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# Abstract

Early-life body mass is a good predictor for later-life performance. It is therefore important to understand the different mechanisms that can effect body mass. Differences in the environment can have a large impact on body mass, and early life body mass is also one of the first traits that get influenced by weather effects. These effects often operate through foraging opportunities and the nutritive value of foraging, as both the quality and quantity of plants are affected by environmental conditions.

The aim of this thesis is to investigate how weather affects temporal variation of juvenile roe deer *Capreolus capreolus* body mass at two different locations. Data on autumn fawn body mass from Ytterøya , a small island at the coast of Mid-Norway, and Siljan, an area south-east in Norway, over several years, as well as weather data from the Norwegian Meteorological Institute are used to examine the variation in body mass.

The three variables examined: snow depth, precipitation and temperature, were all found to have significant effects on autumn fawn body mass. The variables found to have the strongest explanatory power at Ytterøya was precipitation during winter, May, June and July. At Siljan the variables found to be most descriptive of the variation was precipitation and temperature in June. These variables could be related to the length of plant growing period as well as plant quality and quantity during spring and summer. Most surprisingly was that in some months, the weather effects were opposite between the two areas. This displays that weather effects could cause different outcomes in populations, as a populations sensitivity to weather is also affected by other factors such as habitat, density and climatic conditions.

The results demonstrate how populations are largely affected by local differences, and this has to be taken into account when managing ungulates. Variation in weather largely affect an individual's body mass, but it is not expedient to generalize weather effects over larger distances.



## Sammendrag

Kroppsvekt tidlig i livet kan være en god indikator for hvor godt et individ vil gjøre det senere i livet. Det er derfor viktig å forstå de forskjellige mekanismene som påvirker kroppsvekt.

Værforhold kan ha stor effekt på kroppsvekt, og kroppsvekt hos ungdyr er også et av de første trekkene som blir påvirket av ulike miljøforhold. Disse forholdene påvirker ofte individers kroppsvekt gjennom kvaliteten og kvantiteten på mat, samt lengde på plantenes vekstsesong.

Målet ved denne oppgaven er å undersøke hvordan variasjonen i værforhold kan påvirke rådyrs *Capreolus capreolus* kroppsvekt på to ulike steder. Data innsamlet over flere år på Ytterøya, en øy i Trondheimsfjorden i Trøndelag, og Siljan, som ligger i Vestfold og Telemark, samt værdata fra det Metrologiske Institutt ble brukt for å undersøke variasjonen i kroppsvekt hos rådyrkje.

De tre variablene som ble undersøkt var snødybde, nedbør og temperatur, og alle funnet til å ha en signifikant effekt på kroppsvekten til rådyrkje. De mest forklarende variablene på Ytterøya var nedbør om vinteren og i mai, juni og juli, mens på Siljan var temperatur og nedbør i juni viktigst. I begge områdene kan dette tyde på at lengden til plantenes vekstsesong, samt kvaliteten og kvantiteten av planter, er viktig for vekst hos rådyrkje. Mest overraskende var det at væreffektene var motsatt på de to stedene enkelte måneder. Dette viser at vær kan ha forskjellig utfall i ulike populasjoner. Dette kan være fordi det er flere variabler som spiller inn, og som også blir påvirket av været. Eksempler på dette kan være habitat, populasjonstetthet og andre klimatiske forhold.

Resultatene viser hvordan populasjoner kan bli påvirket av lokale forskjeller, noe som det må tas hensyn til ved forvaltning av hjortedyr. Værvariasjoner påvirker i stor grad kroppsmassen til et individ, men det vil ikke være hensiktsmessig å generalisere væreffekter over større avstander: lokale forskjeller må tas med i betraktning.





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# 1 Introduction

The life history of a species has evolved through natural selection to maximize survival and reproductive success under given environmental conditions (Gadgil and Bossert, 1970). Life-history traits, such as fecundity and survival, are affected by both current and past conditions (Lindström, 1999, Metcalfe and Monaghan, 2001, Lummaa and Clutton-Brock, 2002), and climatic conditions at a given time can affect several life-history traits simultaneously (Herfindal et al., 2015). However, factors affecting growth and body condition early in life have lifetime effects on vital rates, indicating that this period of an individual live stage often is the most critical for lifetime performance (Lindström, 1999, Forchhammer et al., 2001, Descamps et al., 2008, Herfindal et al., 2015, Markussen et al., 2019). In addition to this notion, the effect of the disturbance will be stronger the earlier in life it does occur (Lindström, 1999).

In many animals, individual vital rates are closely linked to their body mass (Gaillard et al., 2000), and individual differences in life-history traits frequently involve variation in body mass (Descamps et al., 2008). Studies have shown that adult body mass is strongly affected by additive effects of the year they were born (Pettorelli et al., 2002, Solberg et al., 2004), and often, early-life body mass is a good predictor for later-life performance (Lindström, 1999, Forchhammer et al., 2001, Solberg et al., 2004, Descamps et al., 2008, Markussen et al., 2018, Markussen et al., 2019). Body growth early in life influences age at maturity (Sæther, 1985, Markussen et al., 2018), and a larger body weight is associated with an increase in reproductive rate (Molles, 2013). A larger female is also expected to produce larger litters of large offspring, leading to a stronger family effect (Gamelon et al., 2013). Because of the link between parent and offspring quality, life-history traits can be affected across generations (Herfindal et al., 2015, Markussen et al., 2018).

Environmental conditions and density can have large influence on body mass (Pettorelli et al., 2002, Mysterud et al., 2002, Herfindal et al., 2006a). Density can have delayed effects on body mass, but the immediate effects will rather be on survival (Andersen and Linnell, 2000). Variation in the environment will influence body mass more directly (Solberg et al., 2004, Nielsen et al., 2012). Effects of environmental conditions could be caused by direct and indirect mechanisms (Putman et al., 1996, Nielsen et al., 2012). For example, winter

conditions could have an immediate effect on survival as well as indirect effects operating through body weight. Summer conditions can have large effect on life history traits as animals are dependent on their digestive energy intake during summer to store fat reserves (Holand et al., 1998). Environmental conditions during summer could also affect level of prenatal care and mortality rate in newborns (Andersen et al., 2000, Andersen and Linnell, 1998). In the northern part of Scandinavia, environmental conditions during winter can be crucial for survival and reproduction (Holand et al., 1998, Nilsen et al., 2004, Grøtan et al., 2005). Often, the effect of climatic variations have a delayed response in life-history traits at later stages in life, or even across generations (Herfindal et al., 2015). Delayed effects on abundance through changes in vital rates as a response to climatic variations are challenging to detect (Sæther, 1997). However, juvenile body weight responds more directly to these variations, and is therefore a more reliable measurement when investigating the effect of weather and environmental conditions (Weladji and Holand, 2003, Herfindal et al., 2020).

