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Calf mortality of semi-domesticated reindeer (*Rangifer tarandus tarandus)* in the Finnish reindeer-herding area

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Abstract: During 1999-2008 calf mortality was studied in six reindeer-herding cooperatives in Northern Finland, where 3942 semi-domesticated reindeer (*Rangifer tarandus tarandus)* calves were equipped with radio mortality collars. The calves were weighed and earmarked mostly at 2-5 days of age, or at 2-8 weeks of age. Altogether 460 dead radio-collared calves were found from calving in May until winter round-ups in October-January. In northern mountain herding cooperatives, the average mortality of calves varied between 7-12%. On average, 39-54% of calves found dead were attributed to predation. Golden eagles killed 0-3.5% of calves in different years and areas in Ivalo and Käsivarsi cooperatives. Golden eagles were responsible for 33-43% of the cases and 84-93% of all identified predation. Most calves killed by golden eagles were found in July-August and in open areas. Calves killed by golden eagles were significantly (P<0.01) lighter than those not predated. No predation occurred in the Poikajärvi cooperative, but the annual mortality of calves varied between 0-35% in cooperatives near the Russian border. In Oivanki cooperative brown bears killed on average 2% of the radio-collared calves. Most predation (87%) occurred at the end of May and in early June. In the Kallioluoma cooperative, predator-killed calves found comprised 53% and wolf-killed 45%. Predation was 70% of total mortality in the Halla cooperative, and predation by wolf, bear, lynx and wolverine comprised on average 38%, 20%, 9% and 2.3%, respectively. The sex and pelt color did not significantly affect survival of calves. Birth weight of calves killed by bears was significantly (P<0.01) lighter than those not killed, but those calves killed by lynxes were significantly (P<0.05) heavier than that survived. Bears killed calves mainly in May-July, wolves in July-October and lynx in August-December.

Key words: calf mortality; predation; radio telemetry; semi-domesticated reindeer; survival.

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Introduction

Several studies have shown the major role of large terrestrial carnivores in neonate and juvenile mortality of different ungulate species (see Linnell *et al.,* 1995). Mortality during the first summer is an important factor in the population dynamics of many reindeer (*Rangifer tarandus tarandus)* and caribou *(R. tarandus)* herds, and predation is usually suspected as the primary cause of mortality (Miller & Broughton, 1974; Page, 1985; Mahoney *et al.,* 1990; Skogland, 1991; Whitten *et al.,* 1992; Adams *et al.,* 1995; Valkenburg *et al.,* 2004). Apart from many herding activities and supplementary feeding during winter months, reindeer are free-ranging most of the year. In the northern parts of Fennoscandia semi-domesticated reindeer comprise an important source of prey

for many predators. A similar situation occurs in Finland, especially during the summer and snow-free periods. These areas share parts of their range with different predators including wolverine *(Gulo gulo),* Eurasian lynx (Lynx lynx), brown bear *(Ursus arctos),* wolf *(Canis lupus),* and golden eagle *(Aquila chrysaetos).* Large carnivores may cause substantial losses in semi-domesticated reindeer by preying on both adults and juveniles (Bjärvall *et al.,* 1990; Nybakk *et al.,* 2002; Danell *et al.,* 2006; Nieminen, 2010). Furthermore, golden eagle and red fox *(Vulpes vulpes)* also prey upon reindeer calves (Nybakk et al. 1999; Tveraa *et al.,* 2003; Norberg *et al.,* 2006).

The aim of this study was to investigate the survival, timing, extent, and causes of reindeer calf mortality in six reindeer-herding cooperatives in the Finnish reindeer husbandry area. Studies have been necessary to assess the role of predation in calf losses and the feasibility of current compensation regimes for predator-killed semi-domesticated reindeer. Some results are published earlier in Finnish reports (Norberg & Nieminen, 2004; 2007; Norberg *et al.,* 2005) and in the journal *Rangifer* (Nieminen, 2010; Nieminen *et al.,* 2011).

