Body size of female calves and natality rates of known-aged females in two adjacent Alaskan caribou herds, and implications for management

Patrick Valkenburg[1], Robert W. Tobey[2], Bruce W. Dale[3], Bradley D. Scotton[2] & Jay M. Ver Hoef[1]

[1] Alaska Department of Fish and Game, 1300 College Road, Fairbanks, AK 99701-1599, USA (pat_valkenburg@fishgame.state.ak.us).
[2] Alaska Department of Fish and Game, PO Box 47, Glennallen, AK 99588-0047, USA.
[3] Alaska Department of Fish and Game, 1800 Glenn Highway, Suite 4, Palmer, AK 99645-6736, USA.

Abstract: We studied body mass of female calves and natality rate of adult females in two adjacent Interior Alaskan caribou (Rangifer tarandus granti) herds during 1991-2001. Mass of newborn calves was similar in both herds, but Delta calves gained significantly more mass over summer than Nelchina calves. In contrast, Nelchina calves consistently maintained their mass during winter while Delta calves lost mass. Metatarsus length was similar in both herds in 4-month-old and 10-month-old calves, and it increased over winter in both herds. Natality rates of females ≥3 years old were consistently higher in the Delta Herd than in the Nelchina Herd, primarily because natality in 3- to 5-year-old Nelchina females was low. Although body mass of Delta Herd calves consistently declined over winter, we concluded that nutrition was not significantly limiting herd growth. Managers are more likely to maximize harvest by maintaining the Delta Herd near its present size (i.e., 3500), or allowing it to increase only slightly. The only real option for increasing harvestable surpluses of caribou in the Delta Herd is reducing predation during calving and summer. In contrast, we conclude that summer nutrition significantly limits potential population growth and body mass in the Nelchina Herd, and managers are more likely to maximize harvest by maintaining herd size at or below 30 000 than by allowing the herd to grow to near historical highs (i.e., 60 000–70 000).

Key words: body mass, Delta Herd, metatarsus length, Nelchina Herd, predation, Rangifer tarandus granti, summer range quality, winter range quality.

Rangifer, Special Issue No. 14: 203-209

Introduction

During the late 1970s and 1980s most caribou herds in Alaska grew significantly, and many herds reached relatively high densities (Valkenburg et al., 1996). During this period, the emphasis in caribou research in Alaska broadened from primarily studying predation as a limiting factor to determining the influence of weather and population density on nutrition and productivity (Russell et al., 1993; Valkenburg et al., 1996; Adams & Dale, 1998; Lenart et al., 2002; Valkenburg et al., 2002, in press). This work has been of particular importance in the few caribou herds where the primary management goal is to maximize harvest and where managers have the ability to control herd size through harvest. In these few herds it is important to be able to estimate optimum population sizes that might provide the highest harvests over the long term. Therefore, in the early 1990s, Alaska Department of Fish and Game biologists began monitoring the mass and size of female caribou calves and natality rates of known-age females in several economically important herds (Valkenburg et al., 2002). We chose this approach because changes in body size and natality rate have been shown to be useful indices of nutrition in ungulates and sensitive to changes in climate and population density (McEwan & Wood, 1966; Klein & Strandgaard, 1972; White et al., 1981; Clutton-

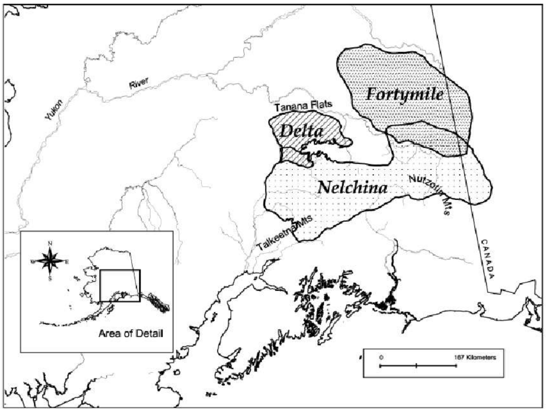

Fig 1. Location of Delta, Nelchina, and Fortymile caribou herds.