Both the quality and quantity of the food resources affect body mass (Andersen and Sæther, 1992, Sæther et al., 1996). The nutritive value of forage, as well as biomass is highly determined by the weather during the plant growing season (Langvatn et al., 1996, Cook et al., 2004). Summer temperature and precipitation can contribute to both the quality and quantity of plants (Langvatn et al., 1996, Lenart et al., 2002). The quality of the nutrition during the summer and autumn, as well as the length of the growing season, largely affect the growth of an individual (Sæther and Haagenrud, 1983, Mysterud et al., 2001, Ericsson et al., 2002, Cook et al., 2004, Nielsen et al., 2014), which consequently gives the individual a higher probability of later-life success, such as survival and reproduction (Lindström, 1999, Forchhammer et al., 2001, Solberg et al., 2004, Descamps et al., 2008, Markussen et al., 2018, Markussen et al., 2019). Factors such as high temperature, low precipitation and full sunlight is thought to decrease the quality of foraging plants (Lenart et al., 2002, Nielsen et al., 2012). Similarly, low air temperature and low precipitation is not favorable for the quantity of the plants (Lenart et al., 2002). High air temperatures has been found to decrease the concentration of nutrients in plants, as well as increasing the phenolic content (defense against herbivores) in above ground shoots (Lenart et al., 2002). Simultaneously, it has also been suggested that a warm July seems to be linked to a higher production of herbs, thus resulting in better foraging conditions (Mysterud and Austrheim, 2014). Low temperatures could also increase the thermoregulatory cost, resulting in a lower effect of the biomass (Descamps et al., 2008).

In Boreal areas, the winter is the period when food availability is at its lowest (Cederlund et al., 1991, Nordengren et al., 2003). Due to snow accumulation the accessibility of foraging reduces substantially as grass and lower level of trees will be out of reach (Nordengren et al., 2003). At the same time, the effect of the plant biomass consumed can be lowered by the presence of snow, as the cost of movement increases with snow depth (Parker et al., 1984). Accordingly, body mass often decline or have a slow growth during winter, depending on the severity of the winter as well as changes in both quality and quantity of available food (Cederlund et al., 1991, Clutton-Brock and Albon, 1983). Additionally, snow-rich winters are often liked with a shorter growing season (Klein, 1970). However, snow rich winters also lead to a prolonged period of snow melt during the spring (Albon and Langvatn, 1992). This leads to a longer period where the plants are of higher quality to herbivores, as they are at an early phenological stage where they are rich in nitrogen and energy (Langvatn et al., 1996). Early in the growing season, small differences in digestibility, as well as quality, of forage plants can have a great effect on body mass (White, 1983).

Weather variables, such as temperature and precipitation, can contribute to synchronized dynamics in growth or life history variation between populations (Grøtan et al., 2005, Herfindal et al., 2020, Cattadori et al., 2005). However, a population's sensitivity to weather is also dependent on habitat, climatic conditions and density (Herfindal et al., 2020, Herfindal et al., 2006b, Nielsen et al., 2012). Therefore, populations may be less synchronized as they respond differently to the same weather conditions (Engen and Sæther, 2005, Herfindal et al., 2020). Consequently, weather conditions leading to an increase in abundance or trait value in one population, may have an opposite effect in another population (Herfindal et al., 2020, Engen and Sæther, 2005).

Roe deer *Capreolus capreolus* is an income breeder, and females should adjust their reproductive effort prior to substantial investment (Andersen et al., 2000, Hewison and Gaillard, 2001). For reproduction, roe deer should rely on food intake rather than fat reserves (Hewison and Gaillard, 2001). However, studies has shown that prenatal care increases with increasing maternal body weight (Andersen et al., 2000). As a result, heavier females have a higher level of prenatal investment, and can produce larger litters, both in size and number of individuals (Andersen and Linnell, 2000). The survival of offspring is more unpredictable in income breeders than in capital breeders, as it depends mostly on resource availability during lactation (Andersen et al., 2000). The conditions during spring and summer are of most importance for roe deer, as the nutritional plane in this time period seems to be crucial on the

survival of fawns (Pettorelli et al., 2003). Roe deer is highly selective feeders, and will select food that are highly digestible and high in nutrients (Pettorelli et al., 2003). Still, because of the high cost of lactation, females should supply energy to their offspring according to their fat reserves (Andersen et al., 2000). Therefore, heavier females are able to achieve a higher level of postnatal care, as they can use their own reserves in addition to energy obtained from daily foraging (Andersen et al., 2000).

Generally, the factors that affect fawn weight is maternal weight, population density, timing of birth and number of siblings (Andersen et al., 2004). Triplets are more common than single fawns in Scandinavia (Andersen et al., 1998), although twins are most common (Andersen et al., 2000). In Norway, a litter will weigh about 15% of maternal weight (Andersen et al., 1998). In a litter with a single fawn or twins, the weight gain of the fawns will be about the same (Andersen et al., 2004). However, in a litter with triplets the daily weight gain will be somewhat lower (Andersen et al., 2004). In Norway, roe deer fawns is born between late April and the start of July (Andersen et al., 2004). The timing of birth is of most importance as it will determine the availability of food for the fawn, as both quality and quantity of food plants vary greatly with the phenological stage of the plant (Bryant et al., 1983). The level of parental care will therefore be adjusted to the resources available

The aim of this thesis is to investigate how weather affect roe deer using data collected on fawn body mass from two different areas. Examination of body mass and environmental variation on several individuals could give an insight in the performance of the population as a result of different environmental conditions. This could be useful information for wildlife managers when setting harvesting quotas (Herfindal, 2006), and could be a useful tool in the management of ungulates. Knowledge about these interactions in a population is also important to make realistic prediction about changes in the population (Portier et al., 1998). Based on the knowledge of body mass being one of the first traits that get effected by temporal variation (Eberhardt, 2002), I predict that high autumn fawn body mass is found after winters with low snow depth and precipitation. Similarly, I predict that higher autumn fawn body mass will be recorded after years where the temperature during early spring is high, as it can result in earlier onset of spring, which consequently result in a longer growing period. I also predict higher body mass after years where the temperature and precipitation is low during summer as it will result in higher forage quality. I expect the weather effects to be similar the same at the two areas, but in different degree as the two locations are relatively far apart.