Study areas

The reindeer-herding cooperative of Ivalo, situated in the municipality of Inari, northern Finland, covers a total land area of 2626 km^2 (see Fig. 1). In Ivalo, there are two herding-groups, Nellim and Southern area partly separated from each other by a fence. The reindeer-herding cooperative of Käsivarsi, situated in the municipality of Enontekiö, covers a total land area 4658 km^2, and is the second largest among the 56 cooperatives in Finland. The cooperative of Käsivarsi is divided into three separate herding-groups by fences: 1) Palojärvi, 2) Kova Labba, and 3) Raittijärvi. The reindeer-herding cooperative of Poikajärvi (2414 km^2) is situated in the municipality of Rovaniemi. These study cooperatives are situated in the north boreal vegetation zone (Ahti *et al.,* 1964).

In Ivalo cooperative, range is dominated by rolling hills with different aged forest stands, mainly Scots pine *(Pinus sylvestris).* Mountain birch *(Betula pubescens czerepanowii)* grows on the slopes of the highest hills. In Käsivarsi, mountains dominate the landscape. The area of coniferous forests is relative small and located in the southern part of the cooperative. In Poikajärvi, the main landscape types are Scots pine and Norwegian spruce *(Picea abies)* forests. Oivanki (1361 km^2) and Kallioluoma (1369 km^2) cooperatives are located in Kuusamo municipality near the Russian border. The reindeer-herding cooperative of Halla in Kainuu, also located near Russian border and north of the wild forest reindeer *(R. t. fennicus)* area in

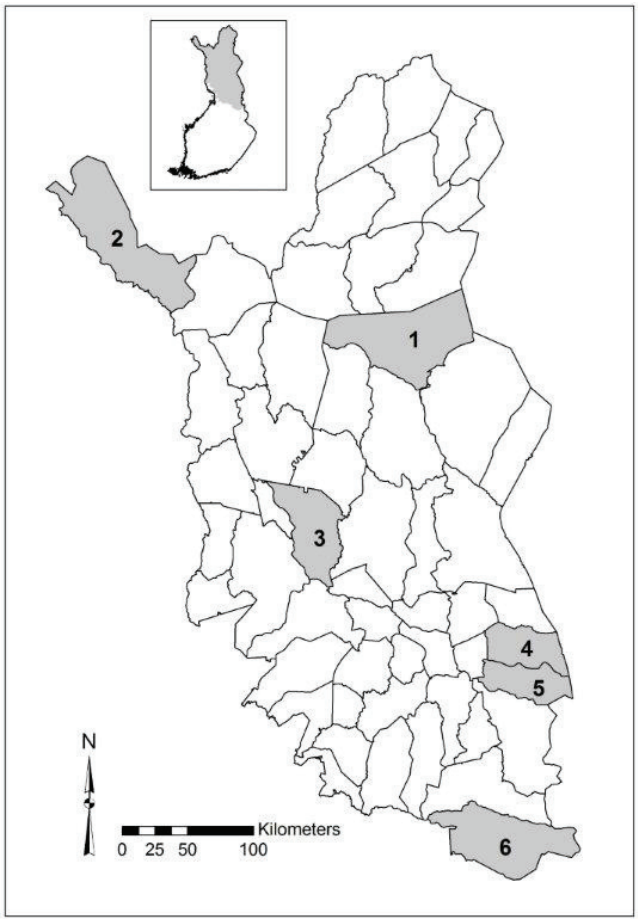

Fig.1. Reindeer-herding cooperatives in the study and Finnish reindeer husbandy area: 1. Ivalo, 2. Käsivarsi, 3. Poikajärvi, 4. Oivanki, 5. Kallioluoma and 6. Halla.

Finland (municipalities of Suomussalmi, Puolanka and Hyrynsalmi), covers a total land area 3592 km^2. It is the eighth largest cooperative in Finland. The cooperatives of Oivanki, Kallioluoma and Halla belong to the middle boreal vegetation zone (Ahti *et al.,* 1968) (Fig. 1). The main landscape types are Norway spruce and Scots pine forests with ericaceous heather and lichen and boggy areas.