Brock et al., 1982; Peters, 1983; Reimers, 1983; Reimers et al., 1983; Skogland, 1983, 1984, 1985; Beninde, 1988; Crete & Huot, 1993; Gaillard et al., 1996; Reimers, 1997). We concentrated our efforts on female calves because they are inexpensive to handle, they can be collared with an adult-sized radio collar, and they are subsequently recruited into the population as known-aged females. Furthermore, the mass and size of 4- and 10-months old calves is largely a function of quality and quantity of available food during late gestation, and during the calf's first summer of life, so calves primarily reflect annual changes in nutrition (Skogland, 1983, 1984; Reimers, 1997; Valkenburg et al., 2000).

Research on calf size and natality has been particularly important to managers of the Delta and Nelchina caribou herds where access for hunters is good, there is a strong hunting tradition, demand for wild meat production is high, and where the caribou have approached or exceeded previous population highs. In 1995, we increased research emphasis on the Nelchina and Delta herds in the hope of determining the relative importance of summer and winter nutrition as limiting factors and providing managers with estimates of optimum population sizes for these herds. In this paper we compare changes in body size of female calves during summer and winter, and natality rates of females, and make inferences about the relative importance of winter and summer nutrition as limiting factors in these two herds. We also discuss management implications and provide initial estimates of optimum population sizes for these herds.

Study herds

Nelchina Herd

The Nelchina Herd has been relatively well studied since 1948, and it has fluctuated considerably in size since then (Van Ballenberghe, 1985; Tobey, 1999). During the late 1940s and early 1950s the herd numbered less than 10 000 but it increased rapidly to about 70 000 by the early 1960s following intensive wolf (Canis lupus) control. By the early 1970s the Nelchina Herd had once again declined below 10 000 and density dependent factors, predation, and overhunting were implicated in the decline (Doerr, 1979; Van Ballenberghe, 1985; Eberhardt & Pitcher, 1992). During 1975-1995 the Alaska Department of Fish and Game allowed the herd to grow while range conditions, and later, body condition, were being monitored. In the late 1980s, as the herd approached 30 000, Nelchina caribou began actively searching for new winter range. In 1987 many caribou moved northeast of traditional winter ranges in the Nelchina Basin to new winter ranges north of the Nutzotin Mountains (Tobey, 1999) (Fig. 1). This movement expanded, and within a few years a majority of the herd began using winter range on both sides of the Yukon–Alaska border (Tobey, 1993). Subsequently, most Nelchina caribou settled on winter range in eastcentral Alaska. These ranges are also used in some years by Fortymile Herd caribou. Until the mid-1990s, about 25–33% of the Nelchina Herd remained on traditional winter ranges in the Nelchina Basin, but since then, only about 10% of the herd continues to use this traditional winter range (Tobey & Scotton, 2001).

By the mid-1990s, the Nelchina Herd numbered about 50 000 and evidence of density-dependent effects on body size of calves and natality rate of adults began to appear (Tobey & Scotton, 2001). High caribou numbers obviously began to affect the distribution and biomass of lichens and other plants on primary summer range in the Talkeetna Mountains. After 1995 the Nelchina Herd declined from reduced calf production and survival and deliberately heavy hunting (Tobey & Scotton, 2001). From 1997 to 2001 the herd varied between 29 000 and 39 000 and hunting was greatly reduced. The newer winter ranges used by the Nelchina Herd after 1987 obviously have a much higher lichen biomass than traditionally used ranges in the Nelchina Basin. Proportion of lichens in the winter diet of caribou on these new ranges is also comparatively high (Valkenburg et al., 2002).

Delta Herd

The Delta caribou herd has been intensively studied since 1979 (Valkenburg et al., 2002). Like most other herds in Interior Alaska, numbers were low (<2500) in the early 1970s. Following wolf control in the mid-1970s, the herd increased rapidly and

Table 1. Mean mass with standard deviations (s) in kg of female newborn, 4-month-old, and 10-month-old caribou calves in the Delta caribou herd.

