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Reindeer Calving Dates and Synchrony

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Abstract

Reindeer are seasonal breeders who have a strict timetable of reproduction. In each year, calving dates of female reindeer should not be too different from each other, i.e. the calving should be in a synchrony. Calving dates and synchrony ensure the survival of calves and population. So the reason why a female reindeer give birth earlier or later is quite important to the raising of reindeer calves and their protection.

Reindeer are typical polygynous, which means all the females in a population share one or several males. So in the same population, the differences exist in factors of female members. For the calving dates of calves with the same male parent, these factors from females are more affective and deserve to be controlled.

The calving dates are also connected with climate, nutrition and other environmental factors. This article aims at finding out which factors affected the reindeer calving date and how each factor worked with the physiological actions. The data came from Kutuharju Field Reindeer Research Station in Kaamanen in Finland with an experiment from 1996 to 2005.

Using linear mixed models with R software, we found that factors, such as different populations and years, the weight of female and whether there was a calf at foot during the rut affected the calving dates in different ways. Furthermore, male and female reindeer calves had different regularity in their birth.

Key Words: calving date, synchrony, nutrition, health and body condition, weight, gestation, calf's sex, female reindeer, log transformation, random effect, linear mixed model.

1. Introduction

As polygynous[1] seasonal breeders, reindeer mate every year in September and give birth in April during the next year. Calving dates and synchrony strongly affect the survival of ruminant[2] offspring (Bunnell, 1982). To survive in the seasonal circumpolar[3] environment, this is particularly evident in reindeer populations.

Calving dates of reindeer should be controlled in a short period. Giving birth too early or late would give calves lower probability to survive or have a good health. If a calf is born too early, it would exclusively get nutrition from dam'[4] milk which made the dam be in negative energy balance (Shipka et al., 2007). On the other hand, if a calf is born too late, it would have less time to build its body and face the coming winter (Bianchet, 1988).

With a high synchrony, 90% of female reindeer are impregnated[5] in a period from 10 to 21 days (Roine, 1974) and give birth in a synchronized period during the next spring (Williams et al., 1988). However, different populations, or the same population in different years, the time of reproduction can be spread to 4 weeks or more (Reimers et al., 1983; White, 1992). The difference of reproduction dates depends on climate (plant phenology[6]) (White, 1992), predation (Post et al., 2003), latitude (Williams, 1988), onset of breeding (Williams, 1988), sex of calves (Rowell & Shipka, 2009) and their interactions (Coulson et al., 2001). Especially for the female reindeer, the variation in time of reproduction are related to the females' age (Ropstad, 2000), weight (Lenvik & Aune, 1988), which present the maternal nutrition and health condition (Cameron et al., 1993). And also, each female reindeer may have its speciality which also affects the calving dates. According to published research, later calving dates follows harsh winters with fewer pasture. Gestation[7] length increases with the age of female reindeer and the length would be shorter if the calf was a female (Mysterud et al, 2009). Meanwhile, older females show lower fertilities[8] (Ropstad, 2000). If the female is too light (less than 60kg), the reproduction could not be met (Lenvik et al., 1988; Eloranta & Nieminen, 1986).

The aim of this article is to find out which factors affected the reindeer calving date and how each factor worked with the physiological actions. The data came from the Kutuharju Field Reindeer Research Station. We used linear models and mixed model with dams' identities as a random variable.

2. Data

Data of this article was collected in the Kutuharju Field Reindeer Research Station in Kaamanen, Finland (69° N, 27° E). The data shows an experiment from 1996 to 2005 in two

[1] Appendix: Table 7
[2] Appendix: Table 7
[3] Appendix: Table 7
[4] Appendix: Table 7
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large rutting[9] enclosures with similar environments: Lauluvaara (13.8 km^2) and Sinioivi (15 km^2) from September to November, and a smaller calving paddock (13.8 km^2) in calving season.

After deleting missing data, there are 638 observations in total, 61 in 1996, 62 in 1997, 60 in 1998, 47 in 1999, 54 in 2000, 66 in 2001, 82 in 2002, 78 in 2003, 66 in 2004 and 62 in 2005. Most female reindeer were observed from 1 to 7 times, i.e. the number of times they gave birth. 6 reindeer were observed 8 times and 2 were observed 9 times.