There were on average 5660 reindeer (adults and calves after slaughtering) in the reindeer-herding cooperative of Ivalo during the study in 1999-2001, 10690 reindeer in Käsivarsi during 2002-04, 4670 in Poikajärvi during 2001-03, 2440 in Oivanki during 1999-2004, and 2270 in Kallioluoma during 2005-06. In Oivanki, the actual study area was the eastern part of the cooperative confined to Russian border. In Kallioluoma, the study area was between main road 5 and the border with Russia. There were approximately 1200 to 1600 adult (>1 year old) reindeer in the cooperative of Halla during the study 2006-08, and yearly about 500-700 calves were born. Reindeer densities (winter stock/km^2) were similar at 2.1 in Ivalo and 2.3 in Käsivarsi. In Poikajärvi, reindeer density was 1.9, in Oivanki 1.8, in Kallioluoma 1.7, and significantly lower in Halla, at 0.6-0.8 reindeer/km^2.

In the entire Finnish reindeer husbandry area, there were an estimated >160 bears, >75 wolverines, >50 lynx, and 15-25 wolves (RKTL, 2008). During 2000-03 in the entire northern reindeer husbandry area (including the 13 cooperatives) the minimum number of large carnivores was: 45-50 brown bears, 40-45 wolverines, 5-10 lynx, and 3 wolves (Kojola & Määttä, 2004). The most abundant among the large carnivores was brown bear in Ivalo and wolverine in Käsivarsi cooperative. In the eastern reindeer husbandry area, the minimum number of brown bears was 80-85 and 15-20 lynx. Most wolves of the Finnish reindeer husbandry area are found in Kainuu (23 000 km^2). In winter 2008, the size of the wolf population there was estimated at 29-37 animals, a decrease of about 50% compared with the previous year. The population size of the lynx was estimated at 140-190 individuals, including 23-31 litters, and the size of the wolverine population at 36-53 animals (Siira *et al.,* 2009). Faeces samples collected during summer 2005 in Kainuu (Näljänkä and Halla cooperatives) were genetically analysed (DNA), and 46 unique brown bears were identified (RKTL, 2008). In winter 2007, 55-62 wolves were estimated in wild forest reindeer area of Kuhmo (RKTL, 2008).

The golden eagle population in Finland is about 440 pairs or territories. About 80% of all golden eagles occur in Lapland (at most 350 pairs in 2006; Large Carnivore Working Group, 2008) and 90% in whole reindeer herding area. In the Kainuu area, 11 territorial pairs of golden eagles were estimated in 2009 (Ollila, 2009).

Material and methods

We fitted 3942 reindeer calves with mortality indicating radio-transmitters (Televilt Inc., Lindesberg, Sweden) fixed on expandable neck collars in six reindeer-herding cooperatives, in five herding-groups and areas during 1999-2008. Radio collars weighed about 100 grams, about 0.3-2.5% of the body weight of the calves at marking. Calf survival and cause-specific mortality were studied two years in the herding groups of Nellim (1999-2000) in Ivalo and Raittijärvi (2002-03) in Käsivarsi, and three years in other herding-groups (Southern area of Ivalo 1999-2001, Palojärvi and Kova-Labba 2002-04) in these cooperatives and also in cooperatives of Poikajärvi, Kallioluoma and Halla. The Oivanki cooperative study continued six years from 1999 to 2004.

Calves were weighed and marked at 2-5 days of age in calving corrals in May/June. Females were fed in corrals for 1.5 months with silage and concentrates during the spring and calving

periods. Mid-summer earmarking took place in the last weeks of June and the first two weeks of July, when calf age was 2-8 weeks. Calves were marked in different corrals of cooperatives. Calves were sexed and weighed, and pelt color recorded upon which the collared calves were reunited with their mothers and released to summer pastures.

Dead collared calves were located by tracking mortality sensor signals from the air (fixed-wing aircraft and helicopter) and by ground triangulation (sensors activate after 2.5 hrs of being motionless). Tracking was performed in 2-3 day intervals during summer until the end of August, and once per week in September and October. Mortality activated radio-collars were located by using hand receivers (Televilt RX-8910®, Televilt Inc., Lindesberg, Sweden and Tracker Maxima® and hound radars, Tracker Inc., Oulunsalo, Finland). Field observations of the site and carcass were recorded and photographed. Cause of death was first investigated in the field (*e.g.*, evidence supporting presence of predator/scavenger species, such as tracks, scats and feathers/downs) and then augmented by necropsies conducted by biologists in the laboratory of the Reindeer Research Station in Kaamanen. The presence of hemorrhaging and perforations, both in the skin and soft tissues of the dead calf, were critical for determining the cause of death by depredation. If the combined evidence from the field site and the necropsy was inconclusive, usually due to late discovery of carcass, the cause of death was classified as unknown (see also Bjärvall *et al.,* 1990; Norberg *et al.,* 2005; 2006).

