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Effects of semi-domesticated reindeer's maternal condition on calf survival

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ABSTRACT

Semi-domesticated reindeer (*Rangifer tarandus*) husbandry in Sweden depends largely on sustainable management and productivity of the herd. Herd productivity is determined by the survival of the herd's offspring from each year, which is affected by factors such as weather conditions, forage abundancy and predation. Predation of the reindeer calves by brown bears (*Ursus arctos*) can become a significant limiting factor of the herd's productivity. Previous studies suggest the reindeer maternal condition to have an effect on calf survival. Data from pregnant reindeer was collected through the years 2010 to 2016 in two Swedish reindeer herding communities with high predation rates (Gällivare and Udtja) as part of a project investigating reindeer calf mortality due to brown bear predation. Among other factors recorded, females were weighed prior to calving and the presence of their calves on the summer and autumn gatherings was recorded individually. Data on reindeer weight at pre-calving was analysed in relation to calf survival. Ordinal regression was used to describe the effect of weight by year and herding community over the probability of calf mortality. Results showed a positive effect of female reindeer's weight at late pregnancy on the odds of survival of the calf until the autumn. The magnitude of the effect of weight was lower than the fixed effect of herding community. Differences in brown bear presence and year-to-year variations can be highly influential on calf survival. The year 2011 was predicted to have the lowest odds of survival, while the reindeer calves in Gällivare community had an overall higher survival rate than the reindeer calves in Udtja.

Keywords: *Rangifer, calf, survival, weight, proportional odds, logistic regression, Sweden.*

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1. Introduction:

1.1 Reindeer husbandry

The history of reindeer (*R. t. tarandus [subspecies]*) domestication dates back to more than thousand years (Borchert, 2001). In Sweden, detailed information of reindeer husbandry dates back to around 400 years, where records of native herders (Sami) begun to be written. The cultural heritage of such practices has been conserved until present times by the same communities that were once nomadic (Bjørklund, 2013). The hunter-gatherer economy of the Sami society is believed to have transitioned during the 16th century from wild reindeer hunting to what would later resemble the pastoralism of contemporary reindeer herders (Lundmark, 2007; Bjørklund, 2013). Throughout their history, fluctuations and alterations of reindeer population in Sweden have been caused by a diversity of factors, from cultural to economic, environmental and political (Lundmark, 2007). The cultural heritage of the Sami has been preserved and recognized internationally, yet its practices are currently facing new challenges that put at risk the success of their traditional ways of living (Hovelsrud *et al.*, 2011).

Reindeer husbandry in Sweden is concentrated in the north, within the counties of Dalarna, Jämtland, Västernorrland, Västerbotten and Norrbotten. In Sweden, there are currently no populations of reindeer in the wild (Kivinen *et al.*, 2010). Constraints of anthropological, ecological, management and climate change-related nature seem to be of most imminent impact for reindeer husbandry (Hovelsrud *et al.*, 2011; Kivinen *et al.*, 2010; Moen, 2008). Rights over use of private-owned land for grazing in northern Sweden that were in dispute for more than a decade were ruled in favour of the herders with sharing rights for the landowners (Torp, 2013), yet conflict over land use has not been completely solved to the likings of both parties (Borchert, 2001). Other raised concerns over industries such as forestry (Widmark, 2009) and mining are still a cause of conflict that compromise the herds' core habitats (Larsen *et al.*, 2018). This creates an effect of cumulative impact, which constrains the availability of pastures, migration paths and calving grounds (Herrmann *et al.*, 2014), creating difficulties for the Sami whose livelihoods depend on reindeer herding.

1.2 Reindeer health and nutrition

Husbandry of semi-domesticated reindeer broadly consists of an extensive grazing system, where herding occurs in a semi-annual migration between summer and winter pastures (Bjørklund, 2013). Herders divide the year in 8 seasons that are denoted by changes in the reindeer's natural activities. The beginning of the year is marked by the gradual exit from winter and entrance to spring, where reindeer move into calving grounds. Land use depends on factors like shelter from cold winds, predators or any type of disturbances that may cause the reindeer to abandon her calf (Jernsletten & Klokov, 2002). Throughout the late spring and until the autumn reindeer feed mostly on leaves from woody plants, graminoids and lichens (Skogland, 1984a). During this period, reindeer graze intensively, accumulating fat until the autumn when pastures wither (Jernsletten & Klokov, 2002; Skogland, 1984a). In forest habitats, insect harassment can influence the selection of foraging paths, which has been suggested to cause a mismatch with "green-up", affecting both the reindeer health and the feed consumption required to overcome the winter (Bergerud & Luttich 2003). When winter arrives, the grazing conditions change and forage availability decreases considerably. Reindeer survives this period with a diet dominated by lichen and complemented with moss and shrubs (Heggberget *et al.*, 2002).

Reindeer's diet niche changes based on the absolute abundance of the most preferred food types (Skogland, 1984a). Since pastures are limited, reindeer husbandry's success turns highly dependent on abundance and quality of such pastures (Lundqvist, 2007). The abundance of forage during the winter period is often considered as a determining factor for the herd size, as winter pastures are less available and its abundance is highly susceptible to changes in weather (Helle & Kojola, 2008). Reindeer have the ability to regulate body reserves as a preventive measure against stochastic occurrences of food shortage, expressing an increased accumulation of body reserves in autumn when risk of low food abundance is high, and losing the gained reserve in spring when the risk has decreased (Fauchald *et al.*, 2004). On the other hand, reindeer can partly compensate for extreme conditions of low forage abundance and quality by forfeiting minerals from their skeleton (Hyvärinen *et al.*, 1977). This however, can have severe consequences over their health and reproductive performance, given that a higher weight of females before calving positively correlates with calf production, (Fauchald *et al.* 2004; Ropstad, 2000). Depending on their age, females with better body condition during winter-spring season have a higher birth weight of their calves and can attain higher growth rates, having a significant impact on fecundity and calf survival (Rognmo *et al.* 1983; Ropstad, 2000).