## 2 Methods

### 2.1 Study species

Roe deer, *Capreolus capreolus*, occur in almost all parts of Europe (Linnell et al., 1998a, Andersen et al., 2004), and has increased both their densities and range the last century (Holand et al., 1998). The large prevalence is a great indicator of the species success, ranging from the Mediterranean coast to northern Norway (Andersen et al., 2004). The Scandinavian roe deer is at the most northern range of the species (Holand et al., 1998), where temporal variation in environmental conditions should have an important impact on population dynamics (Gaillard et al., 2000). Roe deer appear in most of the natural habitats and agricultural landscapes in Europe, except high alpine areas over the tree line (Linnell et al., 1998a). They also have a high tolerance of human activity, which in return has allowed them to occupy plantation forests, mixed forest, farmland and open agricultural plains in addition to Mediterranean forests, shrublands, moorlands and marshes (Linnell et al., 1998a, Holand et al., 1998).

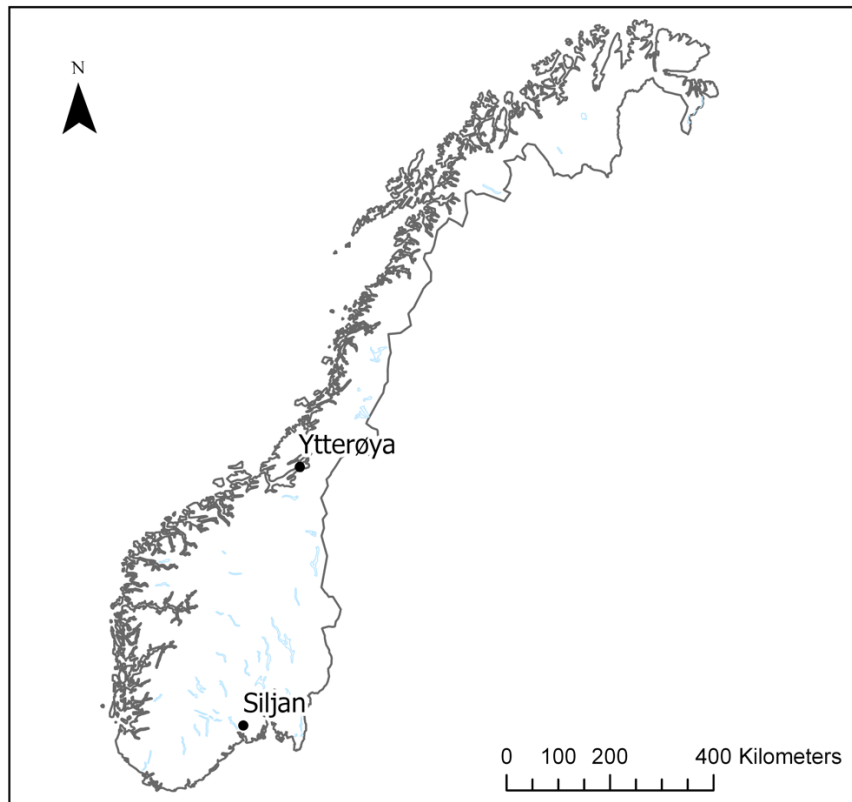
### 2.2 Study areas

The data for this project were collected at two different locations: Siljan and Ytterøya (Figure 2.2.1), both located in the boreal vegetation zone (Moen and Lillethun, 1999). Ytterøya is a small island of 28 km<sup>2</sup> located in the Trondheimsfjord in central Norway, with a vegetation mixed by agricultural land and forests (Herfindal, 2006). The forest are a mixture of pine *Pinus sylvestris*, spruce *Picea abies* and deciduous trees (birch *Betula pubescens* and other broad leafed tree species) (Herfindal, 2006, Puschmann, 2005). The agricultural fields are dominated by grain and grass (Puschmann, 2005). The highest point of Ytterøya is 210 m.a.s.l. (Herfindal, 2006).

At Siljan the roe deer has been harvested within the land property of Fritzøe, an area of 615 km<sup>2</sup> dominated by forest located in south-eastern Norway (Fritzøe skoger, 2019).

Traditionally, the area has been used to produce spruce, and about 69% of the forest is spruce *Picea abies* (Fritzøe skoger, 2020). About 17% of the forest is deciduous and 14% pine *Pinus sylvestris* (Fritzøe skoger, 2020). The forest also have areas of where the trees has been logged, as well as areas of marshland (Fritzøe skoger, 2020). Surrounding agricultural land are mostly grain and grass (Puschmann, 2005). The altitude ranges from 20 to 800 meters

above sea level (Fritzøe skoger, 2020). The annual precipitation is about 1.100 mm (Fritzøe skoger, 2020).



**Figure 2.2.1:** The locations of Ytterøya and Siljan where the data of roe deer body mass was collected.

### 2.3 Data collection

At Siljan the data has been collected over 6 years (1993-1998) by hunters during the annual harvesting. The hunters filled out forms with information regarding the animal and circumstances around the hunt, such as weight, sex and the date which the animal was shot. At Ytterøya individual data on roe deer have been collected since 1984. In both areas, data include age, sex and carcass mass (the mass of the individual minus head, skin, metapodials bleedable blood and viscera) that constitutes on average of 50% of body mass. The weight of 1939 roe deer fawns was included in this study, where 1618 and 321 were from Ytterøya and Siljan, respectively.

Weather data was collected from the Norwegian Meteorological Institute as downscaled 1 x 1 km<sup>2</sup> gridded daily data covering all of Norway (Skaugen et al., 2002). For each of the municipalities, Ytterøya and Siljan, monthly mean temperature (T), mean snow depth (S) and sum of precipitation (P) was calculated by averaging the value of the pixels within the



municipality's borders. Only pixels that was below the climatic tree line was included in the analyzes, to exclude climatic variations from areas roe deer rarely roam.

## 2.4 Statistical analyses

Throughout the hunting season, the weight of the animals will change (Solberg et al., 2004, Solberg et al., 2006, Linnell et al., 1998b). Fawns have been found to have a close to linear growth rate during autumn (Linnell et al., 1998b), thus a linear model was run to evaluate the effect of harvesting date as well as sex. The model estimated that male fawns would be an average of 319 g heavier than female fawns. It also suggested that the fawn body weight increased by 2.6 g per day during the hunting season. Therefore the recorded body mass ( $W$ ) was adjusted according to the equations I (females) and II (males), where  $t$  is the date of harvesting relative to September 1<sup>st</sup>.  $\beta_1$  is the coefficient of  $W$  as a function of date,  $\beta_2$  is the coefficient of  $W$  as a function of sex. Based on expert evaluations and literature, all fawns with a recorded weight above 15 kg was excluded as heavier fawns is highly unlikely and was most likely due to mistakes during ageing or weighing the animals (E.J. Solberg, E. Lund, V. Holte, personal communication). All further analyses are based on  $W_{adj}$ .

$$W_{adj} = W - t * \beta_1 \quad (I)$$
$$W_{adj} = W - t * \beta_1 - \beta_2 \quad (II)$$

Univariate models were used to estimate effects of climatic variables on autumn fawn weight. Every month and environmental factor were treated as independent variables to illustrate the effect of each month using linear models. Correlation among monthly values for each of the climatic variables was investigated to explore to what extent there was temporal autocorrelation within a year. In both areas, weather during the winter months was quite correlated, particularly the snow depth. Based on this, and to reduce the number of exploratory variables, the winter weather variables i.e. winter snow (mean snow depth from January to April), winter precipitation (mean precipitation from January to March) and winter temperature (mean temperature from January to March) was aggregated across months as the mean between the months.