Physiological condition of dead reindeer calves in Halla cooperative was determined by using the oven-dry method of metatarsal marrow fat. Condition was expressed as percent of marrow fat (see Nieminen & Laitinen, 1986).

Statistical analysis

Due to the difference in the marking time and age of calves, the weight of calves at marking ranged between 4.2-32 kg, and therefore for statistical analysis the weights were adjusted to 1st June and to 1st July using a daily growth rate of 270 grams (see Timisjärvi *et al.,* 1982) for all calves weighed in the calving corrals in May. A daily growth rate of 302 grams was used for female calves and 315 grams for male calves weighed later during earmarking (Norberg *et al.,* 2005; 2006).

The daily survival estimates and ´reindeer days´ (one ´reindeer day´= one radio-collared reindeer out for one day) for the radio-collared calves were calculated using the Kaplan-Meier product/limit method (Kaplan & Meier, 1958) and using the computer program ´Kaplan-Meier survivorship analysis version 1.0´ (Pollock *et al.,* 1989) to obtain daily and total survival estimates for the study periods. Daily survival estimates were used to present survivorship curves between May/June and October. For calculating monthly survival estimates, cause specific mortality rates and 95% confidence limits, the program ´Micromort version 1.3´ (Heisey & Fuller, 1985) was used.

Survival estimates for this analysis were calculated based on calves that were: 1) found dead, 2) had dropped their radio-collars during the study, or 3) were recovered in the autumn/winter round-ups (survivors) when radio-collars were taken off. The statistical differences in calf weights in different groups were tested using t-test and stepwise logistic regression. In addition to weight, the effect of sex, pelt color, study year, and possible interactions on survival probability were investigated using logistic regression. Statistical tests were carried out by use of SPSS ver. 7.0 for Windows. The data were examined for statistical significance at $P<0.05$.

Results

During calving, 460 radio-collared calves were found dead in the six cooperatives studied. Pooled survival estimates in the mountain co-

operatives of Ivalo (including all radio-collared calves during years 1999-2001) and of Käsivarsi (years 2002-04) were 0.937 (SE=0.011) and 0.885 (SE=0.011), respectively.

Of 806 reindeer calves radio-collared in Ivalo reindeer-herding cooperative during 1999-2001, 4.6% (37 calves) were found dead, 90.4% survived, and 5.0% were not recaptured until the end of the study (annual monitoring from marking until the end of October). Of 919 radio-collared calves in Käsivarsi cooperative during 2002-04 in total 5.2% (48 calves) were found dead, 87.4% survived, and 7.4% were not recaptured. Highest area-specific annual mortality occurred in Ivalo in 2000, when in total 19 (51.4% of all dead calves) were found dead, and in Käsivarsi in 2004, when 20 radio-collared calves (41.7%) were found dead.

In the northern mountain herding cooperatives of Ivalo and Käsivarsi the average mortality of calves varied between 7-12% (Fig. 2). On average, 39-54% of the calves found dead were attributed to predation, and golden eagles killed 0-3.5% of calves in different years and areas in these cooperatives. Golden eagle predation accounted for 33-43% of the cases and 84-93% of all identified predation. The most calves killed by golden eagles were found during July-August and in the open areas.

In Ivalo cooperative, 8% of all calves found dead were killed by brown bear and 3% by red fox, and in Käsivarsi 6% by wolverine and 2% by unidentified predators. Mortality rates caused by predators other than golden eagle were on average less than 1% in both study cooperatives. The share of other identified causes of death (accidents, traffic, others) was 19% in both cooperatives, while 27-40% of dead calves were associated with unknown causes of mortality. In Ivalo during 1999-2001, a total of 8% of all calves found dead were from accidents and collisions with vehicles, while 6% were by accidents in Käsivarsi. Other causes (11-13%) included disease, stress, and poor condition of calves in both cooperatives. When calves with unidentified causes of death were excluded, predation comprised on average 69% of the observed mortality in Ivalo and 74% in Käsivarsi.