1.3 Reindeer calving

Reindeer are seasonal breeders, with their rutting period occurring through the decreasing daylight in autumn and the calving with the coming of spring (Ropstad, 2000). The impact of anthropogenic interference and subsequent effects influence some parts of the reindeer's cycle more than others. During the beginning of May, calves are born weighing between five and seven kilograms (Eloranta & Nieminen, 1986) and are highly sensitive to disturbances (Jernsletten & Klokov, 2002). Calves are most vulnerable to predation during the first week and thus selection of an optimal calving ground is crucial for the survival of the offspring (Sivertsen, 2017). For communities located in mountainous regions, calving grounds tend to be located in high-elevation lands, while forest herding communities stay in forested areas throughout the entire year (Berg, 2010). Selection of calving grounds is not randomized and reindeer may sacrifice forage abundance for safety and a reduced predator presence in the area when choosing a location (Barten *et al.*, 2001). This in turn may increase the risk of undernourishment and impose constraints over their reproductive performance during the upcoming year. This trade-off stresses over the need of body reserves and quality forage availability for the consequent survival and productivity of the offspring (Ropstad, 2000; Tveraa *et al.*, 2003).

1.4 On predation and survival

Even though female reindeer with low body condition may prioritize their own survival over the offspring's (Tveraa *et al.*, 2003), calf population directly influences the profit made by herders at the end of the year, once that their principal income is obtained through meat production (Ropstad, 2000). Predators have a significant effect on the mortality of reindeer and other ungulates, such as wolves, lynx, eagles and bears (Linnell & Andersen, 1995).

Lundqvist (2007) determined the presence of large carnivores to be a primary factor that indirectly affects the productivity on reindeer. The growing presence of brown bear (*Ursus arctos*) within the forest herding communities has been seen to pose a significant threat to the Swedish reindeer herds (Karlsson *et al.*, 2012; Sivertsen, 2017). Brown bears distribution in Sweden covers two thirds of the country and is highly associated to forests (Kindberg *et al.*, 2011). Control of their population is done by assigned annual hunting quotas. Swedish population of brown bears increased considerably after the Swedish Environmental Protection Agency's (SEPA) management policy from 1991, which allowed a gradual increase of their population size, reaching a peak in 2008 at around 3298 individuals (Swenson *et al.*, 2017). Development of indicators related to calf survivability may prove important for herd management and prevention of otherwise avoidable losses, in order to maintain a sustainable system of reindeer pastoralism, exclusive of the Sami cultural heritage.

The impact of brown bear presence and predation over the reindeer herds within two forest herding communities (Udtja and Gällivare, Norrbotten County, Sweden) was studied during the years 2010-2012 (The Brown Bear Predation Project; Karlsson *et al.*, 2012; Sivertsen 2017). Information regarding female reindeer's body condition in spring was recorded along with pregnancy diagnose. During the same years, observations about the presence of mothers accompanied by their calves were recorded in two occasions. Once at the summer gathering for calf marking (end of June and beginning of July) and a second time during the end of autumn and beginning of winter where the herd is gathered again and some individuals are selected for slaughter (November and December). The studies showed that brown bears predated on calves during late May and early June, right after calving. Results also suggested that reindeer under higher risk of predation might compromise optimal foraging paths and increase movement frequency (Rivrud et al. 2018), which in turn may deteriorate reindeer's body condition and act as a limiting factor on the upcoming seasons (Sivertsen, 2017; Tveraa *et al.*, 2003).

Part of the data has been previously reviewed in search for correlations of the maternal body condition and the survival of the calves (Persson, 2014). This relation was not supported by the data, likely because a general analysis of the means of each community could not account for the effect of other variables. Still, a relationship between these two factors has been shown in the past, suggesting that a higher weight of the females at calving could lead to a higher survival during the period of winter-spring to autumn-winter seasons (Lenvik & Aune, 1988; Rognmo *et al.*, 1983). GPS studies of reindeer and brown bear resource selection report that herds from forest communities avoid young forests and prefer clear-cuts during predation period, which are avoided by brown bears, yet bear behavioural adjustments to search for calves reduced the effect of the reindeer's antipredator responses (Sivertsen, 2017). Karlsson *et al.* (2012) determined that the most effective method for reducing predation was the hunting of adult female brown bears, suggesting that not every bear affects calf mortality the same way. It is likely that a more detailed analysis of the collected data from the Brown Bear Predation Project could provide information on the effects of maternal condition at pregnancy over calf survival in these communities, as well as to describe the general influences of the community of origin and year-to-year variations.

1.5 Objectives

The main objective of this study is to examine the effects of reindeer female body condition in spring on calf survival throughout summer and autumn by analysing the data of two reindeer herding communities, collected during the years 2010, 2011 and 2012 by the Brown Bear Predation Project (BBPP). The maternal body weight of pregnant reindeer is expected to have a positive effect on the calf's probability of survival, which may interact with other factors such as year and community of origin. An evaluation of the different factors that affect calf survival may provide insight over the risk of predation and prediction of casualties early in the year for both communities; and better describe the severity by which each factor affects the risk of predation by brown bear over the reindeer herds.

2. Materials & Methods:

2.1 Reindeer herds and communities

The reindeer herding communities ("sameby" in Swedish) of Udtja and Gällivare are located in the Norrboten County, Sweden and have their annual pasture rotations located within forest areas all year round. Both territories overlap with areas populated by brown bears. In 2009, Udtja and Gällivare reported a loss of about 40% and 60% of the calves respectively within the first half of the year (Karlsson *et al.*, 2012) and much of the loss was attributed to brown bear predation.

