) abortion and stillbirth (b) neonatal (1-14 days of life) (c) 2 weeks-1 month (d) 1-3 months (e) 3-6 months and (f) 6-12 months (Fig. 7b). The greatest number of deaths (12) occurred from abortion/stillbirth and during the neonatal period. Of these, 10 of 12 were from calves of HP cows (Fig. 7a). Causes of abortion/stillbirth remain undetermined although extensive diagnostic work has ruled out common infectious causes. With few exceptions the neonatal deaths were caused by acute infections with *Escherischia coli.* Factors contributing to disease susceptibility in muskoxen of this age are poorly understood and warrant further investigation (Holst, 1990). A total of 7 deaths occurred for all

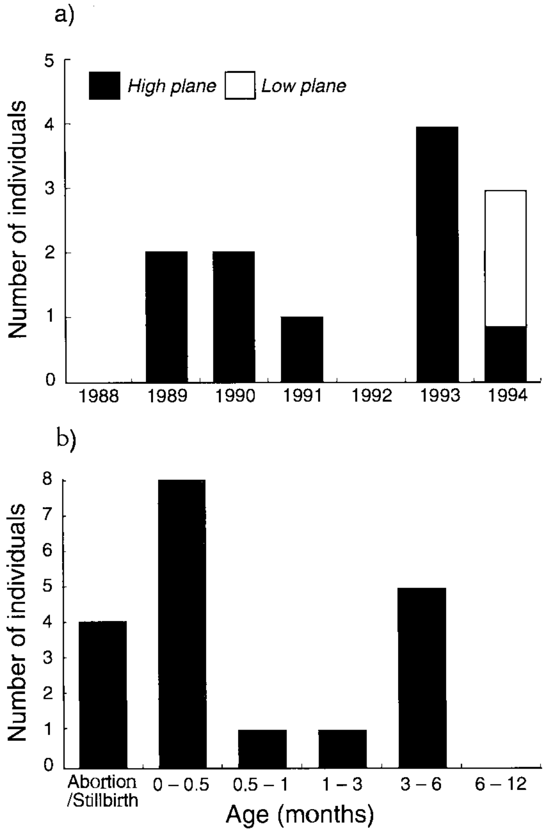

Fig. 7. Calf mortality. (a) late term abortions, stillbirths and neonatal (birth to 14 days) deaths among captive muskoxen, 1988-1994. HP and LP refer to the nutritional plane of the dam. (b) muskox calf mortality up to 1 year of age. These dara combine both nutritional groups and include stillbirths and abortion.

other age groups with 5 of these occurring in the 3-6 month category (Fig. 7b). Four of the 5 deaths at 3-6 months were from an enteritis/malabsorption syndrome of viral and bacterial etiology with a possible nutritional component. This has affected all calves every fall since 1992 and only aggressive medical intervention has prevented higher losses. Again, factors contributing to susceptibility are currently being investigated. The remaining 3 losses were considered incidental (2 died from accidents and 1 from an oral abscess).

The high number of neonatal mortalities among HP cows was unexpected and we are unable to explain these results as a product of the nutritional treatment. High plane cows had more calves (33) than LP cows (21) hence, a greater probability fot calf health problems. Four of the deaths were from primiparous cows (3 HP and 1 LP) and may reflect difficult births and/or poor mothering. High plane cows calved consistently as 3-years-olds, while LP cows were more likely to delay first calving for a year. Two HP cows accounted for 50% (5) of the HP calf deaths.

With the exception of a single report of a breech birth (Norment, 1980), there are no estimates of perinatal and neonatal mortality among wild muskoxen. Thus, although low calf production is often considered the primary cause of low yearling recruitment among wild populations, neonatal mortality is an extremely difficult phenomenon to measure in free-ranging animals. The fact that high neonatal mortality has not been reported in wild populations should not be replaced with a complacent attitude that it doesn't occur.

Conclusions

While acknowledging the constraints captivity places on a population of muskoxen, the tools for analyzing population structure have provided useful insights on the captive population. The nutritional model corroborates field observations of depressed calving in moderate to poor habitats. In addition, finding a trend towards skewed calf sex ratio and later calving among the LP group is intriguing and worthy of further investigation.

Mortality investigations highlight our lack of information on trace mineral status in general. High calf mortality remains a persistent problem among captive muskox herds worldwide (Hoist, 1990). Captive calves are extremely susceptible to a host of infectious and dietary disorders, many of which are common, relatively benign conditions in domestic livestock. Abortions and stillbirths remain a baffling and perseverant problem. Understanding the conditions that contribute to this lack of robustness during pregnancy and in early neonatal life will help us understand the limits to the species adaptability.

