Supplement 1.

Section S1. Methods and data sets

S1.1. Reindeer herding system

Reindeer herding in Finnmark is organized into six major regions with winter pastures in the interior and summer pastures along the coast (Fig. 2 in main article). Within each region, herds are kept in separate pastures. However, some mixing of herds do occur in winter, notably when access to food is scarce and reindeer increase their search for food. Well-defined borders for winter pastures of each herd are missing. Conversely, all herds have well defined summer pastures that are separated by lakes, fjords and man-made fences.

Herding between summer and winter pastures requires coordinated activity to avoid mixing of animals belonging to different owners. Generally, herds utilizing the innermost parts of the winter pastures, close to the Finnish border, are the last to start migration towards the summer pastures, and the first to return to the winter pastures. On the way back and forth, in spring and fall, they graze on the winter pastures of herds located on peninsulas and islands, i.e. those that are the first to leave the winter pastures and the last to return. Herds with summer pastures on islands are generally heavier than those with summer pastures in the interior. Yet, fewer calves are marked per female than herds with summer pastures close to the winter pastures.

Reindeer in Finnmark are free ranging throughout most of the year and are gathered just a few times annually for calf marking, slaughtering and herding between winter and summer pastures. During these gatherings, herders count the total number of animals by sex and age and report the numbers for late winter (31 March). In addition, the number of calves is counted in summer or early autumn prior to the rut (mid-September) when calves are captured and earmarked according to owner. Herders have to report data regarding population size, recruitment and losses to the Reindeer Husbandry Administration annually. These data are managed by the Norwegian Agriculture Agency (https://www.landbruksdirektoratet.no/) and form the basis for the data on reindeer used here. We restricted the current study to the six reindeer management regions with winter pastures in the interior of Finnmark (Karasjok West, Karasjok East, Kautokeino Mid, Kautokeino West, Kautokeino East and Polmak/Varanger) constituting 43 management districts.

S1.2. Calf slaughter weights as a measure of adult condition

Our analysis assume that calf slaughter weights in the previous autumn is a good measure of the general condition of animals in the reindeer herd before the breeding season, including the condition of adult female reindeer. To evaluate this assumption we combine data on the live weight of adult female reindeer with the data on average calf slaughter weights used in the analyses. Data on live adult female reindeer body weights have been collected in a range of individual based studies of semi-domesticated reindeer in Norway (see (see Bårdsen & Tveraa 2012, Ballesteros et al. 2013, Tveraa et al. 2013) and found to be a strong predictor of female reproductive success (e.g. Bårdsen & Tveraa, 2012). Here we use data from the years 2002-2014 from 10 semi-domesticated reindeer herds. One herd contributed with data from all 12 years, while two of the herds contribute with data from only 1 year. In total 53 herd by year observations were used to evaluate the relationship between the average autumn calf slaughter weights and average autumn adult female live weights, and 55 herd by year observations were used to evaluate the relationship between average autumn calf slaughter weights and the average adult female live weights in the subsequent spring. The average autumn calf slaughter weights showed a positive relationship to both average autumn adult female live weights ($r = 0.57$, Fig. S2a) and to the average spring adult female live weights ($r = 0.54$, Fig. S2b).