Udtja's land has an area of approximately 2400 km^2, a reindeer calving/post-calving area of about 1300 km^2 and has a maximum capacity of about 2800 reindeer on winter pastures. Gällivare herding community has an area of about 6000 km^2, a calving/post-calving area of 2500 km^2 and a maximum capacity of 7000 reindeer, (Karlsson et al. 2012). The data used in this study were collected from one group of reindeer in Udtja and two groups in Gällivare. The data collection was carried out as part of the BBPP; a collaboration between the Scandinavian Brown Bear project (available at <bearproject.info>), Wildlife Damage Centre, Swedish University of Agricultural Science (SLU) and the Department of Animal Nutrition and Management, SLU. The studies were commissioned by the Swedish government for the assessment and creation of measures that could reduce reindeer losses to bear predation (Karlsson et al. 2012).

2.2 Data sampling

Collection of data occurred from March 2010 to January 2013 as part of the BBPP. During spring (March and April), the herds were rounded up and gathered in corrals. Reindeer females were weighed individually to the nearest kilogram, by passing them through a weighing scale box specifically designed for the purpose. While inside the scale, females were tested for pregnancy by transrectal ultrasonography (Paul, 2014). Animals were then collared with individual identification for tracking and monitoring in two occasions throughout the year. Weighed females that were observed at the gatherings for calf marking during the summer (June and July) were checked for presence of an accompanying calf. Counting of calves was then performed again during late autumn gathering when calves are selected for culling (November and December). Using these records, information of the females could be paired up with the survival of their respective calf through a non-invasive method of observation.

2.3 Statistical analysis

All analyses were performed using "R for Statistical Computing" (R Core Team, 2017). Each female was grouped with her corresponding weight, pregnancy diagnose (if performed) and recorded calf presence (**Table 1**). Survival was scored with value "0" for the calf being absent in the summer checkpoint, a "1" for the calf being present in summer and a "2" for the calf being present in the autumn. A Logistic Regression (LR) was performed using the dataset from Udtja during the years 2010, 2013 and 2016, using the "*glm*" function from the "stats" package (R Core Team, 2017). Based on the information obtained from the LR analysis and in conjunction with previous literature in the subject, a minimum weight was defined for non-tested individuals to be considered pregnant. After a cut-off point was selected, all following analyses were done using this assumption.

Ordinal Logistic Regression (OLR) was implemented to test the effects of female weight on survival, which is preferred when the dependent variable is categorical, has more than two levels and such levels have a natural order (McCullagh, 1980; Warner, 2008). OLRs were performed using the "*polr*" function from the R-package "MASS" (Venables & Ripley, 2002). A link function was defined by a logit "S", which corresponds to the log-odds of an event "*j*". The sample space of *j* corresponds to the calf either perishing before the summer checkpoint (j = 0), surviving until summer (j = 1) or surviving until autumn (j = 2). Due to probabilities being cumulative for each outcome in the model, an intercept "αj" is defined for each category of survival except for (j = 2), once that $P(Y \leq 2) = 1$. Each independent parameter had assigned an effect "β" on the slope of the regression. Thus, the base model was defined as:

$$S_j = \alpha_j - \beta_1 Weight - \beta_2 Year - \beta_3 Sameby$$

Where:

$$S_j = ln\left(\frac{P(Y \leq j)}{1 - P(Y \leq j)}\right)$$

Due to the nature of the "polr" function, β values are inverted for a more intuitive interpretation, where higher β values are correlated to higher ranks of the categorical dependent variable. Thus, the equation subtracts explanatory variables. The explanatory variables included are weight at pregnancy, year of record (2010, 2011 or 2012) and herding community (sameby) of origin (Gällivare or Udtja). *Weight* of female reindeer at the end of pregnancy was defined as a continuous explanatory variable, while year and sameby of sampling were categorical. The building of the model included year and sameby as explanatory variables as they were previously seen to have a strong effect on calf survival (Persson, 2014). Significance of individual variation among females (ID) was tested using the "*clmm*" function from the R-package "ordinal" (Christensen, 2015), which is capable of adding such variation as a random-effect into an OLR. This was done in compensation to the lack of records of reindeer's age at pregnancy, which have been shown to have a significant effect on the fertility of the animal (Ropstad, 2000; Rönnegård *et al.*, 2002).

Under the proportional odds assumption, each β_p value is held constant for all logit forms, producing a single β value for each parameter (p), but a different intercept (α) for each category (j) of the dependent variable. A Likelihood Ratio Test (LRT) was performed to test the proportional odds assumption. Using the "*vglm*" function from the "VGAM" package (Thomas & Wild, 1996), both a Proportional Odds Logistic Regression (POLR) and a Partial Proportional Odds Logistic Regression (PPOLR) were modelled and compared for goodness of fit.

3. Results:

In spring 2010, 1035 female reindeer were tested in Udtja, of which almost all were pregnant and able to be collared with individual ID tags. Gällivare community joined the project in 2011, where the same process was carried out and 893 female reindeer were diagnosed pregnant and collared. During the years 2011 and 2012 in Udtja, 245 additional (to the ones collared in previous years) individuals were weighed and collared but no pregnancy tests were performed, while 457 female reindeer were tested and included in Gällivare between the year 2011 and 2012.