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References

Albon, S. D., Mitchell, B., Huby, B. J. & Brown, D. 1986. Fertility in female red deer (*Cervus elaphus*): the effects of body composition, age and reproductive status. – *J. Zool. Lond.* 209: 447–460.

Blake, J. E., McLean, B. D. & Gunn, A. 1991. Yersiniosis in free-ranging muskoxen on Banks Island, Northwest Territories, Canada. – *J. Wildl. Dis.* 27: 527–533.

Ferns, P. N. 1977. Muskox abundance in the southern part of the range in east Greenland. – *Arctic* 30: 52–60.

Gunn, A., Decker, R. & Thomas, W. B. 1984. Possible causes and consequences of an expanding muskox population, Queen Maud Gulf area, Northwest Territories. – *In:* Klein D.R., White, R.G. & Keller, S (eds.). *Proceedings of the First International Muskox Symposium. – Biol. Pap. Univer. Alaska,* Spec Rep. 4: 1–46.

Gunn, A., Miller, F. L. & McLean, B. 1989. Evidence for and possible causes of increased mortality of adult male muskoxen during severe winters. – *Can. J. Zool.* 67: 1106–1111.

Hamilton, W. J. and Blaxter, K. L. 1980. Reproduction in farmed red deer. 1. Hind and stag fertility. – *J. Agric. Sci.* 95: 261–273.

Holst, B. 1990. *International Studbook for Muskox.* Copenhagen Zoo, Denmark.

Jingfors, K. T. & Klein, D. R. 1982. Productivity in recently established muskox populations in Alaska. – *J. Wildl. Manage.* 46: 1092–1096.

Lassen, P. 1984. Muskox distribution and population structure in Jameson Land, east Greenland, 1981-1983. – *In:* Klein D. R., White, R. G. & Keller, S. (eds.). *Proceedings of the First International Muskox Symposium. - Biol. Pap. Univer. Alaska,* Spec Rep. 4: 19–24.

Latour, P. 1987. Observations on demography, reproduction and morphology of muskoxen (*Ovibos moschatus*) on Banks Island, Northwest Territories. – *Can. J. Zool.* 65: 265–269.

Le Henaff, D. & Crête, M. 1989. Introduction of muskoxen in northern Quebec: the demographic explosion of a colonizing herbivore. – *Can. J. Zool.* 67: 1102–1105.

McLaren, M. A. & Green, J. E. 1985. Status of muskoxen on eastern Melville Island in spring, 1982. – *Can. Field-Nat.* 99: 156–162.

Norment, C. J. 1980. Breech presentation of the fetus in a pregnant muskox. – *J. Mamm.* 61 (4): 776–777.

Olesen, C. R. 1993. Rapid population increase in an introduced muskox population, West Greenland. – *Rangifer* 13: 27–32.

Parker, G. R., Thomas, D. C., Broughton, E. & Gray, D. R. 1975. Crashes of muskox and Peary caribou populations in 1973-74 on the Parry Islands, Arctic Canada. – *Progress Notes, Canadian Wildlife Service* 56: 1–10.

Parker, K. L., White, R. G., Gillingham, M. P. & Holleman, D. F. 1990. Comparison of energy metabolism in relation to daily activity and milk consumption by caribou and muskox neonates. – *Can. J. Zool.* 68: 106–114.

Rowell, J. E., White, R .G. & Hauer, W. E. 1997. Progesterone during the breeding season and pregnancy in female muskoxen on different dietary regimens. – *Rangifer* 17 (3): 125–129.

Smith, T. 1984. Population status and management of muskoxen on Nunivak Island, Alaska. – *In*: Klein D.R., White, R.G. & Keller, S (eds.). *Proceedings of the First International Muskox Symposium. – Biol. Pap. Univer. Alaska,* Spec Rep. 4: 52–56.

Spencer, D. L. & Lensink, C. J. 1970. The muskox of Nunivak Island, Alaska. – *J. Wildl. Manage.* 34: 1–15.

Thing, H., Klein, D. R., Jingfors, K. & Holt, S. 1987. Ecology of muskoxen in Jameson Land, northeast Greenland. – *Holarc. Ecol.* 10: 95–103.

Vincent, D. & Gunn, A. 1981. Population increase of muskoxen on Banks Island and implications for competition with Peary caribou. – *Arctic* 34: 175–179.

White, R. G., Rowell, J. E., & Hauer, W. E. 1997. The role of nutrition, body condition and lactation on calving success in muskoxen. – *J. Zool. Lond.* 243: 13–20.

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