S1.3. JAGS model code

```
model {
# Define the priors for the parameters
## Reproductive success sub-model parameters
BwsnowT ~ dnorm(0,0.0001)     # prior for Winter snow slope temporal
BsponT ~ dnorm(0,0.0001)      # prior for Spring onset slope temporal
BplprodT ~ dnorm(0,0.0001)    # prior for Plant productivity slope
BnadT ~ dnorm(0,0.0001)       # prior for number of adults slope temporal
BjervT ~ dnorm(0,0.0001)      # prior for Plant productivity slope temporal
BgaupeT ~ dnorm(0,0.0001)     # prior for Plant productivity slope temporal

## Body condition sub-model parameters
BMwsnowT ~ dnorm(0,0.0001)    # prior for Winter snow slope temporal
BMsponT ~ dnorm(0,0.0001)     # prior for Spring onset slope temporal
BMplprodT ~ dnorm(0,0.0001)   # prior for Plant productivity slope temporal

for (s in 1:Nsite){ # full random slopes model
## Note that calf body mass (CBM) is used as a proxy for body condition, but the notation
## CBM is used throughout the code
Bcbm[s] ~ dnorm(mu.betabm,inv.var.betabm)      #  prior for calf body mass slope
BMnad[s] ~ dnorm(mu.betanad,inv.var.betanad)   #  prior for DD slope on body mass
}  # Random slope

## Hyperpriors for heterogeneous effects
inv.var.betabm  ~ dgamma(0.1, 0.1)
mu.betabm       ~ dnorm(0,0.001)
inv.var.betanad  ~ dgamma(0.1, 0.1)
mu.betanad       ~ dnorm(0,0.001)

## Fixed geographic type effect
```

```
for(j in 1:Ntype){ # 3 types; Island, Island-Continental and Continental
Btype[j] ~ dnorm(mu.beta,inv.var.beta)   #  Fixed geographic Type effect
BMtype[j] ~ dnorm(mu.betatbm,inv.var.betatbm)   #  Fixed geographic Type effect
            }

## Hyperpriors for fixed geographic effect
inv.var.beta  ~ dgamma(0.1, 0.1)
inv.var.betatbm  ~ dgamma(0.1, 0.1)
mu.beta  ~ dnorm(0,0.001)
mu.betatbm  ~ dnorm(0,0.001)

## District random effect
tau.dist <- 1 / (s.dist * s.dist)
tau.distbm <- 1 / (s.distbm * s.distbm)
s.dist ~ dunif(0,1000)
s.distbm ~ dunif(0,1000)
for (i in 1:Nsite){
B0.dist[i] ~ dnorm(0, tau.dist)
BM0.dist[i] ~ dnorm(0, tau.distbm)
             }
## process error
tau.pro <- 1 / (sdtau.pro * sdtau.pro) # Process noise precision
tau.probm <- 1 / (sdtau.probm * sdtau.probm) # Process noise precision
sdtau.pro ~ dunif(0, 1000)
sdtau.probm ~ dunif(0, 1000)

## measurement error:
tau.err <-  1 / (sdtau * sdtau) # precision (i.e. tau) for the m.error variance
sdtau ~ dunif(0,1000)
```

```
## normal for calf body mass

for (s in 1: Nsite){

for (t in 2: nyears){ # because we have to use the previous year to predict calf body mass at year t

Cbmass[s,t] ~ dnorm(muCBM[s,t], tau.probm)

muCBM[s,t] <- BMtype[Type[s]] + BM0.dist[s] + BMwsnowT*Wsnowt[t-1] + BMsponT*Sonsett[t-1] + BMplprodT*Pprodt[t-1] + BMnad[s]*Nadults[s,t-1] ## Only temporal effects # random slope DD


logitf[s,t] ~ dnorm( mu[s,t] , tau.pro ) ## including process error

## Constrain parameters using regression on the link scale

mu[s,t] <- Btype[Type[s]] + B0.dist[s] + BwsnowT*Wsnowt[t] + BsponT*Sonsett[t] + BplprodT*Pprodt[t] + BnadT*Nadultst[t] + Bcbm[s]*muCBM[s,t] + BjervT*Njervt[t] + BgaupeT*Ngaupet[t] # Only temporal effects

f[s,t] <- exp(logitf[s,t])/(1+exp(logitf[s,t])) #

        }

        }


# Likelihood

for (s in 1: Nsite){

for (t in 2: nyears){

K[s,t] ~ dnorm(log(rho[s,t]), tau.err) # Calves

rho[s,t] <- S[s,t] * f[s,t]  # NB: No measurement error in the no females


 res[s,t] <- K[s,t] - log(rho[s,t])

 Calf.new[s,t] ~ dnorm(log(rho[s,t]), tau.err)

 res.new[s,t] <- Calf.new[s,t] - log(rho[s, t])

        }

        }

#### Derived quantities: fit statistics

fit <- sum(res[,2:nyears])  #

fit.new <- sum(res.new[,2:nyears])  #
```

```
# Predictions: should not take into account process variance (cf. Williams 1982-extra-binomial variation). Does not matter much here.

for(s in 1:Nsite){

for(t in 2:nyears){

PredK[s,t] <- (exp(mu[s,t])/(1+ exp(mu[s,t])))*S[s,t]

#PredK[s,t] <- (exp(mu[s,t]+0.5*(sdtau.pro*sdtau.pro))/(1+ exp(mu[s,t]+0.5*(sdtau.pro*sdtau.pro))))*S[s,t]

        }} #


}
```