First, the response is built from the number of days between the calving date and January 1st of the year, named **BirthDate**.

Then we chose following factors as independent variables.

Different populations of reindeer or a same population in different years had different calving dates. So the variables "Loc" and "Year" were needed.

Loc: Location of the rutting enclosure the female was in. This variable could be "Laul" as "Lauluvaara" or "Sin" as "Sinioivi".

From Figure 1, we can see that there were some differences between the two populations in the two different rutting enclosures. Hence, the variable "Loc" was needed as the factor of the two populations.

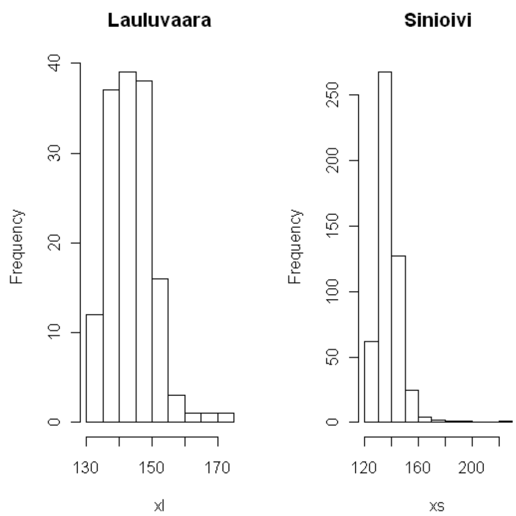

Figure 1: Histograms of Calving Dates in Two Different Rutting Enclosures

Year: The year when the female reindeer mated. From the histograms in figure 2, we can see that in each year, though the calving dates kept a synchrony, the mean of the distribution was distinctive.

ID: Identity number of the female (from 188 different females in total).

This variable was chosen as a random effect for the characteristics of each female. Most females' data were taken more than once, and the initial factor of females which contained in this "ID" variable might affect the calving date.

[9] Appendix: Table 7

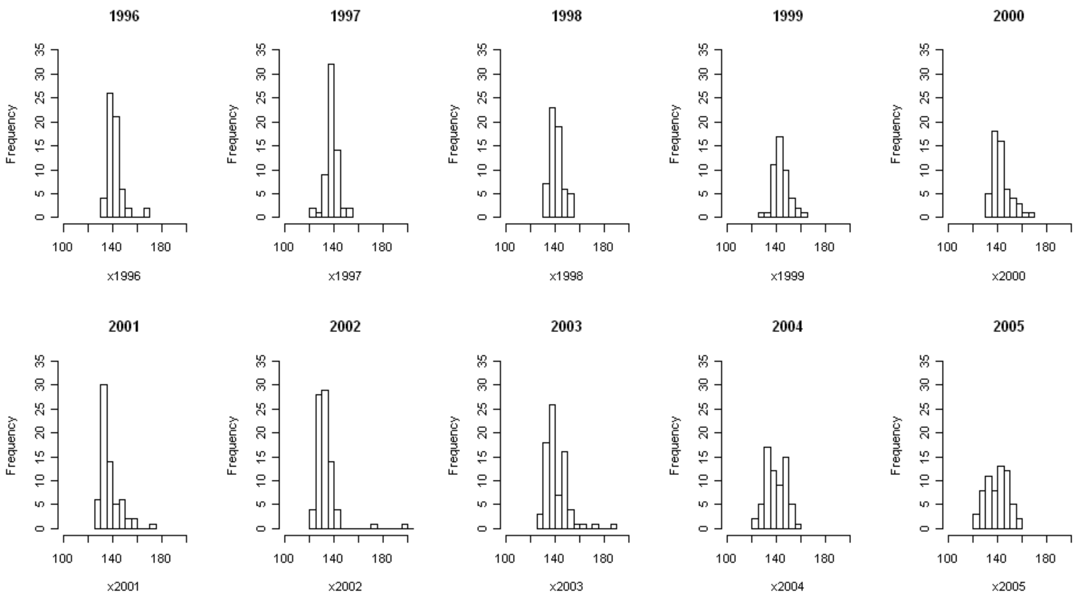

Figure 2: Histograms of Calving Dates in Different Years

Age: Age of the female during the rut.

The age of mothers might be important to mothers' body condition and experience. Older female means more experience but also lower fertilities.

W1: Female's weight in September before the rut. It represents the female's health and body condition.