Birth year	Newborn mass, s, n	4 months Oct mass, s, n	10 months Apr mass, s, n	Mean mass Change Oct–Apr
1991		57.9, 2.6, 14	54.0, 2.6, 17	-3.9
1992		54.0, 2.6, 17	55.5, 2.9, 12	+1.5
1993		55.8, 3.0, 11	n.a.	
1994		59.6, 3.0, 15	55.8, 2.7, 15	-3.8
1995	8.31, 0.24, 19	59.5, 2.7, 15	54.8, 3.3, 15	-4.7
1996	7.40, 0.19, 28	55.8, 3.0, 14	53.7, 2.5, 14	-2.1
1997	7.99, 0.20, 35	58.2, 2.2, 20	56.1, 3.0, 12	-2.1
1998	7.70, 0.29, 15	56.4, 2.6, 16	52.9, 2.6, 13	-3.5
1999	7.89, 0.19, 35	57.1, 2.9, 14	52.1, 2.6, 12	-5.0
2000	7.76, 0.32, 16	56.6, 4.0, 14	55.4, 1.4, 11	-1.2
Mean	7.84	57.1	54.4	-2.6

Table 2. Mean weights and standard deviations (s) in kg of female newborn, 4-month-old, and 10-month-old caribou calves in the Nelchina caribou herd.

Birth year	Newborn mass, s, n	4 months Oct mass, s, n	10 months Apr mass, s, n	Mean mass Change Oct–Apr
1995		53.5, 1.5, 15	53.1, 1.2, 16	-0.4
1996	7.19, 0.19, 17	48.3, 2.1, 10	49.1, 1.0, 23	+0.8
1997	7.91, 0.21, 30	55.5, 1.8, 10	57.0, 1.1, 15	+1.5
1998	8.57, 0.18, 30	50.6, 0.9, 25	53.1, 1.2, 15	+2.5
1999	8.14, 0.21, 27	52.0, 0.8, 38	48.6, 0.8, 27	-1.4
2000	7.02, 0.15, 31	53.5, 1.1, 37	52.5, 0.9, 26	-1.0
Mean	7.77	52.0	52.2	+3.0

reached a historic high level of 10 700 in 1989 (Boertje et al., 1996; Valkenburg et al., 1996). Wildlife managers had deliberately allowed the herd to grow to determine if density-dependent factors would eventually regulate herd size. As the herd increased, caribou changed winter ranges frequently and used nontraditional winter range in the Tanana Flats. Following severe summer and winter weather in the early 1990s, the herd declined because of heavy predation and reduced calf survival (Valkenburg et al., 1996). Between 1995 and 2001 the herd remained relatively stable at about 3500-4500 caribou (Valkenburg et al., 2002). During the decline in the early 1990s, it was clear that nutrition was relatively poor compared with the late 1970s and early 1980s – body size and survival of calves was low, and natality rate in adults declined. After the population was reduced in the early 1990s and weather patterns moderated, nutritional condition of the herd largely recovered (Valkenburg et al., 2002). However, the proportion of lichens in the winter diet has remained relatively low compared with other Interior herds, and caribou have continued to pioneer new winter ranges (Valkenburg et al., 2002).

Methods

During 1991-1995 we monitored mass and skeletal measurements of samples of 4-month-old and 10-month-old female caribou calves in the Delta Herd, and during 1996-2000 we monitored mass of newborn calves and mass and skeletal measurements of newborn, 4-month-old, and 10-month-old female caribou calves in the Delta and Nelchina caribou herds. We located newborn calves (1-2 days old) with a Robinson (R-22) helicopter and captured them by hand after running them down. Older calves were darted from helicopters (Valkenburg et al., 1999). Four-month-old calves were captured during 27 September-14 October, and 10-month-old calves were captured during 1-25 April. Calves were weighed with calibrated electronic or spring scales, and metatarsus length of 4-month-old and 10-month-old calves was measured with calipers. We monitored natality rates of radio-collared female caribou during mid to late May by documenting the presence of hard antlers and/or distended udders (Bergerud, 1964; Whitten, 1995).

We used a linear model of mixed effects to examine potential differences in newborn, 4-month-old, and 10-month-old female calf mass. We used the same model to examine differences in metatarsus length in 4-month-old and 10-month-old female calves. The following model was used:

$$Z_{ijk} = \mu + \eta_i + Y_j + (\eta Y)_{ij} + \varepsilon_{ijk}$$

where Z_{ijk} is the mass (or metatarsus length) for the ith herd, i = Delta or Nelchina, for the jth year, and k indicates the replicate for the ith herd in the jth year; μ is an overall mean effect, η_i is a fixed effect for herd, Y_j is a random effect for year, and $(\eta Y)_{ij}$ is an interaction term that allows separate random effects among years for each herd. We used this model for each age class: newborns, 4-month-olds, and 10-month-olds. We compared age-specific natality rates of radiocollared females between herds by calculating confidence limits for the binomial distribution.

