Estimating Maternal Effects on Growth of Reindeer (*Rangifer t. tarandus*)

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Introduction

Meat production is the main source of revenues from reindeer. Calves, slaughtered at age of 5 – 7 months, make up the main part of meat production. Maternal effects influence greatly calf growth and survival in reindeer and are therefore important factors in meat production (e.g. Weladji et al. (2003)).

Reindeer herders select the breeding animals based on their phenotypes in the hasty round-ups in autumn. Mass selection for size and growth of calves only, may lead to losses in maternal ability, due to possible negative genetic correlation between production and maternal traits. Therefore it is crucial to consider also maternal effects in selection.

Maternal effects are poorly studied in reindeer. Maternal effects remain undistinguished without knowledge of sires. Until recently, sufficient pedigree data with paternal information have not existed. In this study we estimate the genetic components of growth of reindeer and distinguish also the maternal effects in the variation of weights.

Material and methods

Material. Traditionally kept reindeer, as semi-domesticated animals, have neither individual information nor pedigree data. Finnish Game and Fisheries Research Institute's Reindeer Research Station in Inari, Finland (61°10′N) use experimental herd that is maintained by Reindeer Herders' Association. The herd has been extensively used in research and there are detailed data originating since the late 1960's.

Starting from the year 1987 paternities are confirmed using DNA marker analyses. The analyses are done at the University of Life Sciences in Ås, Norway (Røed et al. 2002). Sire information makes data unique as it is possible to separate dam and sire effects in the data analysis.

Data consist of 1754 animals, weighed at birth in May and before selection in September. In addition pedigree information is available from 3096 reindeer. The yearly number of sires and dams in the herd has been between 0 – 13 and 57 – 94, respectively, in 1987 – 2009. Number of animals with records and family structure are shown in Table 1.

Analysed traits are birth weight (BW) and growth of calf (GR). Growth is calculated by subtracting BW from calf autumn weight and deviding the difference by calf age in days.

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Table 1: Number of weighed animals and of their known dams and sires in the data of the period 1987 – 2009 (purchased animals' parents outside the pedigree)

	Number of born	Sires unknown, dam known	Both sire and dam known	Purchased animals
No. of animals	1706	871	835	48
No. of known parents		289 dams	245 dams 71 sires	

Statistical analyses. (Co)variance components for BW and GR were analysed using restricted maximum likelihood (REML) methodology applied to a multiple trait animal model. Multivariate analysis was performed using DMU package (Jensen and Madsen 2006). The largest fitted animal models had direct genetic (vector $\boldsymbol{a}$) and maternal genetic effects ($\boldsymbol{m}$) and maternal permanent environmental effects ($\boldsymbol{p}$) as random effects. Fixed effecs ($\boldsymbol{b}$) in BW and GR were sex (2 classes), birth year (23 classes) and parity (due to the small numbers of observations only three classes: parities 1–2, 3–8, 9–); in addition calving time in spring (two periods with varying cut point over years) was significant for birth weight. The autumn weights were not corrected for the age at weighing. The following models were used:

$$\boldsymbol{y} = \boldsymbol{Xb} + \boldsymbol{Z_a a} + \boldsymbol{e} \qquad \text{(Model 1)}$$
$$\boldsymbol{y} = \boldsymbol{Xb} + \boldsymbol{Z_a a} + \boldsymbol{Z_m m} + \boldsymbol{e} \qquad \text{(Model 2)}$$
$$\boldsymbol{y} = \boldsymbol{Xb} + \boldsymbol{Z_a a} + \boldsymbol{Z_m m} + \boldsymbol{Z_p p} + \boldsymbol{e} \qquad \text{(Model 3)},$$

where $\boldsymbol{y}$ is the vector of observations. $\boldsymbol{X}$, $\boldsymbol{Z_a}$, $\boldsymbol{Z_m}$ and $\boldsymbol{Z_p}$ are the incidence matrices of fixed effects; direct additive genetic effects; maternal genetic effects and permanent environmental effect of the dam, respectively. Assumptions: $\mathbf{V}(a) = \mathbf{A}\sigma^2_a$, $\mathbf{V}(m) = \mathbf{A}\,\sigma^2_m$, $\mathbf{V}(p) = \mathbf{I}\sigma^2_p$; $\mathbf{V}(e) = \mathbf{I}\sigma^2_e$, where $\mathbf{A}$ is the additive relationship matrix, $\mathbf{I}$ is the identity matrix and σ^2_a, σ^2_m, σ^2_p and σ^2_e are direct and maternal additive genetic, maternal permanent environmental, and residual variances, respectively. The random effects were assumed to follow normal distribution.

Results and discussion

Number of weighed animals and averages with standard deviations are shown in Table 2. Male calves are clearly heavier than females in all ages. Calving time affects BW: heavier females tend to calve earlier and to also have heavier offspring. Parity is significant, because very young and old dams have smaller offspring (Figure 1).