Because the records during summer and autumn were done by visual scanning, some individuals may have not been observed. In addition, it is possible that other individuals were not present in the gatherings. Thus, reductions in the number of observations from the original data were made due to missing records in either spring or summer. Females that were not observed in summer but had a calf present in winter were assumed to have had the calf also present in the summer. The final collection of data from years 2010, 2011 and 2012 that was analysed is summarized in **Table 1**. Data gathered in a second part of the BBPP during the years 2013 to 2016 (n=1952; Frank et al, 2017; Korpinen, 2017) was analysed separately to estimate the probability of pregnancy for non-tested individuals based on their weight.

Table 1: Summary of sampled female reindeer by year and community (sameby). Calves that did not survive beyond spring can be inferred from the difference between observed calves and pregnant females.

Sameby (Years)	Total no. of individuals	Weight ≥ 60Kg	Tested	Pregnant	Pregnant or weight ≥ 60Kg	No. of observed females with calf	
Gällivare						*Summer*	*Autumn*
(2011)	486	384	416	396	466	294	97
(2012)	216	178	216	188	188	134	51
Udtja							
(2010)	698	617	698	698	698	441	284
(2011)	648	589	0	-	589	325	110
(2012)	227	191	0	-	191	98	50
Total	**2275**	**1959**	**1330**	**1282**	**2132**	**1292**	**592**

3.1 Preliminary analysis of pregnancy

Female reindeer sampled in Udtja during the years 2010, 2013 and 2016 had a mean weight in spring of 74.8 kg (SD = 9.8), with 94.5% being pregnant. During the sampled years a small amount of weighed individuals resulted in negative pregnancy diagnose (n = 107; total sample = 1952). The mean weight of pregnant females is 0.36 kg higher than the mean weight of all females (**Table 2**). Individuals not diagnosed as pregnant showed lower weights in average, yet only seven kilograms below the average weight of pregnant individuals.

Table 2: Reindeer weight distribution by pregnancy diagnose. Weight in kilograms.

Pregnancy diagnose	Min. weight	1st quartile	Median weight	Mean weight	3rd quartile	Max. weight
Negative	35.0	62.5	71.0	68.0 ±10.7	76.0	87.0
Positive	40.0	69.0	76.0	75.2 ±9.6	82.0	100.0

Output from logistic regression is summarized in **Figure 1**. The results predict a positive pregnancy diagnose probability of 95% (P= 0.952, 95% CI [0.942, 0.962]) for a female reindeer weighing 74 kg in spring; and 96.7% (P= 0.968, 95% CI [0.959, 0.977]) for 80 kg.

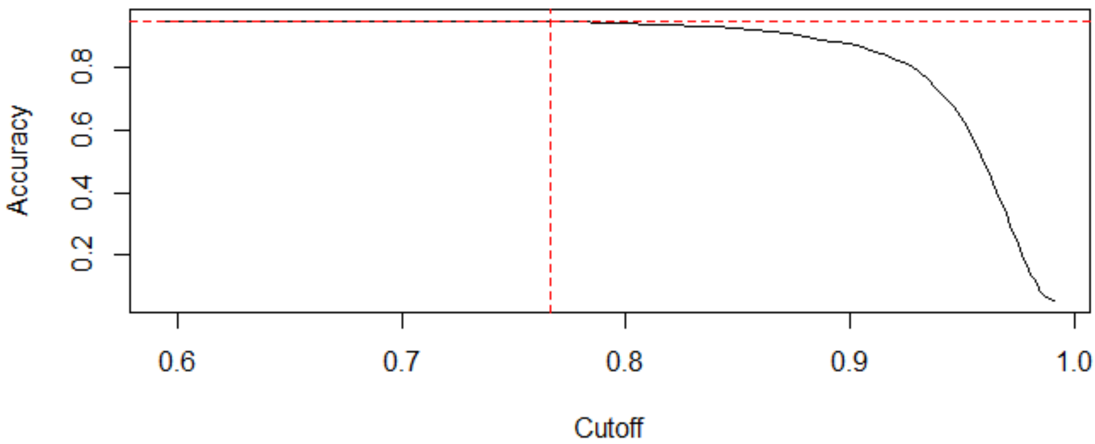

Figure 2: Plot of accuracy of prediction vs cut-off point for assumption of positive pregnancy.

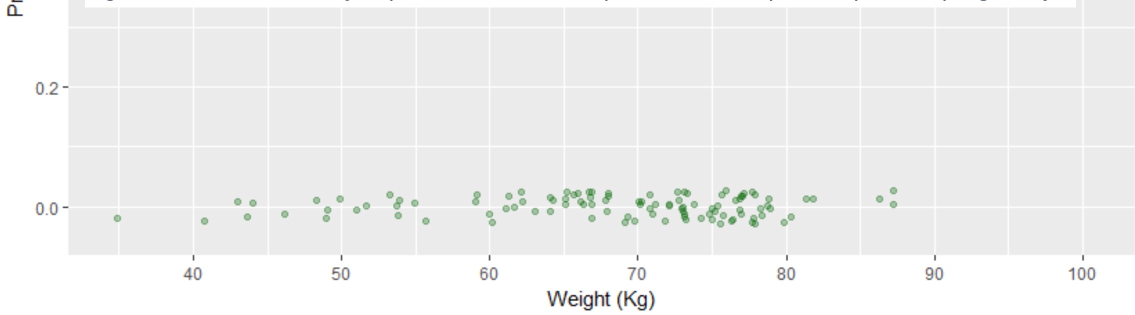

Figure 1: Logistic Regression plot on data from individuals tested during years 2010, 2013 and 2016.

Based on ROC Curve information, maximum accuracy of prediction is 0.947 percent (**Figure 2**), which corresponds to a cut-off point of 47 kg (Cut-off point at P = 0.766). Assuming a positive pregnancy for all the sampled individuals, 5.5% would be comprised of false positives, while 4.5% would fall under this class if the threshold for pregnancy were set at 60 kg. Based on the previous information, OLR analyses were conducted with the assumption of positive pregnancy for females over 60 kg. This was done in order to include most calves being born in optimal conditions and decrease the number of non-pregnant females and stillborn.