Next, the variables found to have a significant effect on autumn fawn weight at the different locations were included in location-specific model selection procedure based on AICc to

Identify the potential combination of variables providing the most parsimonious model explaining variation in fawn weight. Due to a small sample size, AICc were used (the corrected AIC), where there is a penalty equation for low sample size compared to the number of parameters (Burnham et al., 2011).

As a final step, to test for area-specific weather effects, the variables included in the area-specific top models were included in a candidate set of models. This time with area\*weather variable interaction term. This was done separately for the highest ranked area-specific models due to a low sample size not allowing to include a high number of parameters in a model.

Ecological data are often collinear as ecological data are often complex, and the responses are linked to many explanatory variables that are correlated (Graham, 2003). To check whether there was any multicollinearity, the correlation coefficients among all explanatory variables were estimated. All statistical analyses were done in R version 3.6.1 for MacOS.

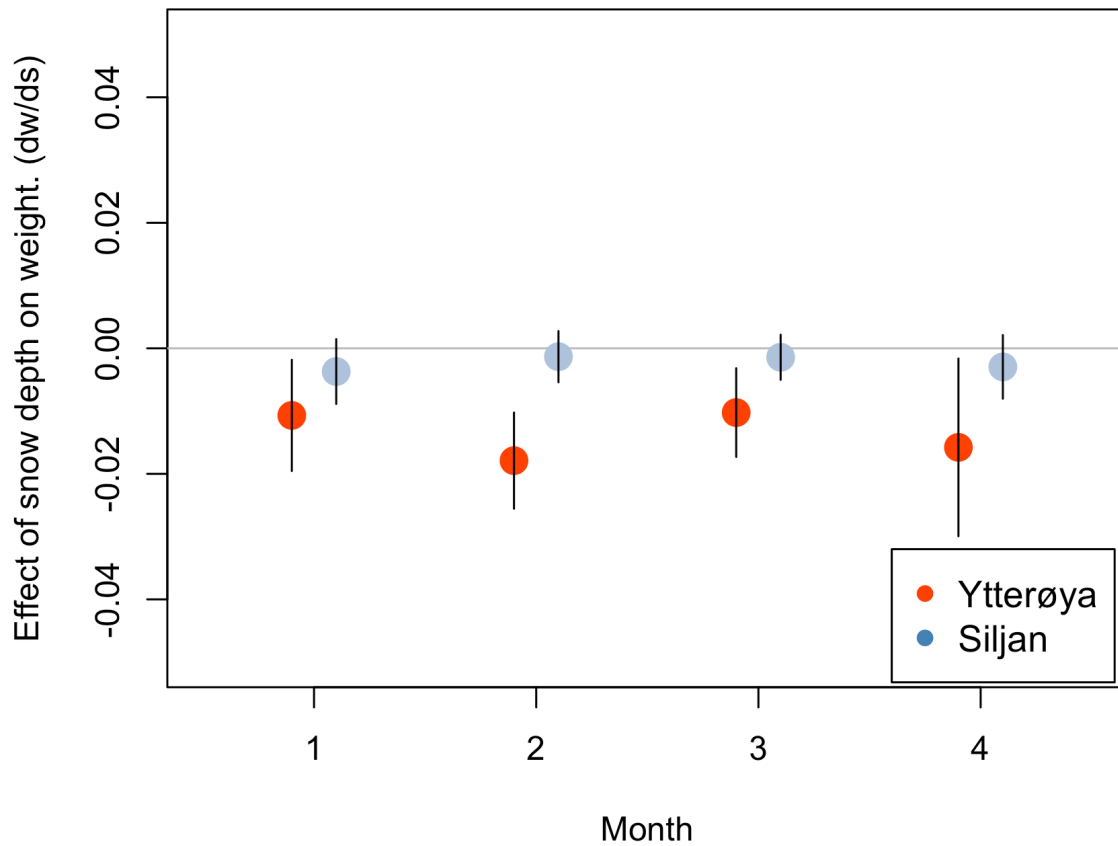
### 3 Results

The mean adjusted weight of all fawns (normalized to September 1<sup>st</sup> and female) were 8.72 kg (SD = 1.41 kg, range = 3.51 kg – 13.97 kg). The mean fawn weight at Ytterøya was 8.61 ± 1.40 kg (over a period of 20 years, n = 1618). At Siljan the mean weight of the fawns was 9.24 ± 1.37 kg (over a period of 6 years, n = 321). The weight difference between the two areas was significant ( $p < 0.001$ ). The mean temperature at Ytterøya between January and July was 5.4 °C (range = -1.29 – 14.97, years = 20), mean precipitation was 222 mm (range = 142 – 271, years = 20) and the mean snow depth between January and April was 11.7 cm (range = 4.2 – 16.1, years = 20). At Siljan the mean temperature between January and July was 5.4 °C (range = -2.9 – 16, years = 6), mean precipitation was 207 mm (range = 142 – 293, years = 6) and the mean snow depth between January and April was 46.6 cm (range = 35.3 – 53.1, years = 6). There was a significant difference in mean snow depth between the two areas ( $p = 0.001$ ), however the differences in mean temperature ( $p = 0.99$ ) or precipitation ( $p = 0.62$ ) were not significant.

#### 3.1 Effect of snow depth on fawn body mass

At Ytterøya, all months had a significant effect of snow depth on fawn weight (Figure 3.1.1). The models predicted negative relationships between monthly snow depth and fawn weight. Snow depth in January had a negative effect on autumn fawn weight with a decrease of 10.7 g with an increase in snow depth of 1 cm (SE = 4.5,  $p = 0.018$ ). In February the model predict a decrease of 17.9 g (SE = 3.9,  $p < 0.001$ ), in March the decrease in fawn weight was predicted to be 10.2 g (SE = 3.6,  $p = 0.005$ ) and in April 15.8 g (SE = 7.2,  $p = 0.029$ ). The results of the correlation test (Table 3.1.1) show a high positive correlation ( $\rho$ ) of snow depth between January, February, March and April ( $\rho = 0.43 - 0.81$ ,  $p < 0.056$ , years = 20). The effect of snow depth in these months combined showed a decrease in fawn weight by 23.9 g per cm (SE = 0.006,  $p < 0.001$ , years = 20).