Of 404 reindeer calves radio-collared in Poikajärvi reindeer-herding cooperative during 2001-03 only 2.5% (10 calves) were found dead, 93% survived, and 4.5% were not recaptured until the end of the study. The average mortality from calving period in May to the end of October was 5.7% and from 15th June to the end of October 1.4%. No predation occurred, and causes of death included poor condition of calves and traffic.

Annual mortality of calves varied between 0-35% in cooperatives near the Russian border. Of 580 reindeer calves radio-collared in the eastern part of Oivanki during 1999-2004, 7.2% (42 calves) were found dead, 86.6% survived and 6.2% were not recaptured until the end of the study. The average mortality from the calving period in May to the end of October was 9.7% and from 15th June to the end of October was 2.3%. In Oivanki, most mortality (87%) occurred in May and June. The most prominent cause of death was predation by brown bear comprising on average 2% of all radio-collared calves during 2000-04. When calves with unidentified causes of death were excluded, predation comprised on average 50% of the observed mortality in Oivanki. From all identified causes of death (n=18) 33.3% were killed by brown bear and wolverine, while lynx and wolf killed 5.6%.

In the eastern part of Kallioluoma, 139 of 587 radio-collared calves (23.7%) were found dead within the study period 2005-06. Mortality of radio-collared calves was on average 18-19% by the end of June, and 28-29%, 36-39% and 42-46% by the end of October, December, and mid-January, respectively. Predator-killed calves comprised 53% and wolf-killed calves were 45% of all the dead calves found. Wolf predation was on average 18% while the total

rate of all predation was at least 21%. Large carnivores comprised 92-97% of the total predation. The mortality rate due to other sources of mortality than predation was on average 10%. From all identified causes of death (*n*=100 calves) brown bear killed 62%. Bear and lynx killed 3%, and golden eagle 1%.

Of 546 radio-collared reindeer calves during 2006-08 totally 177 (32.4%) were found dead during the research period until mid-January in Halla cooperative in Kainuu area. The total mortality in 2006-08 was 30.7% at the end of October and increased to 34.6% by mid-January (see Fig. 2). Predation was 70% of total mortality, and predation by wolf, bear, lynx, and wolverine comprised on average 38%, 20%, 9%, and 2.3%, respectively. The mortality of reindeer calves was slightly higher in Suomussalmi near Russian border than in Hyrynsalmi/Puolanka area, because of bear and wolf predation. The sex and pelt color did not significantly affect survival of calves.

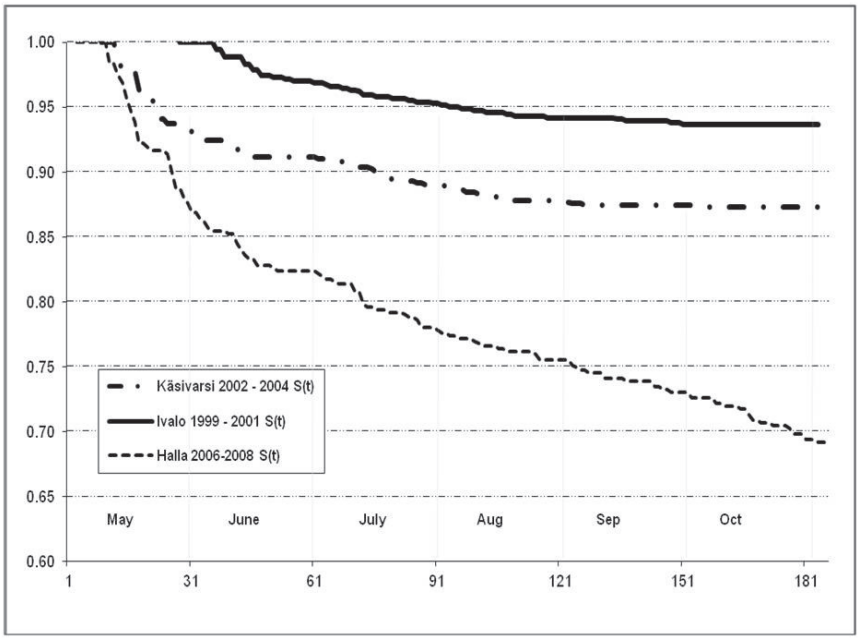

Fig. 2. Total survival curves for radio-collared reindeer calves in Ivalo (in 1999-2001), Käsivarsi (in 2002-04) and Halla (in 2006-08) reindeer-herding cooperatives, expressed as days after 1 May (day 1). (Mortality (M) = 1 – Survival(S)).