DW: W1-W3 (W3: Female's weight in June the next year after the calf's birth. It was not contained in the model but was important in defining DW.).

DW is a factor shows the process when the calf in its mother's uterus[10]. For example, Mother's health and nutrition condition during the gestation.

CF: Whether female had a calf at foot during the rut. If it had a calf that time, CF=1. If not, CF=0.

This variable was connected with both experience and body condition. Having a calf at foot during the rut might mean much experience. At the same time, it also showed the condition that the mother might produce milk during its gestation period.

CSex: Calf's sex. This variable could be "m" as "male" or "f" as "female".

In some former research, male calves showed longer gestation (Rowell & Shipka, 2009) than females because they needed more time to build their bone and muscle.

3. Methods

3.1 General Linear Model

We are interested in the factors that affected reindeer calving date. From the beginning, the variable "BirthDate" was chosen as the dependent variable in our linear model. The independent variables we chose originally were all the factors mentioned in part 2 except ID.

[10] Appendix: Table 7

First, we tried a general linear model which has a formula that: $y = X\beta + \varepsilon$ (1), and checked the residuals of the model.

In a linear model, first we put all the possible variables into the model, and then selected them according to their p-value. We put H_0: This variable is not significant. If the p-value is small, reject H_0 and see the variable significant.

If the variable is not significant, we should delete it in our model. However, there were some interactions between independent variables. That means we should only delete one of the insignificant variables each time and check the model again. Each time we deleted the variable that was the most insignificant with the largest p-value.

After "checking" and "deleting" as was shown above, we got the final models.

3.2 Linear Mixed Model

When the number of unknown parameters is large, we need to consider random effects with a linear mixed model. In our data, the characteristics of female reindeers were much more than factors we got and the IDs of female reindeers should therefore be added as a random effect.

First consider the random effects model as: $y_{ij} = \mu + u_i + e_{ij}$ (2), where μ was the fixed overall mean parameter. u_i was an individual effect for i= 1, 2, 3, …q. q=188. e_{ij} was the residual effect for j=1, 2, …, n, where n is the total number of measurements. We assume that: $u_i \sim iidN(0, \sigma_n^2)$, $e_{ij} \sim iidN(0, \sigma^2)$.

For the analysis we consider the linear mixed model specified as: $y = X\beta + Zu + e$ (3), where y was a vector with length n. X and Z were design matrices for fixed effects β and random effects u.

4. Results

4.1 General Linear Model

After checking the normal assumption of residuals, we found that a transformation for response was needed. After building a new variable named **logBirthDate** which defined as: logBirthDate = log (BirthDate - 100), we got the QQplot of the residual as Figure 3.

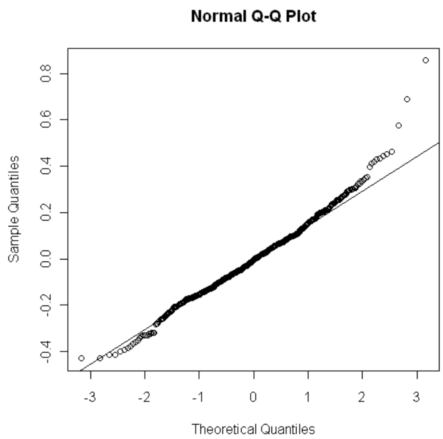

Figure 3: QQplot of Residuals from the Regression with "logBirthDate" as Response

First, we put all the variables into our model. The result came out as Table 1.

Table 1: Original Result of General Linear Model

Coefficients	Estimate	Standard Error	P-value
Intercept	3.875	0.087	$< 2\times10^{-16}$
Age	2.657×10^{-4}	0.003	0.935
Loc (Sin=1)	-0.174	0.018	$< 2\times10^{-16}$
W1	-4.585×10^{-4}	0.001	0.710
DW	-0.002	0.002	0.163
Csex	-1.000×10^{-4}	0.013	0.994
CF (m=1)	0.003	0.016	0.874
Year(1997)	-0.110	0.031	4.13×10^{-4}
Year(1998)	0.068	0.031	0.032
Year(1999)	0.146	0.034	1.63×10^{-5}
Year(2000)	0.118	0.033	3.32×10^{-4}
Year(2001)	-0.028	0.031	0.266
Year(2002)	-0.188	0.030	5.72×10^{-10}
Year(2003)	-0.050	0.030	0.095
Year(2004)	-0.029	0.031	0.348
Year(2005)	-0.099	0.035	0.005

From Table 1, the effect of year and location was extremely significant. However, the effect of age, female weight before rut, calves' sex and whether the female had a calf at foot during the rut were not so significant. The effect of the weight lost during gestation was more significant than other factors.