Table 2: Number of weighed animals and means (with standard deviations) of birth weight, autumn weight and growth and differences in weights between sexes

	Birth weight (kg)	Autumn weight (kg)	Daily growth (kg)
Number of records	1673	1320	1286
Male / Female	843 / 823	656 / 655	643 / 642
Average (kg)	5.88 (1.00)	44.46 (6.65)	0.305 (0.056)
Male	6.07 (1.00)	46.19 (7.15)	0.319 (0.059)
Female	5.71 (0.94)	42.80 (5.61)	0.291 (0.049)

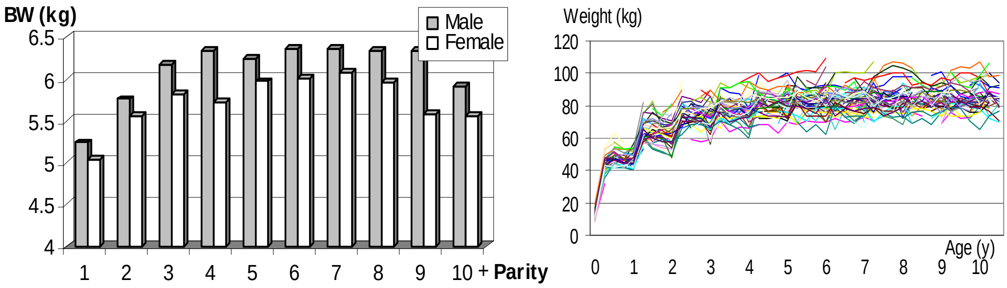

Figure 1: Effect of parity on birth weigth of reindeer calves; and weight change in females over years

Heritability estimates for BW and GR are moderate to high (Table 3). If maternal effects are excluded, heritability is biased upwards in BW. Including maternal genetic and permanent environment effects in the model reduces the direct heritability (h^2_a). Dam's permanent environmental effect (p) hides some part of maternal heritability (h^2_m) especially in birth weight.

Table 3: Estimates of direct (h^2_a) and maternal (h^2_m) heritabilities, proportion of dam's permanent environmental variance over phenotypic variance (c^2) and direct-maternal correlations (r_{am}) in reindeer birth weight and growth$^{\alpha}$

Trait	model	h^2_a	h^2_m	c^2	r_{am}
BW	1	0.50±0.05	-	-	
BW	2	0.30±0.10	0.29±0.06	-	-0.19±0.08
BW	3	0.30±0.11	0.19±0.11	0.07±0.06	-0.18±0.08
GR	1	0.32±0.06	-	-	
GR	2	0.36±0.08	0.24±0.05	-	-0.71±0.20
GR	3	0.35±0.13	0.22±0.12	0.02±0.02	-0.75±0.19

$^{\alpha}$estimates ±S.E.

The results are in line with earlier studies in reindeer. Appel and Danell (1998) reported estimates of direct and maternal heritabilities for calf summer (1 – 2 months old) weight 0.35 and 0.37, and for calf autumn weight 0.18 and 0.15, respectively. They were estimated without paternal pedigree information.

In the studies on goats, sheep and beef cattle, direct and maternal effects on birth weight have been of the range 0.1 – 0.4 and 0.1 – 0.3, and for growth of the range 0.1 – 0.3 and 0.05 – 0.3, respectively (Ligda et al. (2000); Maria et al. (1993), Meyer (1992); Näsholm and Danell (1996); Shaat and Mäki-Tanila (2009)). The high values in reindeer may be due to the good quality of the data.

Direct-maternal correlation (r_{am}) was moderately negative in BW and highly negative in GR, with relatively high standard errors. Appell and Danell (1998) reported also negative r_{am} for reindeer; -0.10 and -0.15 for summer weight and autumn weight, respectively. In sheep, goats and beef cattle the estimates of r_{am} have varied considerably: -0.56 – 0.10 and -0.99 – 0.5 for birth weight and growth, respectively (Maria (1993), Meyer (1991), Shaat and Mäki-Tanila (2009)). Very high negative estimates of r_{am} may indicate suboptimal data structure (Maniatis and Pollott 2003).

Maternal genetic effects are high in reindeer early growth. Applying this information to reindeer breeding in practice is challenging because of the traditional herd management system with no written records of individuals. Selection takes place in round-ups, without any knowledge of sires and as mass selection. Because of the deep, unwritten knowledge of reindeer herders about their animals and dam lines, maternal abilities have been taken into account to some extent.

The results can be used to find the guidelines for planning a breeding scheme for reindeer and support the importance of gathering the maternal information in practice.

Conclusion

The research station data is sufficient for investigating maternal effects on reindeer birth weight and growth. Maternal effects are very important in semi-domesticated animal. Direct and maternal heritabilities are moderate and of the range of parameters in other related species. Due to negative correlation between direct and maternal genetic effects, maternal effects should be considered when selecting breeding animals in order to avoid undesirable development in maternal abilities.

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