Results

During 1995-2000 mass of newborn female caribou calves in the Delta and Nelchina caribou herds did not differ (P=0.66) (Tables 1-3). Mass of 4-month-old Delta calves was greater than 4-month-old Nelchina calves (P=0.001), and remained higher than Nelchina calves at 10 months of age (P=0.03) (Tables 1-3). There was no difference in metatarsus lengths in either 4-month-old (P=0.77) or 10-month-old (P=0.33) calves between the two herds (Tables 4-6). Natality rates of radiocollared Nelchina females (≥3-years old) were lower than radiocollared Delta females (P=0.02) primarily because a majority of Nelchina females often did not produce their first calf until age 4, and natality was lower in 4- and 5-year-old females (P<0.04) (Tables 7 and 8). There was no difference in natality rates of radiocollared Delta and Nelchina females 6-years old and older (P=0.9).

Discussion

Even though female Delta caribou calves consistently lost mass over winter, at 10 months of age they remained heavier than Nelchina calves because Nelchina calves gained significantly less mass over summer, and they were not able to gain mass over winter. Because of the apparently superior winter nutrition of the Nelchina caribou we would

Table 3. Model predictions for mean mass and standard deviation (s) in kg of newborn, 4-month-old, and 10 month-old female caribou calves in the Delta and Nelchina caribou herds.

	Newborns		4 months		10 months	
Herd	Estimate	s	Estimate	s	Estimate	s
Delta	7.85	0.19	57.11	0.61	54.62	0.75
Nelchina	7.98	0.21	52.27	0.69	52.25	0.82

Table 4. Mean metatarsus lengths with standard deviations (s) in cm of female 4-month-old and 10-month-old caribou calves in the Delta caribou herd.

Birth year	4 months Oct length, s, n	10 months Apr length, s, n	Mean length change Oct–Apr
1991	35.6, 0.2, 14	36.3, 0.3, 16	0.7
1992	35.3, 0.2, 15	36.9, 0.3, 12	1.2
1993	35.1, 0.2, 14	n.a.	
1994	36.1, 0.2, 15	37.2, 0.2, 14	1.1
1995	35.7, 0.3, 12	37.0, 0.2, 15	1.3
1996	35.8, 0.2, 14	37.8, 0.4, 8	2.0
1997	36.0, 0.3, 15	36.7, 0.5, 12	0.7
1998	35.7, 0.2, 16	37.2, 0.2, 14	1.5
1999	35.7, 0.3, 13	36.6, 0.3, 12	0.9
2000	35.7, 0.3, 14	37.7, 0.3, 11	2.0
Mean	35.7	37.0	1.3

Table 5. Mean metatarsus lengths with standard deviations (s) in cm of female 4-month-old and 10-month-old caribou calves in Nelchina caribou herd.

Birth year	4 months Oct length, s, n	10 months Apr length, s, n	Mean length change Oct–Apr
1995	35.6, 0.3, 15	37.2, 0.3, 16	1.6
1996	35.5, 0.3, 10	36.8, 0.2, 18	1.3
1997	35.9, 0.3, 10	37.5, 0.1, 15	1.6
1998	35.4, 0.2, 25	37.1, 0.1, 15	1.7
1999	35.9, 0.2, 38	37.5, 0.2, 28	1.6
2000	35.5, 0.2, 36	37.2, 0.2, 25	1.7
Mean	35.6	37.2	1.6

Table 6. Model prediction for mean metatarsus length and standard deviation (s) in cm of 4-month-old and 10-month-old female caribou calves in the Delta and Nelchina caribou herds.

	4-month-olds		10-month-olds	
Herd	Estimate	s	Estimate	s
Delta	35.66	0.10	37.01	0.14
Nelchina	35.62	0.11	37.23	0.15

Table 7. Natality rates of radiocollared known-aged female caribou in the Delta caribou herd, 1991–2000.