### Effect of snow depth



**Figure 3.1.1:** Effect of snow depth (cm) on fawn weight (kg). Opaque colors are significant, transparent colors are not significant.

**Table 3.1.1:** Above the diagonal: coefficients of correlation ( $\rho$ ) between snow depths in different months at Ytterøya. Below the diagonal: corresponding p-values. Number of years = 20.

	January	February	March	April
January		0.70	0.49	0.43
February	< 0.001		0.72	0.69
March	0.029	< 0.001		0.81
April	0.056	< 0.001	< 0.001	

The result from Siljan showed no significant effect of snow depth on autumn fawn weight ( $p > 0.16$ ) (Figure 3.1.1). Similarly, the effect of the snow depth in the months combined was not significant ( $p = 0.328$ ). There were high correlations between snow depth in the months between January and April (Table 3.1.2) ( $\rho = 0.84 - 0.96$ ,  $p < 0.034$ , years = 6).

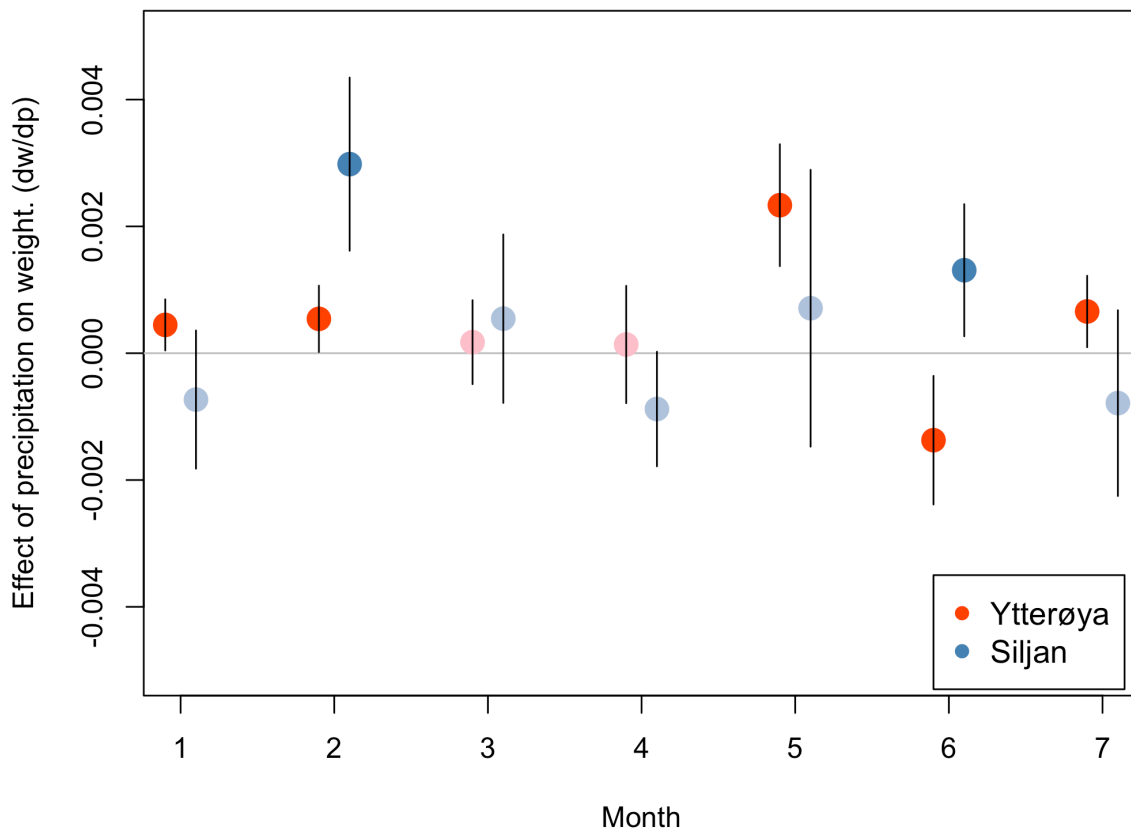
**Table 3.1.2:** Above the diagonal: coefficients of correlation ( $\rho$ ) between snow depths in different months at Siljan. Below the diagonal: corresponding p-values. Number of years = 6.

	January	February	March	April
January		0.95	0.84	0.88
February	0.004		0.96	0.95
March	0.034	0.002		0.96
April	0.020	0.003	0.002	

### 3.2 Effect of precipitation on fawn body mass

There was a positive relationship between precipitation in January and autumn fawn weight at Ytterøya with an increase of fawn weight by 0.4 g per mm precipitation (SE = 0.2,  $p=0.030$ ) (Figure 3.2.1). Precipitation in February also had a positive effect on fawn weight, predicting an increase of 0.5 g per mm (SE = 0.27,  $p = 0.043$ ). The month with the highest positive effect of precipitation at Ytterøya was May with an increase of autumn fawn weight by 2.3 g per mm (SE = 0.49,  $p < 0.001$ ). Precipitation in July also had a positive effect on fawn weight by 0.7 g per mm (SE = 0.29,  $p = 0.022$ ). The only month with a negative effect was June, where an increase of 1 mm precipitation was predicted to give a decrease of autumn fawn weight by 1.4 g (SE = 0.52,  $p = 0.008$ ). Precipitation during March and April did not affect fawn body mass significantly at Ytterøya ( $p > 0.607$ ). The correlation test (Table 3.2.1) showed a significant positive correlation between precipitation between January and May at Ytterøya ( $\rho = 0.49$ ,  $p = 0.028$ , years = 20), and March and April as well ( $\rho = 0.45$ ,  $p = 0.049$ , years = 20).

### Effect of precipitation



**Figure 3.2.1:** Effect of monthly precipitation (mm) on weight (kg). Opaque colors are significant, transparent colors are not significant.

**Table 3.2.1:** Above the diagonal: coefficients of correlation ( $\rho$ ) of precipitation in different months at Ytterøya. Below the diagonal: corresponding p-values. Years = 20.