3.2 Regression model and probability estimates

Females with no pregnancy records and weight lower than 60 kg were removed from the data; leaving a total of 2132 observations for the estimation of parameters. Throughout the three years, 72% of the pregnant females did not have a calf in autumn; and about 40% of the calves died before the summer gathering.

Observations of calf presence were ranked based on calves' "last-seen" records as in **Figure 3**. If the calf was not observed in any of both checkpoints, the female was ranked at "0". If the calf was observed in summer and autumn or only in autumn, the mother is automatically ranked at "2", even if there was no records of the calf presence in summer, therefore assuming that the calf was present during the summer but was not recorded. This resulted in a categorical ordinal value to be assigned to each individual, which was then used as outcome variable for the construction of the ordinal model.

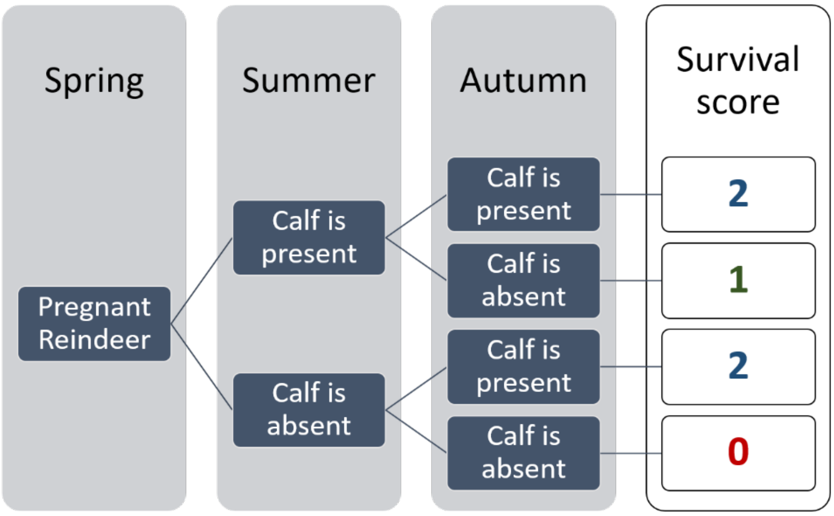

Figure 3: Diagram of how calf survival was ranked. Female reindeer were scored based on the gathering where their calf was last observed.

Results from OLR are summarized in **Table 3**. Reference values for categorical explanatory variables were Year 2010 and Gällivare sameby. All parameters show to be statistically significant for the sampled data (p-value < 0.001). Predictions over the ranks of the categorical outcome can be interpreted as:

0. Calf not surviving until the summer gathering / Calf dying before the summer gathering.

1. Calf surviving until the summer gathering, but not until the autumn gathering.

2. Calf surviving until the autumn gathering for culling.

The conditions for lowest predicted survival are for reindeer in Udtja sameby and the year 2011. Because the interest resides on the reindeer calf being able to survive until the second gathering (late autumn to winter), we can define the odds of a "success" as the estimated probability of surviving until autumn (category 2) over the estimated probability of not surviving beyond summer (category 0 or 1).

Table 3: Parameter Estimates of OLR model.

Parameter	Value	Std. Error	t value	p-value	95% Conf. Int.	
Weight	0.035	0.0045	7.685	<0.001	0.026	0.043
Sameby Udtja	-0.472	0.0997	-4.739	<0.001	-0.668	-0.277
Year 2011	-0.713	0.1028	-6.935	<0.001	-0.915	-0.512
Year 2012	-0.530	0.1306	-4.055	<0.001	-0.786	-0.274

Based on this definition, predicted values show that by increasing one kilogram in weight, the estimated odds of success increase by around 3.5% ($P < 0.001$) if all other variables are held constant. This can also be interpreted as a reindeer calf's odds of success being around 1.415 times greater than another calf (from the same year and community) whose mother weighed ten kilograms less before parturition.

Based on the information obtained in the model, the previous changes in odds of success may not vary when the year and sameby are taken into account. For the same situation, the estimated odds of success for a female reindeer from Gällivare sameby are 1.135 times greater than that of a female reindeer, which is ten kilograms higher in weight that belongs to the Udtja sameby. Predictions on probability of survival based on the constructed OLR model are summarized in **Figure 4**. For easier interpretation, the rank of the outcome variable is labelled by the interval of time during which the calf perished. Again, predictions over the Year 2010 and the Sameby of Gällivare needs to be taken with caution since they are built based on data from Udtja and years 2011-2012. Probabilities of a calf dying before summer (red lines in Fig. 4) are above 50% for almost all of the prediction conditions at females' 40 kg of weight at pregnancy, while the probabilities of a calf dying after the autumn (blue lines in Fig. 4) do not exceed 60% even with 100 kg of weight at pregnancy.