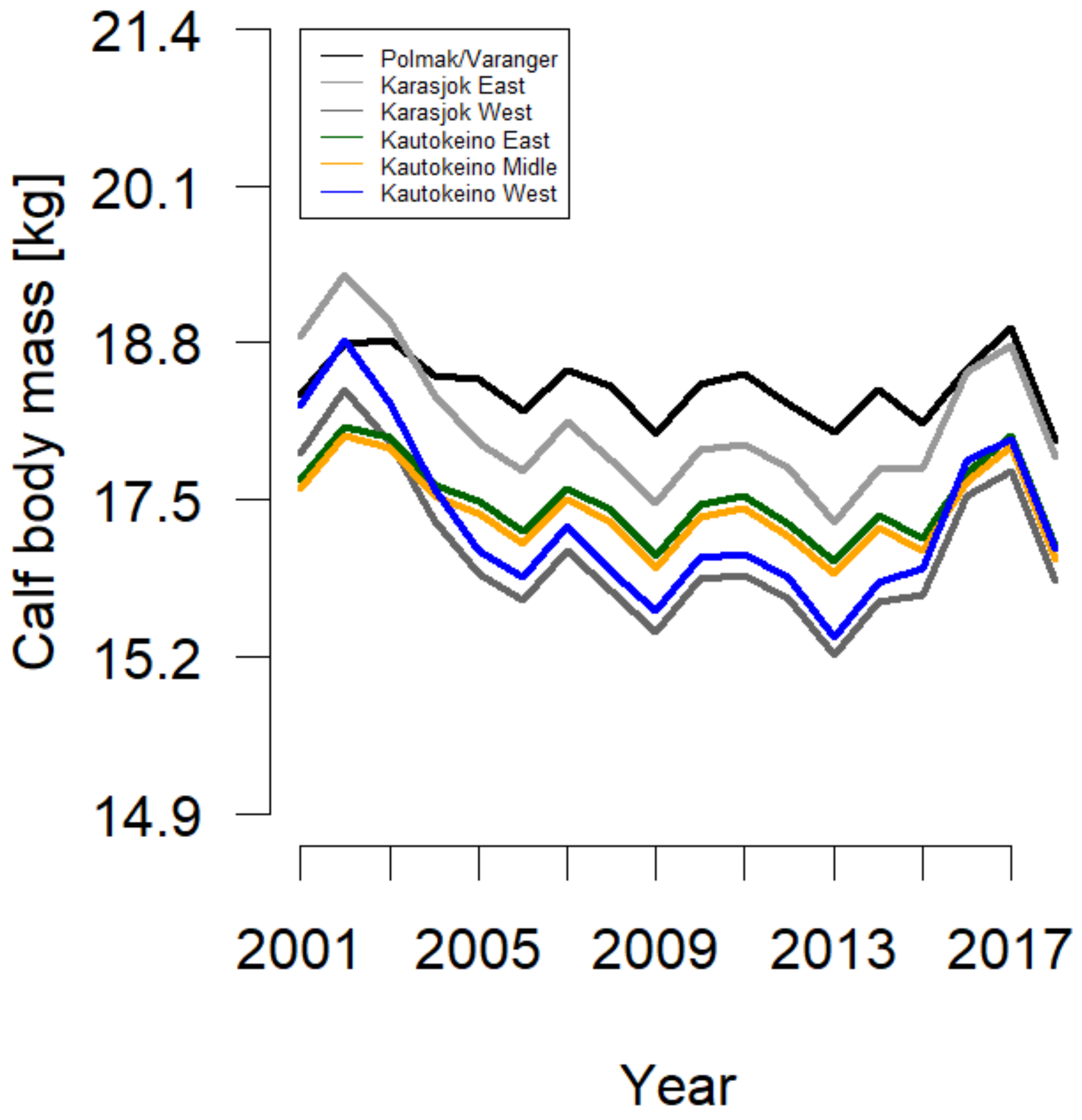

Fig. S1. Model based estimates of calf body mass across years for the six regions in Finnmark. Note that values for body condition are taken from the latent variable in the model (i.e. $\mu BC_{s,t}$).