	January	February	March	April	May	June	July
January		0.02	0.15	-0.29	0.49	-0.06	-0.37
February	0.930		0.05	0.06	0.20	0.20	0.20
March	0.516	0.836		0.45	-0.26	-0.20	-0.15
April	0.220	0.791	0.049		-0.11	-0.11	0.33
May	0.028	0.389	0.273	0.657		-0.25	0.06
June	0.803	0.400	0.387	0.633	0.280		0.4
July	0.111	0.400	0.534	0.153	0.792	0.878	

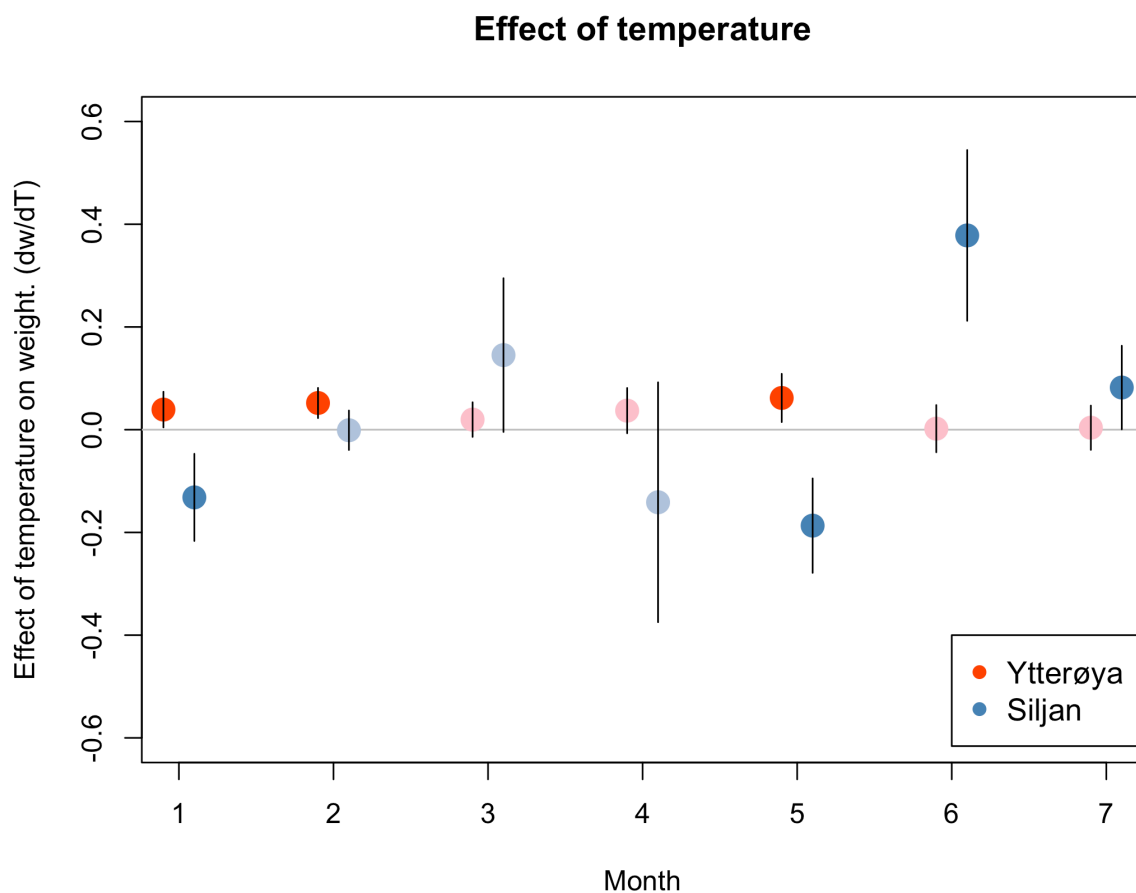
At Siljan, precipitation had a positive effect on autumn fawn weight in February and June (Figure 3.2.1). In February the increase was found to be 2.98 g per mm (SE = 0.69,  $p < 0.001$ ), and in June 1.3 g per mm (SE = 0.52,  $p = 0.014$ ). No other months had significant effects of precipitation at Siljan ( $p > 0.056$ ). At Siljan there were positive correlations between January and March (Table 3.2.2) ( $\rho = 0.8$ ,  $p = 0.055$ , years = 6), and between February and March ( $\rho = 0.31$ ,  $p = 0.055$ , years = 6). The results show a strong negative correlation of precipitation between April and May at Siljan ( $\rho = -0.84$ ,  $p = 0.039$ , years = 6).

**Table 3.2.2:** Above the diagonal: coefficients of correlation ( $\rho$ ) of precipitation in different months at Siljan. Below the diagonal: corresponding p-values.

	January	February	March	April	May	June	July
January		-0.06	0.80	0.32	-0.02	0.32	0.07
February	0.914		0.31	-0.56	0.24	0.51	0.03
March	0.055	0.554		0.37	-0.38	0.58	-0.02
April	0.541	0.245	0.471		-0.84	0.32	0.22
May	0.968	0.641	0.462	0.039		-0.30	-0.12
June	0.533	0.305	0.223	0.540	0.564		0.47
July	0.897	0.953	0.967	0.679	0.825	0.351	

### 3.3 Effect of temperature on fawn body mass

The models predicted a positive correlation between temperature and autumn fawn weight in January, February and May at Ytterøya (Figure 3.3.1). In January it was predicted an increase of 39.1 g per degree Celsius increase (SE = 17.69,  $p = 0.027$ ), in February 52 g (SE = 14.98,  $p < 0.001$ ) and in May 61.8 g (SE = 23.93,  $p = 0.01$ ). No other months was found to be significant ( $p > 0.1$ ). Results of the correlation test (Table 3.3.1) show a significant positive correlation between the temperature in January and February ( $\rho = 0.58$ ,  $p = 0.007$ , years = 20) at Ytterøya.



**Figure 3.3.1:** Effect of temperature ( $^{\circ}\text{C}$ ) on weight (kg). Opaque colors are significant, transparent colors are not significant.



**Table 3.3.1:** Above the diagonal: coefficients of correlation ( $\rho$ ) of temperature in different months at Ytterøya. Below the diagonal: corresponding p-values. Years = 20.

	January	February	March	April	May	June	July
January		0.58	0.11	-0.07	0.02	0.09	-0.07
February	0.007		0.38	0.24	0.38	0.34	-0.26
March	0.658	0.098		0.20	-0.10	0.23	-0.21
April	0.771	0.317	0.396		0.30	-0.20	-0.02
May	0.935	0.102	0.689	0.205		0.21	-0.10
June	0.706	0.149	0.332	0.393	0.372		0.13
July	0.782	0.277	0.366	0.934	0.683	0.580	

At Siljan the models predicted a decrease in fawn weight with an increase in temperature in February and May (Figure 3.3.1). In February the decrease in fawn weight was 131.8 g per degree Celsius (SE = 43.11,  $p = 0.002$ ), and in May 186.8 g (SE = 46.71,  $p < 0.001$ ). However, in June and July an increase in temperature was predicted to increase autumn fawn weight. In June the increase is predicted to be 378.2 g per degree Celsius (SE = 84.51,  $p < 0.001$ ), and 82.1 g in July (SE = 41.34,  $p = 0.048$ ). At Siljan no significant correlations were found (Table 3.3.2). However, the result show signs of a negative correlation between May and June ( $\rho = -0.77$ ,  $p = 0.076$ , years = 6).