The ordinal regression predicts the probability of an event falling in each of the three categories (0, 1 or 2) when given specific conditions, with the sum of the probabilities being equal to one. Thus, a predicted outcome could be defined as the category of highest estimated probability. For example, the predicted outcome for a pregnant female weighing 75kg from the Gällivare sameby and year 2012 would be in category 2, given that it has the highest estimated probability of all the possible outcomes ($\hat{P} = 0.35$). Under this form of prediction, most of the outcomes for category 2 are skewed towards high values of weight, while the range where a predicted outcome would fall under category 2 is always on a short range of weight. This means that although the odds of success are considerably affected by differences in weight, the most frequent outcome would be of calves dying before summer for all different conditions;

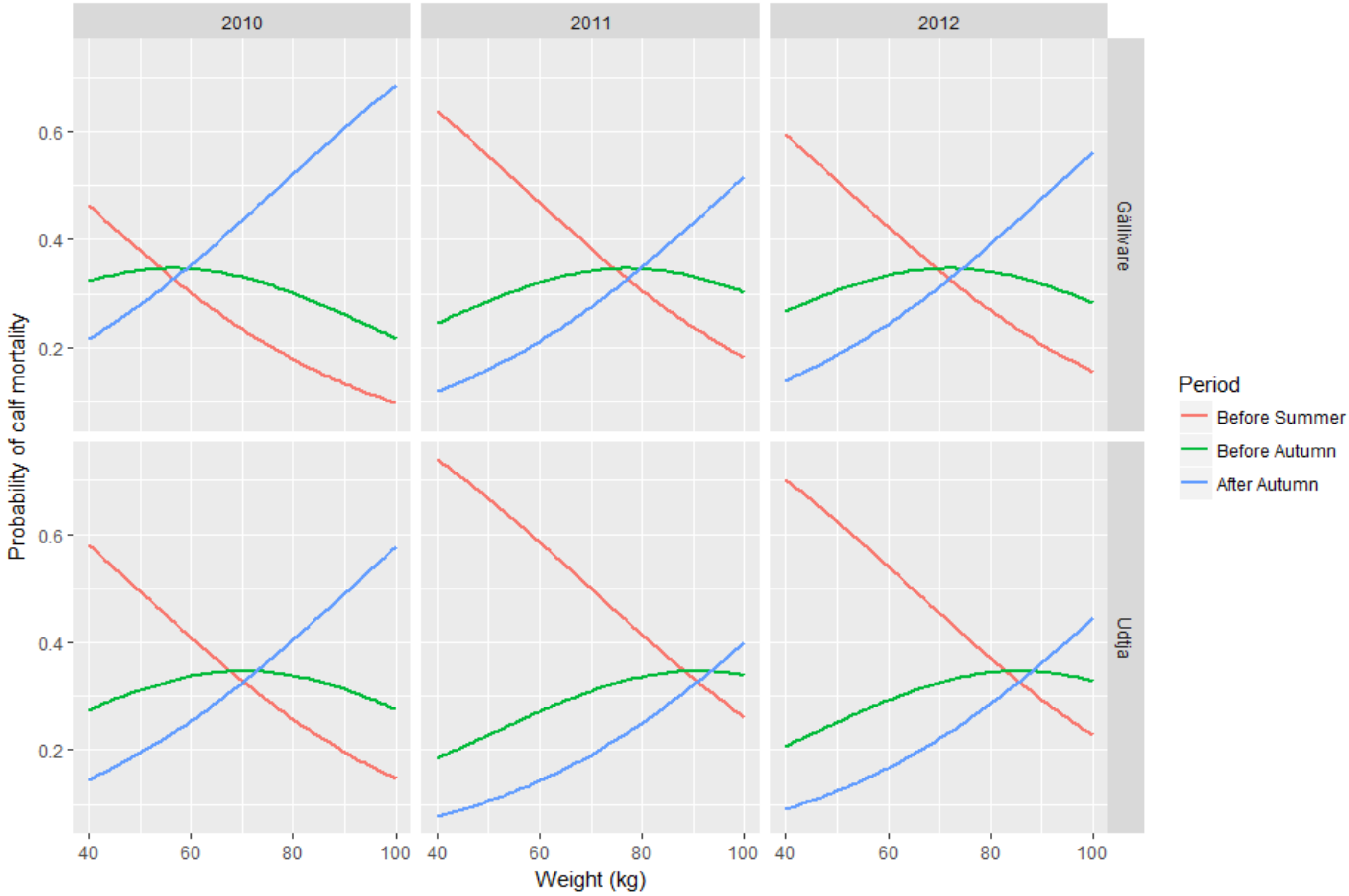

Figure 4: Plotted results from OLR for predicted probability of survival based on Weight, District and Year. Red line represents the probability of a calf dying before the summer gathering. Green line represents the probability of a calf being observed during the summer but dying before the autumn gathering. Blue line represents the probability of a calf surviving until the autumn gathering.

yet if the calf survives beyond spring, it is unlikely to die before the autumn gathering.

3.3 Model optimization and goodness of fit

LRT for odds proportionality resulted in rejection of null hypothesis when comparing all parameters from the POLR with the PPOLR model ($p = 8.245e^{-16}$). Yet null hypothesis was not rejected when proportionality was assumed for the *Weight* variable (p = 0.177). This means that the effects of the *Year* and *Sameby* variables are significantly different between the different logit functions, while the effect of *Weight* does stays approximatively constant for all functions. Given that for the parameter of interest (Weight), the null hypothesis of proportional odds assumption test could not be rejected, the proportional odds model is considered sufficient to describe the current data. Although the parameters estimated for PPOLR maintained their direction of change (i.e., slope sign), predictions regarding sameby and year need to be handled with care, since the magnitude of their effect may not be accurate.

Because the females sampled were tagged, the individuals could be tracked throughout the different years. Therefore, the construction of a mixed effects model that accounted for individual variation was tested for goodness of fit. A random effect of individual variation was added to the model, yet LRT did not confirm the null model to have a lower goodness of fit than the more complex one. In addition, an interaction between the parameters of weight and sameby was found to have a marginal significance. This was not added to the presented model, once that it could not be assumed proportional odds for sameby effect, as well as this interaction being of marginal significance.