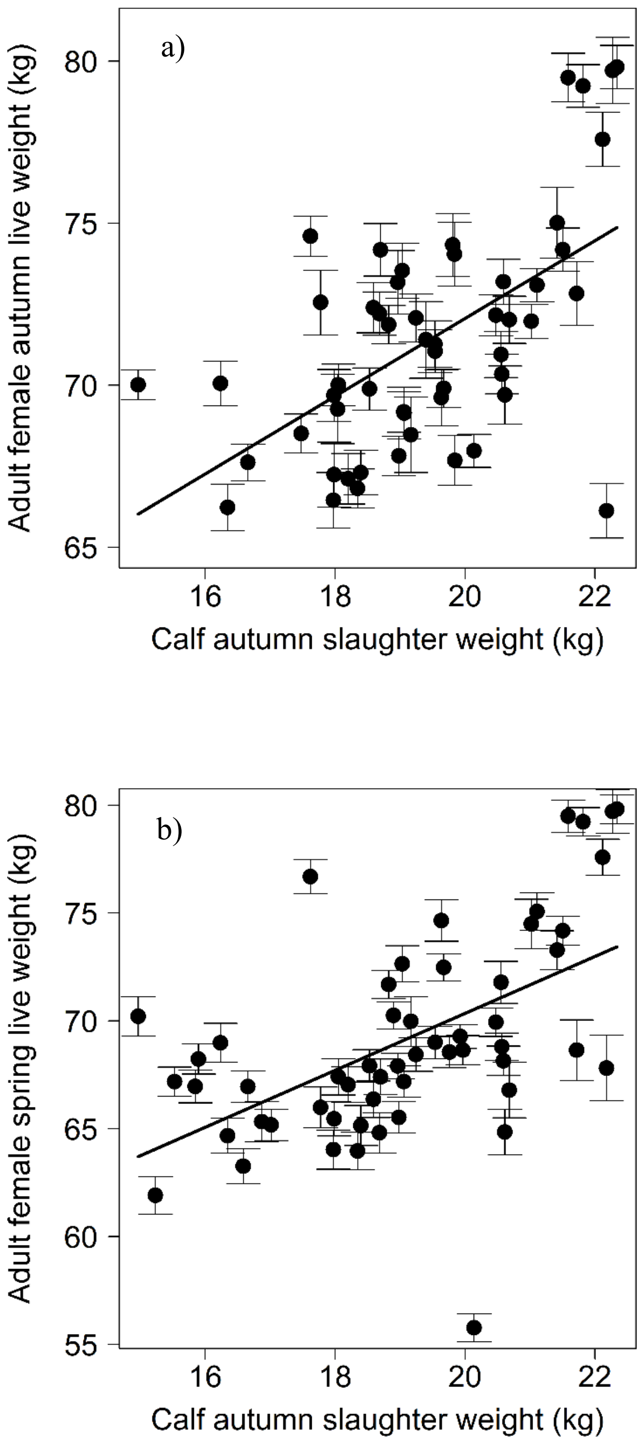

Fig. S2. The relationship between average autumn calf slaughter weights and a) the average live weight of adult female reindeer in the herd the same autumn, b) the average live weight of adult female reindeer in the same herd the subsequent spring. The best fit regression lines drawn in the figures (adult live weight = β_0 + β_1 * calf slaughter weight), are given by for a) β_0 = 48.1 (SE = 4.7), β_1 = 1.20 (SE = 0.24), and for b) β_0 = 44.0 (SE = 5.4), β_1 = 1.32 (SE = 0.28).

LITERATURE CITED

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