**Table 3.3.2:** Above the diagonal: coefficients of correlation ( $\rho$ ) of temperature in different months at Siljan. Below the diagonal: corresponding p-values. Years = 6.

	January	February	March	April	May	June	July
January		0.74	0.36	-0.28	0.78	-0.58	-0.55
February	0.094		0.74	-0.57	0.36	-0.04	-0.54
March	0.477	0.091		-0.14	0.17	0.37	0.07
April	0.591	0.238	0.793		0.24	0.04	0.42
May	0.066	0.490	0.749	0.643		-0.77	-0.27
June	0.232	0.937	0.475	0.946	0.076		0.26
July	0.262	0.265	0.902	0.412	0.602	0.614	

### 3.4 Monthly correlation

In the months of January to April there was found to be a negative correlation between snow depth and temperature ( $\rho = -0.48 - -0.56$ ,  $p < 0.001$ ), in these months there was not found a significant correlation between snow depth and precipitation ( $p > 0.01$ ) (Table 3.4.1). There was a significant positive correlation between precipitation and temperature in the months of January and February ( $\rho = 0.38 - 0.39$ ,  $p < 0.001$ ), the same trend could also be seen in March ( $\rho = 0.14$ ,  $p = 0.118$ ). However, in the months from April to July the trend was a weak negative correlation, with a significant result in July ( $\rho = -0.12 - -0.24$ ,  $p > 0.008$ ).

As there was found to be high correlation between snow depth in all winter months (January - March) (Table 3.1.1), and snow depth, temperature and precipitation were correlated (Table 3.4.1). Monthly variables of snow depth, precipitation and temperature during winter months were aggregated because of high correlation among the monthly variables.

**Table 3.4.1:** coefficients of correlation ( $\rho$ ) between precipitation and temperature, precipitation and snow depth as well as snow depth and temperature for the months from January to July. The coefficients of correlation for the aggregated months (January – March) is also presented as winter.

Period	Precipitation/Temperature	Precipitation/Snow depth	Snow depth/Temperature
January	0.39 ( $p < 0.001$ )	0.15 ( $p = 0.109$ )	-0.52 ( $p < 0.001$ )
February	0.38 ( $p < 0.001$ )	0.01 ( $p = 0.900$ )	-0.56 ( $p < 0.001$ )
March	0.14 ( $p = 0.118$ )	0.15 ( $p = 0.010$ )	-0.46 ( $p < 0.001$ )
April	-0.13 ( $p = 0.163$ )	0.09 ( $p = 0.347$ )	-0.48 ( $p < 0.001$ )
May	-0.12 ( $p = 0.206$ )	-	-
June	-0.17 ( $p = 0.059$ )	-	-
July	-0.24 ( $p = 0.008$ )	-	-
Winter	0.61 ( $p < 0.001$ )	-0.06 ( $p = 0.005$ )	-0.5 ( $p < 0.001$ )

### 3.5 Multivariate modelling of weather effects on fawn body mass

Based on the climate variables that showed significant effect in the univariate tests, and aggregation of correlated monthly weather variables, the candidate model set for explaining variation in fawn body mass at Ytterøya included all possible combinations of the following variables: Snow depth during winter ( $Wins$ ), precipitation during winter ( $Win_P$ ), precipitation

in May ( $May_P$ ), precipitation in June ( $Jun_P$ ), precipitation in July ( $Jul_P$ ), Temperature during winter ( $Win_T$ ) and temperature in May ( $May_T$ ). The highest ranked model explaining the variation in fawn body weight at Ytterøya included precipitation during winter (January, February and March) as well as precipitation in May, June and July (Table 3.5.1).

Precipitation in May, June and July were included in all models with  $\Delta AICc < 2$ , and precipitation during winter were represented in the three highest ranked models.

**Table 3.5.1:** Ranking of models explaining variation in autumn fawn weight at Ytterøya. Only models with  $\Delta AICc < 2$ , relative to the highest ranked model are shown. The set of candidate models included all possible combination of winter snow depth ( $Wins$ ), winter precipitation ( $Win_P$ ), May precipitation ( $May_P$ ), June precipitation ( $Jun_P$ ), July precipitation ( $Jul_P$ ), winter temperature ( $Win_T$ ) and May Temperature ( $May_T$ ).

Rank	$Wins$	$Win_P$	$May_P$	$Jun_P$	$Jul_P$	$Win_T$	$May_T$	$\Delta AICc$	weight
1	-	x	x	x	x	-	-	0	0.128
2	-	x	x	x	x	-	x	0.24	0.113
3	x	x	x	x	x	-	-	1.31	0.066
4	-	-	x	x	x	x	x	1.79	0.052
5	x	x	x	x	x	-	x	1.81	0.052
6	-	x	x	x	x	x	-	1.94	0.049

Thus, the highest ranked model confirmed the results from the univariate tests, where fawn body mass was positively related to precipitation in winter, May and July, and negatively related to precipitation in June (Table 3.5.2).

**Table 3.5.2:** Summary of the best ranked model in table 3.5.1. The model include winter precipitation ( $Win_P$ ), precipitation in May ( $May_P$ ), precipitation in June ( $Jun_P$ ) and precipitation in July ( $Jul_P$ ). The unit of precipitation is mean precipitation during the month.

Variable	Estimate (kg)	Standard Error	t-value	p-value
$Win_P$	0.00127	0.00044	2.876	0.004
$May_P$	0.00151	0.00053	2.821	0.005
$Jun_P$	-0.00173	0.00062	-2.767	0.006
$Jul_P$	0.00126	0.00034	3.721	< 0.001

The set of candidate models based on the significant results from the univariate tests at Siljan included all possible combinations of precipitation in winter ( $Win_P$ ) and June ( $Jun_P$ ), as well as temperature during winter ( $Win_T$ ), May ( $May_T$ ), June ( $Jun_T$ ) and July ( $Jul_T$ ). The top ranked model explaining variation in fawn body mass at included temperature and precipitation in June (Table 3.5.3). Temperature in June was included in all seven models with  $\Delta AICc < 2$ , whereas precipitation in June was represented in four of the seven models. Thus, the highest ranked model confirmed the results from the univariate tests, where fawn body mass was positively related to precipitation and temperature in June (Table 3.5.4). The second best model only included temperature in June, while the third best model include winter precipitation (January, February and March), precipitation in June and temperature in June.