The average adjusted weight of those radio-collared calves that survived in Ivalo cooperative was significantly higher (mean 9.8 kg, SD=2.0 kg, *n*=169) than weight of dead calves (mean 7.8 kg, SD=2.2 kg, *n*=12; t=2.79, df=179, P=0.006). Calves killed by golden eagle were significantly lighter (mean 7.2 kg, SD=2.2 kg, *n*=5; t=2.47, df=172) than surviving calves, and also lighter than those calves that died from other causes (mean 8.2 kg, SD=2.4 kg, *n*=7). In Kova Labba herding-group (Käsivarsi cooperative) calves killed by golden eagle were 1.7 kg lighter (mean 10.7 kg, SD=1.4 kg, *n*=5) than those calves that survived (mean 12.4 kg, SD=1.9 kg, *n*=259; t=1.9, df=262, P=0.053).

The average adjusted weight (on 1st July) of those radio-collared calves killed by golden eagles in Ivalo cooperative was significantly lower (mean 12.8 kg, SD=1.7 kg, *n*=11) than mean weight of survivors (16.6 kg, SD=2.5 kg, *n*=560; t=760, df=10.84, *P*<0.001). Also, mean weight of calves killed by all predators was significantly lower (13.1 kg, SD=1.7 kg, *n*=13) than mean weight of survived calves (t=7.05, df=13.17, *P*<0.001). The weight of calves killed by golden eagle in Palojärvi herding-group in Käsivarsi was significantly lower (mean 13.0 kg, SD=1.7 kg, *n*=5) than mean weight of survived calves (19.3 kg, SD=3.4 kg, *n*=280; t=409, df=283, *P*<0.001). Mean weight of calves killed by all predators was significantly lower (12.2 kg, SD=2.2 kg, *n*=7) than mean weight of survived calves (t=5.46, df=285, *P*<0.001). Weight of calves killed by golden eagle in Kova-Labba herding-group was very low and significantly lower (mean 7.2 kg, SD=3.2 kg, *n*=6) than mean weight of survived

calves (13.4 kg, SD=4.3 kg, *n*=28; t=3.03, df=31, P=0.005). No significant effect of pelt color on calf survival in Ivalo and Käsivarsi cooperatives was found.

The average adjusted weight (on 1st June) of those radio-collared calves that were found dead in Poikajärvi cooperative was slightly lower (mean 8.0 kg, SD=2.6 kg, *n*=10) than mean weight of survivors (9.3 kg, SD=2.1 kg, *n*=155; *P*<0.05). The average adjusted weight of those radio-collared calves that were found dead also in Oivanki cooperative was slightly lower (mean 9.3 kg, SD=2.5 kg, *n*=38) than mean weight of survivors (11.0 kg, SD=2.1 kg, *n*=348; *P*<0.001). The weight of calves killed by predators (8.6 kg, SD=1.2 kg, *n*=8) were significantly lower than weight of survivors (11.0 kg, SD=2.1, *n*=347; t=3.23, df=353, P=0.001) (see also Norberg *et al.,* 2005). In contrast to previous calf mortality, the weight of the calves in Kallioluoma cooperative did not have significant effect on the mortality.

Birth weight of calves killed by bears in Halla was significantly (*P*<0.01) lighter, but killed by lynx significantly (*P*<0.05) heavier than that of survivors. Bears killed calves mainly in May-July, wolves in July-October and lynx in August-December. Causes not associated with predation comprised 11.9% of total mortality, and included traffic accident and other accidents. Metatarsal fat content was < 25% in calves dead by bad condition and disease. Excluding the deaths from unknown causes (*n*=11), and if unknown calves eaten by different predators, mainly by bears (*n*=18), were also killed by these predators, total predation was very high, 83.1%.