4. Discussion

Results of the present study confirm a positive relationship between female reindeer's weight at late pregnancy and the odds of calf survival until the time of culling, yet the magnitude of the effect was relatively low when compared to other factors as the year and sameby. Proportional odds assumption showed to be valid for this parameter but not to be the best fit for the effect of year and sameby. The year 2011 was predicted to give the lowest odds of survival, while Gällivare sameby had an overall higher survival rate than Udtja. Estimations of calf survival could be better described by a more complex model than the one presented; while detailed data could greatly benefit the description of interactions between the factors included.

4.1 Pregnancy predictions based on weight

Results over predicted pregnancy showed a higher probability of pregnancy for lower weight than in previous literature, where the minimum weight for a female reindeer becoming pregnant has been estimated to be 60 kg, as an optimal criterion for calf production (Ropstad, 2000). A study done by Eloranta & Nieminen (1986) that tracked reindeer for around 15 years. It showed stillbirths to be a principal cause of calf mortality, with 17.1% of calf deaths being stillbirths and 20.7% dying of poor condition. It also showed a correlation between stillbirths and low female weight at pregnancy, suggesting that if maternal weight were too low, the calf would die before parturition. The focal point of this study is calf mortality caused by predation; therefore, setting a cut-off point higher than 47 kg was likely avoid the inclusion of too many stillbirths as born calves. In addition, assuming positive pregnancy for females below 60 kg of weight would risk inclusion of individuals under the optimal conditions for production, which even if their calves were not predated, they could perish due to other circumstances such as low forage availability, parasites, diseases, cold weathers or mere accidents (Nieminen *et al.*, 2013). Although there were not many, some individuals with weight below 60 kg had a positive pregnancy diagnose. There is a chance that some stillbirths were then included in the analysis, but it is expected this number to have been greatly reduced.

4.2 Calf survival and predictors of predation

In accordance with other studies, results corroborated the female maternal condition to have an effect on calf survival. Chances of a calf surviving until the autumn are likely to be benefited through an increased birthweight, which in itself is related to an improved maternal condition before calving. This chain of effects have been even linked to the maternal condition during the previous winter (Rönnegård *et al.*, 2002; Veiberg *et al.*, 2017), which could make the estimated effects in my study more difficult to interpret, as year and female

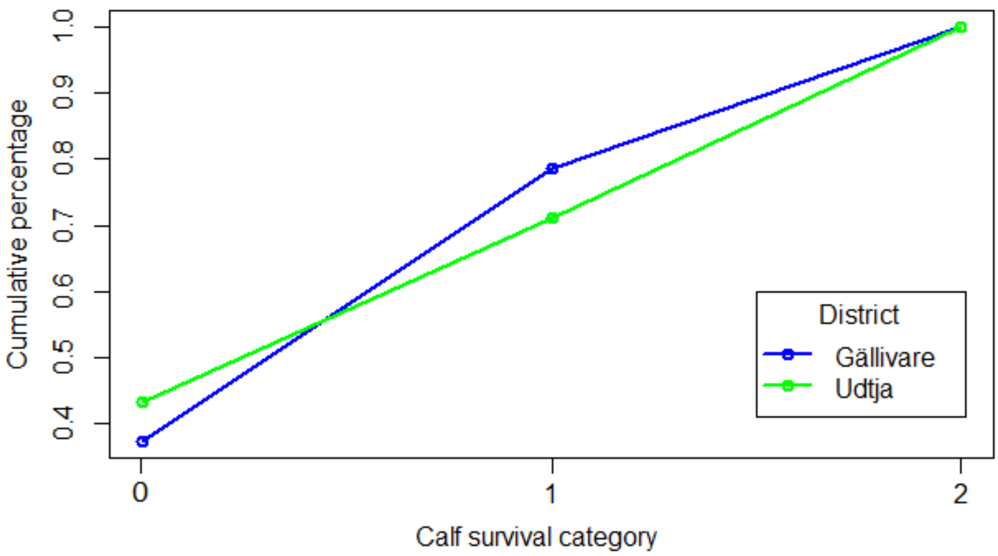

Figure 5: Cumulative percentages of calf survival by district. The Gällivare sameby shows the percentage of observations skewed in direction to the higher ranks of the survival category.

weight parameters may not be fully independent. In the present results, collinearity between them was not observed to be significant in this sample, possibly due to the small range of sampled years, although its occurrence may not be discarded for larger samples.

Variations on the effect of the sameby over reindeer calf survival may be more complex to explain due to a variety of factors. Bluntly stated, results predict that a reindeer calf is more likely to survive beyond spring if the individual belongs to Gällivare sameby. In truth, calf mortality in the analysed data was overall lower for this community (**Figure 5**). Additionally, a marginal significance was found for an interaction between the female reindeer weight and the community of origin meaning that a difference in weight before calving could have a higher or lower impact on calf survival depending on the district of origin. The combination of both results could be caused by differences such as in phenotypic traits of the herd through different breeding strategies (Rönnegård, 2003), the physical geography of the place, the available forage and its quality or the number of predators present in each sameby (Barten *et al.*, 2001).

Indeed, pregnant reindeer from Udtja sameby were reported to be heavier in average for years 2011 and 2012 (Karlsson *et al.*, 2012), which may reflect differences between the herds' phenotypic traits. This could be unintuitive at first glance, but the fact that reindeer are larger could affect the estimation of maternal condition based on weight and thus, overestimate the condition of the reindeer from the specific community. On the other hand, amount of estimated brown bear potentially residing in the area has been observed to be larger in Udtja sameby (71 individuals in Udtja and 58 in Gällivare sameby; Karlsson *et al.*, 2012), while the total bear-caused mortality was reported to be almost double of that in Gällivare (29% vs 16%; Sivertsen, 2017). Thus, the effect that a higher female weight before calving has on calf survival could be interacting with the characteristics of the forestry in calving terrain, areal limitations, reindeer's population density and breeding strategies of each sameby (Sivertsen *et al.*, 2016).