Usually, we set p=0.05 as the critical value to judge whether the variable is significant. However, this value is often too strict in biological cases. Hence, we set p=0.2 as the critical value. As long as the p-value is not more than 0.2, we left it in the model. After deleting factors one by one, considering "Year" as one factor without deleting them respectively, the result is shown in Table 2.

Table 2: Final Result of General Linear Model

Coefficients	Estimate	Standard Error	P-value
Intercept	3.844	0.026	$< 2\times10^{-16}$
Loc (Sin=1)	-0.174	0.018	$< 2\times10^{-16}$
DW	-0.003	0.002	0.070
Year(1997)	-0.109	0.031	4.16×10^{-4}
Year(1998)	0.067	0.031	0.033
Year(1999)	0.147	0.033	9.87×10^{-6}
Year(2000)	0.118	0.032	2.46×10^{-4}
Year(2001)	-0.030	0.031	0.331
Year(2002)	-0.190	0.029	1.77×10^{-10}
Year(2003)	-0.052	0.029	0.078
Year(2004)	-0.029	0.030	0.330
Year(2005)	-0.102	0.034	0.003

After the step-by-step regression, we know that females had early calving dates reduced more weight during the gestation.

4.2 Linear Mixed Model

The original result of Linear Mixed Model is in Table 3.

Table 3: Original Result of Linear Mixed Model

Coefficients	Estimate	Standard Error	P-value
Intercept	4.023	1.000×10^{-1}	$< 2\times10^{-16}$
Age	7.528×10^{-4}	3.603×10^{-3}	0.835
Loc (Sin=1)	-1.934×10^{-1}	1.822×10^{-2}	$< 2\times10^{-16}$
W1	-2.265×10^{-3}	1.433×10^{-3}	0.115
DW	-2.593×10^{-3}	1.734×10^{-3}	0.135
Csex (m=1)	2.068×10^{-5}	1.281×10^{-2}	0.999
CF	2.007×10^{-2}	1.586×10^{-2}	0.206
Year(1997)	-1.398×10^{-1}	2.855×10^{-2}	1.30×10^{-6}
Year(1998)	6.202×10^{-2}	2.918×10^{-2}	0.034
Year(1999)	1.502×10^{-1}	3.160×10^{-2}	2.59×10^{-6}
Year(2000)	1.367×10^{-1}	3.134×10^{-2}	1.55×10^{-5}
Year(2001)	-6.023×10^{-3}	3.012×10^{-2}	0.842
Year(2002)	-1.805×10^{-1}	2.942×10^{-2}	1.67×10^{-9}
Year(2003)	-5.391×10^{-2}	2.967×10^{-2}	0.070
Year(2004)	-2.455×10^{-2}	3.058×10^{-2}	0.423
Year(2005)	-1.086×10^{-1}	3.569×10^{-2}	0.002

From Table 3, we found that factors Age and Csex are obviously insignificant.

The estimated variance of ID is 0.0612, and the estimated residual variance is 1.110. The individual differences between mothers did exist.

After deleting the factors which had p-values more than 0.2, the result is in Table 4.

Table 4: Final Result of Linear Mixed Model

Coefficients	Estimate	Standard Error	P-value
Intercept	4.013	0.089	$< 2\times10^{-16}$
Loc (Sin=1)	-0.193	0.018	$< 2\times10^{-16}$
W1	-0.002	0.001	0.078
DW	-0.003	0.002	0.102
CF	-0.021	0.015	0.181
Year(1997)	-0.140	0.028	1.18×10^{-16}
Year(1998)	0.062	0.029	0.033
Year(1999)	0.151	0.031	1.99×10^{-16}
Year(2000)	0.137	0.031	1.16×10^{-5}
Year(2001)	-0.005	0.030	0.857
Year(2002)	-0.180	0.030	1.50×10^{-16}
Year(2003)	-0.054	0.030	0.071
Year(2004)	-0.024	0.030	0.436
Year(2005)	-0.108	0.031	0.003

From Table 4, location and year are significant factors to affect the calving dates. And those factors made the calving date become later: lighter weight during the rut, less weight lost during the gestation, not having a calf at foot during the rut.