	Proportion parturient (%) in late May						
Year	Yearlings	2-year-olds	3-year-olds	4-year-olds	5-year-olds	≥6-year-olds	All cows 3 years and older
1991	0/4 (0)		2/7 (29)	8/10 (80)	3/3 (100)	11/14 (79)	24/34 (71)
1992	0/16 (0)	0/5 (0)	0/1 (0)	6/7 (86)	8/8 (100)	12/12 (100)	26/28 (93)
1993	0/11 (0)	0/10 (0)	0/5 (0)	0/1 (0)	1/3 (33)	6/15 (40)	7/24 (29)
1994	0/10 (0)	0/12 (0)	2/9 (22)	4/5 (80)	1/1 (100)	13/15 (87)	20/30 (67)
1995	0/13 (0)	0/7 (0)	7/11 (64)	8/8 (100)	4/5 (80)	13/13 (100)	32/37 (86)
1996	0/16 (0)	1/11 (9)	5/5 (100)	9/10 (90)	6/6 (100)	15/16 (94)	35/37 (95)
1997	0/12 (0)	0/11 (0)	5/10 (50)	3/4 (75)	8/9 (89)	16/17 (94)	32/40 (80)
1998	0/17 (0)	1/8 (13)	9/10 (90)	7/7 (100)	3/3 (100)	18/22 (80)	37/42 (88)
1999	0/10 (0)	1/13 (8)	6/7 (86)	5/7 (71)	7/7 (100)	16/17 (94)	34/38 (89)
2000	0/9 (0)	0/10 (0)	8/12 (66)	5/5 (100)	6/6 (100)	14/18 (78)	33/41 (80)
2001	0/15 (0)	1/7 (14)	2/8 (25)	8/10 (80)	4/6 (67)	15/17 (88)	29/41 (71)
All years	0/133 (0)	4/94 (4)	46/84 (55)	52/65 (80)	51/57 (89)	149/176 (85)	309/392 (79)

Table 8. Natality rates of radiocollared known-aged female caribou in the Nelchina caribou herd, 1993–2000.

	Proportion parturient (%) in late May						
Year	Yearlings	2-year-olds	3-year-olds	4-year-olds	5-year-olds	≥6-year-olds	All cows 3 years and older
1993							19/29 (66)
1994							NA
1995							18/20 (90)
1996		0/7 (0)					10/15 (66)
1997		0/2 (0)	3/6 (50)	NA	NA	5/6 (83)	8/12 (66)
1998		0/2 (0)	5/11 (45)	6/8 (75)	NA	6/7 (86)	17/26 (65)
1999		NA	3/12 (25)	6/9 (66)	2/6 (33)	6/7 (86)	17/34 (50)
2000		NA	0/8 (0)	6/10 (60)	4/10 (40)	5/5 (100)	15/25 (60)
2001		0/5	1/6 (10)	6/6 (100)	7/8 (75)	9/14 (64)	23/34 (68)
All years		0/16 (0)	12/43 (28)	24/33 (73)	13/24 (54)	31/39 (79)	127/195 (65)

have expected to see consistently higher newborn calf mass (cf. Skogland, 1984), but mass of newborn calves was similar in both herds. Because of the apparently superior summer nutrition of Delta caribou we expected to see consistently higher natality in Delta females (cf. Reimers, 1997). Natality rates of 3- to 5-year-old Delta females were higher than natality rates of 3- to 5-year-old Nelchina females.

Despite higher natality and better summer nutrition in the Delta Herd, relatively few calves remained in the herd in autumn because of heavy predation by wolves, grizzly bears (*Ursus arctos*), and golden eagles (*Aquila chrysaetos*) (Valkenburg et al., 2002). Despite the higher natality of the Delta Herd, autumn calf:cow ratios in the Nelchina Herd were consistently higher than in the Delta Herd. During winter, mortality of the radiocollared calves was similar in both herds (i.e., about 40%) (Tobey & Scotton, 2001; Valkenburg et al., 2002).