Birth weight of calves that were lost or killed by predators during the study in Halla was on average 0.2 kg lower (mean 6.3 kg) than that of survivors. Birth weight of calves killed by bears was significantly (*P*<0.05) lower (mean 5.8 kg), but those killed by lynx was significantly (*P*<0.05) higher (mean 6.7 kg). Condition of calves was, however, fair or good (metatarsal fat content > 30%). The birth weight of male and female calves and pelt color did not affect survival differently, as there were no significant interaction between weight, sex and color on calf survival.

Discussion

According to Reimers (1983) mortality rates in calves of Svalbard reindeer *(R. t. platyrhynchus),* existing in an environment almost free of predators, are approximately 1% and 19% in the age intervals 0-6 and 6-12 months. The mortality rates among 0-6 month old reindeer calves is expected to be within the range of 6-21% found also in the predator-free South-Georgia (Leader-Williams, 1980), and lower than 45-60% found in many *Rangifer* herds subject to predation (Rehbinder, 1975; Bergerud, 1980). Wolves, bears, and golden eagles have been the most important predators of radio-tagged reindeer/caribou calves in both North America and Russia, as 80-89% of mortalities were caused by predation (see Bergerud, 1980).

In a study conducted in northeastern Finnish Lapland, mortality from golden eagles comprised annually 3-4% of the radio-collared cohort in 1997-98 (Norberg *et al.,* 2006). In studies conducted in central Norway, Nybakk et al. (1999) found golden eagle predation to account for 1-2% among radio-collared calves, while Kvam et al. (1998) observed a total mortality of 8%, and calves killed by golden eagle comprised 40% of all calves found dead. In the present study golden eagle was also the most significant cause of death both in mountain cooperatives of Ivalo and Käsivarsi, causing up to 3.5% annual mortality rate among radio-collared calves.

The majority of semi-domesticated reindeer calves are born in northern Finland in May with peak calving occurring from 18-23 May (Eloranta & Nieminen, 1986; Weladji *et al.,*

2006). In this study, 52% of calf mortality in Nellim and 87% in Kova-Labba reindeer herding group took place before the end of June. In Oivanki, most mortality (87%) occurred in May-June. According to Linnell et al. (1995) predation generally comprises the major share of the total mortality of juvenile ungulates. Many studies of reindeer/caribou have also demonstrated that calf mortality is usually highest during the first days and weeks after calving and then decreases considerably during summer and autumn (see Eloranta & Nieminen, 1986; Whitten *et al.,* 1992; Adams *et al.,* 1995; Norberg *et al.,* 2005).

In a study conducted in central Norway, 89% of the total mortality of calves from August to April was due to predation, and 60% of calves with identified cause of death were killed by lynx. Predation comprised an even higher proportion, 94% of all identified mortality, when examined from August to mid-November (Nybakk *et al.,* 2002). Also in northern Norway, predation accounted for 75% of the calf losses during summer and winter, and lynx was the main predator (55%) (Mathisen *et al.,* 2003). In Halla, predation caused 70% of all calves found dead and 87% of all identified mortality. Predation by wolf, bear, lynx, and wolverine comprised 38.4%, 20.3%, 9.0%, and 2.3% of all radio-collared calves found dead, respectively (see also Nieminen, 2010).

Highest mortality in mountain areas occurred in this study during July and August and was caused mainly by golden eagles. We conclude that access to, and use of alpine highlands and other open areas influenced the risk of reindeer calves to predation by golden eagles, and subsequently the temporal survival distribution in study cooperatives. We also emphasize the relative importance of golden eagles as a mortality factor in the northern part of the Finnish reindeer husbandry area, where the proportion of open alpine landscape is much higher than in the southern area (see also Nieminen *et al.,* 2011).