Lundqvist (2007) studied the correlations between several environmental factors and reindeer productivity of 51 herding communities in Sweden. Results showed that variation in productivity was larger between districts than between years. Additionally, variation on animal condition was significantly influenced by animal density and harassing insect activity during the summer; a strong correlation was also found between animal condition on the previous year and the current. These results suggests that the individual characteristics of each location can provide advantages or disadvantages to calf production that influence the following year. At the same time, the locations are susceptible to intense annual variations, which in turn affect the survival and production throughout more than a single year.

A factor that is known to have a significant effect in the calf's birthweight is the age of the reindeer at pregnancy (Lenvik & Aune, 1988; Ropstad, 2000; Rönnegård *et al.*, 2002; Skogland, 1984b). A study by Eloranta & Nieminen (1986) that followed a herd in Finland for fourteen years reported that reindeer female weight increased until the age of five, that older females gave birth to heavier calves (about one kg heavier) and that females between 3 to 4 years of age had the highest amount of successful calvings (calving percentage of 87.9%). Unfortunately, the age of sampled females was not being recorded at the time of sampling. Persson (2014) reported the tested females of the same data to be all over 2 years of age, yet this information could not be corroborated since there are no description of the methods used for age estimation. Some communities had a 100% of the sample diagnosed pregnant during certain years, which could mean that the sample selection was not random and thus the individuals recorded are fairly close in age. Still, the same cannot be said for the differences between communities regarding the sampling methods and thus could be cause of confounding within the sameby variable, exaggerating its magnitude of effect over weight and, consequently, calf survival.

Other missing information that could improve estimations are the gender of the calves. Differences in behaviour between sexes could potentially influence the survival of the individuals through differences in the risk of being predated or amount of general exposure to danger (Mathisen *et al.*, 2003), as well as that males seem to be born with a higher weight than females (0.3 kg heavier; Eloranta & Nieminen, 1986). Given that records were only made before parturition and not after calving, no data on the gender or weight of the newborn calves were collected. The absence of these two factors may have reduced the amount of variation in calf survival explained by the ordinal model. For future studies, a description of the herd's population pyramid could provide insight over these unaccounted factors and determine the impact of both over the risk of calf predation by brown bear.

Using the collar ID of each female it was possible to track the individuals sampled in more than one year of record and include this information in the model. This would not measure the effect of female age or gender itself, but account for differences between individuals that are not related to the other parameters in the model. Results showed that no significant information was added by the inclusion of reindeer ID. This is likely due to being too few individuals present in more than one year of records (n = 79). Several individuals were changed between each year and while the reindeer included in the sample from years 2011 and 2012 were expected to be younger than those from 2010, individual variation was not significant for this data. For a more refined analysis of this variation in the future, a parameter that ranks individuals based on the first year it was present in the records could be used as a way of estimating relative age between individuals. In this way, if a female reindeer was present in all three years it could be differentiated from an individual only present on the second or third.

Predicted probabilities for the categories of calf survival demonstrated to be in accordance with the literature, where the maternal condition prior to calving has an effect over the offspring's survival through an increased calf birth weight (Eloranta & Nieminen, 1986; Korpinen, 2017; Lenvik & Aune, 1988; Ropstad, 2000; Säkkinen *et al.*, 1999). In addition, the range of weight where the probability of survival until summer was highest (green line in Figure 4) was very narrow under all different conditions. This could also be explained by the period of intense predation occurring during the first week of calving (Karlsson *et al.*, 2012; Sivertsen, 2017). If a calf survives beyond spring, it is likely that also survives until the autumn due to the lower risks of predation and thus, the probability of a calf dying after the summer gathering is relatively low once it has survived throughout spring. On the other hand, estimated probabilities of calves surviving until autumn are significantly inclined to the upper range of female weight pre-parturition, being restricted to females weighing over 70 kilograms. In addition, estimated probabilities of survival until the autumn never surpassed 60% (excluding predictions for the year 2010 in Gällivare, which have been regarded as not reliable). This emphasizes the fact that both communities have a low percentage of calf survival (Karlsson *et al.*, 2012) and that only a small part of the risk of predation and mortality can be explained by accounting only for the effects of year and location. It appears that weight has an effect on the risk of predation, yet once there are no weak calves, predation rates will depend more on the bears and herds' population density, along with the amount of territorial overlap between bears and the calving area (Sivertsen, 2017). It has not been studied how predation over reindeer calves occur, whether the size of the mother and their antlers have a deterrent effect on the daring of bears to predate or if the maternal instinct plays any role at all in the protection of the young ungulate. A more accurate depiction of the factors that influence the risk of predation on the reindeer calves can only be obtained by more in-depth collection of data through a prolonged period of time. A thorough description of the brown bear predatory behaviour, in conjunction with the mother's protective instinct over the calves may significantly increase the knowledge related to calf survival under forest habitats of reindeer.

Although the presented model was sufficient to describe the effects of female weight at pregnancy over the probabilities of calf survival until autumn, models with highest goodness-of-fit can be applied to describe the data. Complex models that account for a higher number of influencing factors can be constructed in future studies using a larger and more detailed amount of records. This can provide an accurate description of the most critical influences for prevention of high losses due to predation and allow developing measures and strategies to improve the productivity of the herd.

Because of this, the continuation of projects like the BBPP and the contributions made by the scientific community are of significant importance to the acquisition of knowledge for the development of solutions to the challenges that semi-domesticated reindeer herding in Sweden is currently facing and, or will, face in the future.

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