Historically, the Nelchina Herd reached a population high of about 70 000 during the early 1960s, followed by a major decline to less than 10 000 by 1972 (Van Ballenberghe, 1985; Eberhardt & Pitcher, 1992). There has been much debate about causes of the decline, but there was clear evidence that nutrition was limiting (Eberhardt & Pitcher, 1992). In view of the strong evidence of nutritional limitation on summer range while the herd has recently fluctuated between 50 000 and 30 000, it seems even more unlikely now that the high caribou population present on the Nelchina range in the 1960s was sustainable. Similar strong evidence of limiting summer nutrition was not documented in the Delta Herd during its population high in 1989, although the herd peaked and declined so rapidly that there may not have been sufficient time for evidence of poor summer nutrition to become obvious (Valkenburg et al., 1996).

Management implications

At present, harvestable surpluses of caribou are relatively low in the Nelchina and Delta herds and harvest must be restricted largely to males to keep herd sizes from declining. To increase harvestable surpluses of caribou in the Delta Herd it may be desirable to increase herd size slightly (perhaps to about 4000-5000) even though there are indications that winter food is not abundant. At the present time there is no evidence that winter range is significantly limiting population growth either through production or survival. However, if herd size is increased we expect that body condition of females would decline during winter (particularly during severe winters), and neonatal calf survival would eventually decline (Adams et al., 1995). It appears therefore, that reducing predation is the only real option for increasing harvest -- the herd is currently stable or declining slowly because of high mortality of calves in summer and this mortality is not related to nutrition (Valkenburg et al., 1999; Valkenburg et al., 2002).

In the Nelchina Herd, reducing herd size further or maintaining it at about 30 000 may alleviate overuse of summer range and thus improve natality in 3- to 5-year-olds. The dilemma for managers of the Nelchina Herd is that predation is probably already a significant limiting factor, and reducing herd size further might exacerbate the problem. However, it seems inadvisable at present to allow herd size to increase because of the already strong effect of the heavily used summer range on natality.

Acknowledgements

We thank J. Larrivee, L. Larrivee, R. Swisher, and T. Cambier, J. Woolington, J. Selinger, M. Potter and D. Young for help with flying and/or fieldwork. L. McCarthy, S. Arthur, A. Magoun, and S. Peterson reviewed and suggested improvements on early drafts of the manuscript. Funding for this study was entirely from the Federal Aid in Wildlife Restoration program and matching funds provided by Alaskan hunters and trappers. This paper was improved with comments by Serge Couturier and one anonymous reviewer.

References

Adams, L. G., Singer, F. G. & Dale, B. W. 1995. Caribou calf mortality in Denali National Park, Alaska. – J. Wildl. Manage. 59: 584-594.

Adams, L. G. & Dale, B. W. 1998. Reproductive performance of female Alaskan caribou. – J. Wildl. Manage. 62: 1184-1195.

Beninde, J. 1988 (original publication 1937). Natural history of red deer. Paul Parey, Hamburg and Berlin. 223pp. (In German).

Bergerud, A. T. 1964. A field method to determine annual parturition rates for Newfoundland caribou. – J. Wildl. Manage. 28: 477-480.

Boertje, R. D., Valkenburg, P. & McNay, M. E. 1996. Increases in moose, caribou, and wolves following wolf control in Alaska. – J. Wildl. Manage. 60 (3): 474-489.

Clutton-Brock, T. H., Guiness, F. E. & Albon, S. D. 1982. Red deer; behavior and ecology of two sexes. University of Chicago Press, Chicago.

Crete, M. & Huot, J. 1993. Regulation of a large herd of migratory caribou: summer nutrition effects calf growth and body reserves of dams. – Can. J. Zool. 71: 2291-2296.

Doerr, J. 1979. Population analysis and modeling of the Western Arctic caribou herd with comparisons to other Alaskan Rangifer populations. Thesis, University of Alaska Fairbanks. 340pp.

Eberhardt, L. L. & Pitcher, K. W. 1992. A further analysis of the Nelchina caribou and wolf data. – Wildl. Soc. Bull. 20 (4): 385-395.

Gaillard, J. M., DeLorme, D., Boutin, J. M., Van Laere, G. & Boisaubert, B. 1996. Body mass of roe deer fawns during winter in 2 contrasting populations. – J. Wildl. Manage. 60: 29-36.