The design of the present study in Halla cooperative was similar to that of the four-year program that monitored reindeer calf mortality in Sweden in the 1980s (Bjärvall *et al.,* 1990), and also studies in 1995-96 in central Norway (Nybakk *et al.,* 2002) and in 1997-98 in northeastern Finnish Lapland (Norberg *et al.,* 2006). The total mortality recorded in the present study was, however, much higher (32.4%) than total mortality (14.3%) recorded in Umbyn, Sweden and in Lappi reindeer-herding cooperative in Finland (8.5%). The total mortality was also slightly higher than that in North-Trøndelag in Norway (31.0%) from August to April.

During 2006-08 in the Halla cooperative large predators (mainly wolf and lynx) killed 380 to 455 reindeer yearly, and compensation for predator-killed reindeer to reindeer owners was 5-6.5 times more than slaughter incomes. According to reindeer owners many wolves from Russia and Kuhmo are visiting Halla cooperative and killing reindeer mainly during summers and autumns. Predation accounted for a higher part of total mortality recorded in the present study (70%) than in studies in Sweden (65%) and in Finland (53%). In the Norway study, predation was higher (75.3%) than in the present study. Indeed, caribou herds exposed to predation may lose usually 50% of the annual calf crop (Bergerud, 1980), and predation can constitute up to 93% of total annual mortality in calves (Mahoney *et al.,* 1990). Nevertheless, the annual mortality recorded in the present study was higher than earlier reported from Sweden and Finland. If unknown calves eaten by different predators, mainly by bears, were also killed by these predators, total predation was highest in Halla at 83%. In central Norway 89.3% of the total mortality in calves was also due to predation, and predation by lynx was the dominant cause (42.4%) (Nybakk *et al.,* 2002).

A common perception is that animals preyed upon are either smaller or in poorer nutritional condition compared to survivors, and several studies (*e.g.*, Haukioja & Salovaara, 1978; Eloranta & Nieminen, 1986; Tveraa *et al.,* 2003) have shown that body weight of reindeer calves at calving and also during the first summer is positively correlated with survival. Although golden eagles are capable of killing ungulates up to the size of an adult reindeer in certain conditions (Bergo, 1987), they usually kill smaller than average calves (Nybakk *et al.,*1999; Norberg *et al.,* 2005; 2006). In the radio-collar study conducted in central Norway (Nybakk *et al.,* 1999), calves were marked during July and early August, and calves killed by golden eagles weighed on average 2.7-4.1 kg less than surviving calves. Also in the present study in mountain cooperatives, the weights of calves (adjusted to 1st June and to 1st July) killed by golden eagles were 1-3.8 kg lower than weights of survived calves. Mean weight of calves killed by all predators was also lower than mean weight of calves that survived, but there was no significant difference in weights of predator-killed calves compared to calves that died on other causes.

Birth weight of calves that were lost or killed by predators in Halla cooperative was slightly lower, but birth weights of calves killed by brown bears were significantly (P<0.05) lower than surviving calves. In our earlier study in nine reindeer herding cooperatives in Finland, birth weight of the lost calves was on average 0.4-0.5 kg lower than birth weight of the survived calves. In Oivanki cooperative, calves killed by bears also had 0.5 kg lighter birth weight compared to those that survived (Norberg *et al.,* 2002). Calves killed by lynx in Halla had, however, significantly (P<0.05) higher birth weight (mean 6.67 kg) than surviving calves. Most small calves were lost or killed by bears during early and mid-summer, and lynx killed bigger reindeer calves mainly during autumn. Also in central Norway predation by lynx peaked in autumn and early winter (Nybakk *et al.,* 2002).

In the present study, golden eagles were responsible for 33-43% of the cases and 84-93% of all identified predation in mountain cooperatives in the northern Finland. Most calves killed by golden eagles were found during July-August and in open areas. Predator-killed calves comprised >50% and wolf-killed calves 45% of all the dead calves found in Kallioluoma, in the southeastern cooperative near border of Russia. Our results showed, however, highest predation and calf mortality in Halla, in the southern cooperative, also near the Russian border and wild forest reindeer area of Finland. The total mortality was >30% at the end of October and reached 35% by mid-January. Predation was 70% of total mortality, and predation by wolf comprised on average 38% and by brown bear 20%. The economic consequences for reindeer husbandry of this area makes it questionable to what extent reindeer husbandry in its present form can be continued in Kainuu, southeastern reindeer-herding region of Finland.

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