The estimated variance of ID is 0.0611, and the estimated residual variance is 1.109.

4.3 Different Sex of Calves

When we respectively analysis the data with male or female calves with linear mixed models, we got more ideas than in above parts (Table 5 & Table 6):

Table 5: Result of Linear Mixed Model in Male Data

Coefficients	Estimate	Standard Error	P-value
Intercept	4.230	0.125	$< 2\times10^{-16}$
Age	0.008	0.005	0.107
Loc (Sin=1)	-0.208	0.026	4.13×10^{-14}
W1	-0.005	0.002	0.004
Year(1997)	-0.122	0.040	0.002
Year(1998)	0.032	0.040	0.422
Year(1999)	0.101	0.041	0.016
Year(2000)	0.105	0.045	0.021
Year(2001)	-0.019	0.043	0.656
Year(2002)	-0.189	0.042	1.23×10^{-5}
Year(2003)	-0.083	0.039	0.037
Year(2004)	-0.045	0.041	0.272
Year(2005)	-0.126	0.040	0.002

Table 6: Result of Linear Mixed Model in Female Data

Coefficients	Estimate	Standard Error	P-value
Intercept	3.835	0.040	$< 2\times10^{-16}$
Loc (Sin=1)	-0.173	0.027	1.51×10^{-9}
DW	-0.004	0.002	0.051
Year(1997)	-0.124	0.042	0.003
Year(1998)	0.090	0.045	0.046
Year(1999)	0.163	0.050	0.001
Year(2000)	0.145	0.043	0.001
Year(2001)	-0.015	0043	0.734
Year(2002)	-0.155	0.042	0.001
Year(2003)	-0.009	0.043	0.845
Year(2004)	-0.006	0.043	0.897
Year(2005)	-0.072	0.052	0.166

In male-calves data, dams' age and the weight before rut show an obvious effect to calving dates. Older age and lighter weight of females lead to late calving dates. However, in female-calves data, the above factors didn't show significant effect but the factor DW is important. Dams gave earlier birth to female calves lost more weight during their gestation.

5. Discussion

This study showed that different populations did have variations of calving dates. This mainly caused both by different environment and the estrous cycle of male reindeers. Year was also related to calving date. A freezing winter might delay the start of the next spring, as well as the peak season of pasture. Female reindeer would need to give later birth to wait for enough nutrition.

The rutting time was also the start of gestation. Lighter female reindeer were in worse health condition. Weaker females need more time to build calves' organs. Although females were impregnated in different time, the fetus started the period of rapidly growing up together. Dams gave birth earlier built their calves' body in shorter time, and they lost more weight during the gestation. Meanwhile, females that gave birth earlier also started their lactation earlier. They paid more nutrition on milk as well as gestation since we took W3 of every female in the same time. Having calves during rut might deplete females' experience, physical strength, as well as the nutrition that should be provided to fetus. A female didn't have a calf at foot might have its first gestation as the observation. And also, a female deer in lactation must get more nutrition and energy to produce milk. It was also more for the fetus.

Comparing with female-calves data, dam's fertility and health condition were more important for a male calf. Male calves needed more nutrition to build their bone and muscle. So for a weaker dam, the gestation would be longer. The variable DW didn't affect the male calves' calving date obviously but this variable shows the important nutrition factor to the calves. This might because some female reindeer couldn't provide enough nutrition had miscarriages, and the male calves were never born.

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Appendix

Table 1 Biological Proper Noun[11]

Noun	Implication
polygynous	A social structure of animal population that one or several males live with a lot of females.
ruminant	Any animal that brings back food from its stomach and chews it again.
circumpolar	Inhabiting areas near one of the earth’s poles.
dam	Female parent of an animal.
impregnate	Make a female animal pregnant.
phenology	The study of patterns of events in nature, especially in the weather and in the behavior of plants and animals.
Gestation	The time that the young animal develops inside its mother’s body until it is born.
fertility	Ability of give birth.
rut	The time of year when male animals become sexually active.
uterus	The organ in female animals in which baby develop before they are born.

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