Klein, D. R. & Strandgaard, H. 1972. Factors affecting growth and body size of roe deer. – J. Wildl. Manage. 36: 64-69.
Lenart, B., Bowyer, R. T., Ver Hoef, J. & Ruess, R. W. 2002. Climate change and caribou: effects of summer weather on forage. – Can. J. Zool. 80: 664-678.
McEwan, E. H. & Wood, A. J. 1966. Growth and development of the barren-ground caribou: heart girth, hind foot length, and body weight relationships. – Can. J. Zool. 44: 401-411.
Peters, R. H. 1983. The ecological implications of body size. Cambridge University Press, New Haven, Connecticut.
Reimers, E. 1983. Growth rate and body size differences in Rangifer, a study of causes and effects. – Rangifer 3 (1): 3-15.
Reimers, E. 1997. Rangifer population ecology: a Scandinavian perspective. – Rangifer 17: 105-118.
Reimers, E., Klein, D. R. & Sorumgaard, R. 1983. Calving time, growth rate, and body size of Norwegian reindeer on different ranges. – Arct. Alp. Res. 15: 107-118.
Russell, D. R., Martell, A. M. & Nixon, W. A. C. 1993. Range ecology of the Porcupine Caribou Herd in Canada. – Rangifer Special Issue No. 8. 168pp.
Skogland, T. 1983. The effects of density dependent resource limitation on size of wild reindeer. – Oecologia 60: 156-168.
Skogland, T. 1984. The effects of food and maternal conditions on fetal growth and size in wild reindeer. – Rangifer 4 (2): 39-46.
Skogland, T. 1985. The effects of density-dependent resource limitation on the demography of wild reindeer. – J. Anim. Ecol. 54: 359-374.
Tobey, R. W. 1993. Nelchina Herd caribou management progress report of survey-inventory activities. – In: S. M. Abott (ed.). Alaska Department of Fish and Game. Federal Aid in Wildlife Restoration. Grants W-23-5 and W-24-1. Study 3.0. Juneau, Alaska, pp. 86-100.
Tobey, R. W. 1999. Nelchina Herd caribou management progress report of survey-inventory activities. – In: M. V. Hicks (ed.). Alaska Department of Fish and Game. Federal Aid in Wildlife Restoration. Grants W-24-5 and W-27-1. Study 3.0. Juneau, Alaska, pp. 80-96.
Tobey, R. W. & Scotton, B. 2001. Nelchina Herd caribou management progress report of survey-inventory activities. – In: M. V. Hicks (ed.). Alaska Department of Fish and Game. Federal Aid in Wildlife Restoration. Juneau, Alaska, pp. 90-105.
Valkenburg, P., Tobey, R. W., & Kirk, D. 1999. Velocity of tranquilizer darts and capture mortality of caribou calves. – Wildl. Soc. Bull. 27 (4): 894-896.
Valkenburg, P., Keech, M. A., Sellers, R. A., Tobey, R. W. & Dale, B. W. 2002. Investigation of regulating and limiting factors in the Delta caribou herd. Alaska Department of Fish and Game. Federal Aid in Wildlife Restoration. Research Final Report. Grants W-24-5, W-27-2, W-27-3, W-27-4, and W-27-5. Study 3.42. Juneau, Alaska. In press.
Valkenburg, P., Spraker, T. H., Hinkes, M. T., Van Daele, L. H., Tobey, R. W. & Sellers, R. A. 2000. Increases in body weight and nutritional status of transplanted Alaskan caribou. – Rangifer Special Issue No. 12: 133-138.
Valkenburg, P., Davis, J. L., Ver Hoef, J. M., Boertje, R. D., McNay, M. E., Eagan, R. M., Reed, D. J., Gardner, C. L. & Tobey, R. W. 1996. Population decline in the Delta Caribou Herd with reference to other Alaskan herds. – Rangifer Special Issue No. 9: 53-62.
Van Ballenberghe, V. 1985. Wolf predation on caribou: the Nelchina case history. – J. Wildl. Manage. 49: 711-720.
White, R. G., Bunnell, F. L., Gaare, E., Skogland, T. & Hubert, B. 1981. Ungulates on arctic ranges. – In: L. C. Bliss, J. B. Cragg, D. W. Heal & J. J. Moore (eds.). Tundra ecosystems: a comparative analysis. IBP 25, Cambridge University Press, Cambridge, pp. 397-433.
Whitten, K. R. 1995. Antler loss and udder distention in relation to parturition in caribou. – J. Wildl. Manage. 59: 273-277.