**Table 3.5.3:** Ranking of models explaining variation in autumn fawn weight at Siljan. Only models with  $\Delta AICc < 2$ , relative to the highest ranked model are shown. The candidate set of models include all possible combinations of winter precipitation ( $Win_P$ ), precipitation in June ( $Jun_P$ ), winter temperature ( $Win_T$ ), May temperature ( $May_T$ ), June temperature ( $Jun_T$ ) and July temperature ( $Jul_T$ ).

Rank	$Win_P$	$Jun_P$	$Win_T$	$May_T$	$Jun_T$	$Jul_T$	$\Delta AICc$	weight
1	-	x	-	-	x	-	0	0.107
2	-	-	-	-	x	-	0.19	0.098
3	x	x	-	-	x	-	1.34	0.055
4	-	-	-	x	x	-	1.41	0.053
5	-	x	-	-	x	x	1.77	0.044
6	-	-	-	-	x	x	1.89	0.042
7	-	x	x	-	x	-	1.92	0.041

**Table 3.5.4:** Summary of the best ranked model in table 3.4.3. The model include precipitation in June ( $Jun_P$ ) and temperature in June ( $Jun_T$ ).

Variable	Estimate (kg)	Standard Error	t-value	p-value
$Jun_P$	0.000796	0.000533	1.492	0.137
$Jun_T$	0.347	0.0869	3.992	< 0.001

### 3.6 Difference in weather effects between the two areas

The final step in the statistical analysis was to combine the results from Ytterøya and Siljan. By adding area as a factor and allowing for area\*weather interactions, this allowed for testing to what extent variation in fawn body mass was best explained by a) identical weather variables at the two contrasting localities and subsequently b) if effects of weather conditions could be modelled with common coefficients across the two localities.

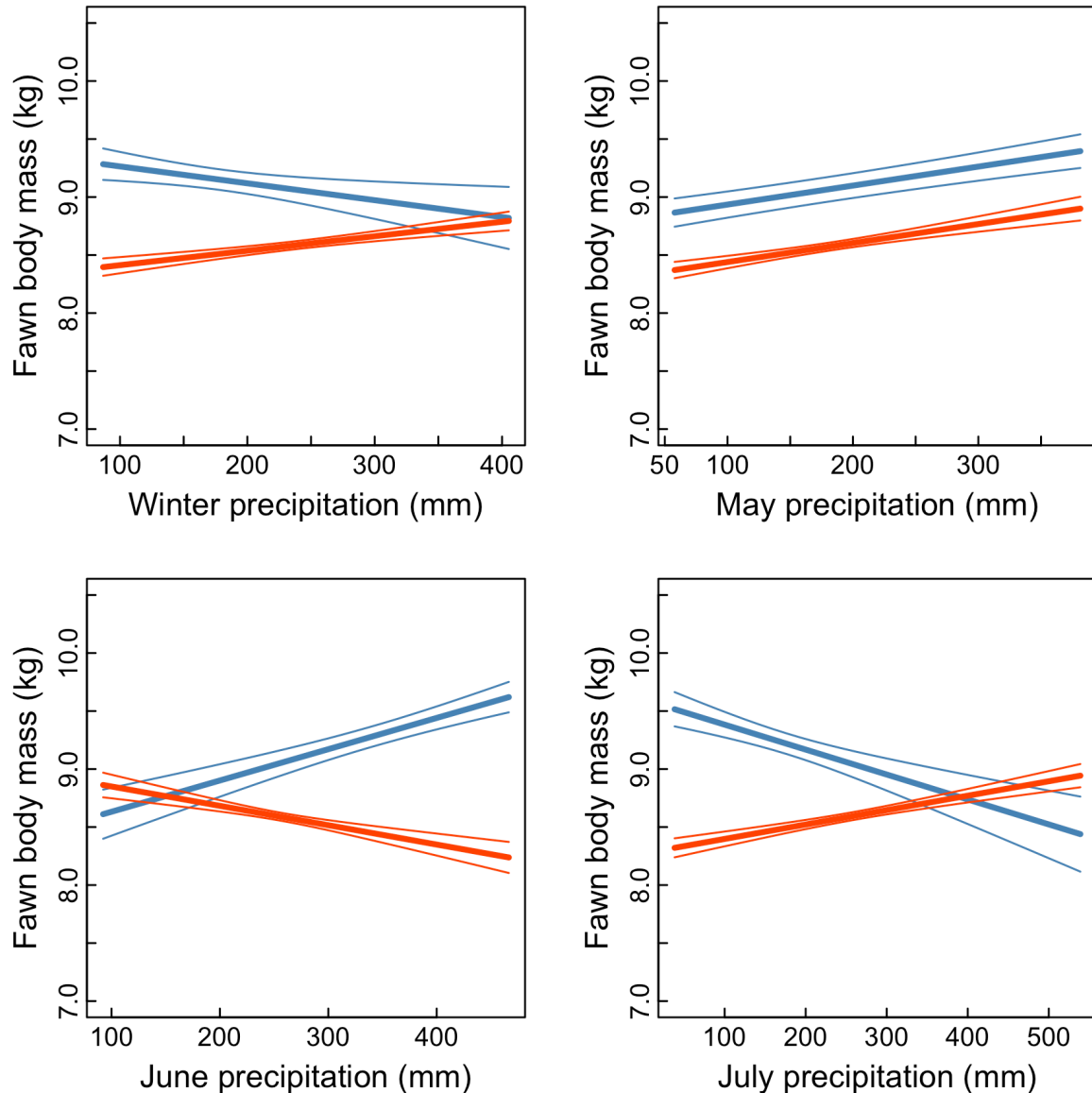
Using the weather variables included in the highest ranking model for Ytterøya (Table 3.5.1) as the basis for the candidate model set, the highest ranked model included the interactions between area and precipitation during winter and precipitation in June and July, in addition to their main effects and the main effect of May precipitation (Table 3.6.1). These interactions were included in both models that had a  $\Delta AICc < 2$ . The summary of the top ranked model (Table 3.6.2) was used to predict the effect of the weather variables. The relationship between fawn body mass and precipitation during May was similar in the two areas, the effect of precipitation the rest of the year differed between Siljan and Ytterøya (Figure 3.6.1). Winter precipitation had a positive effect on Ytterøya, while the effect was negative at Siljan. Both Ytterøya and Siljan had positive effect of May precipitation on fawn body mass. In June, the areas had opposite effects of precipitation, where Ytterøya had a negative effect and Siljan had a positive effect. In July the predicted effect of precipitation was positive at Ytterøya, and negative at Siljan.

**Table 3.6.1:** Ranking of models explaining variation in autumn fawn weight, only including the parameters found to be of most importance at Ytterøya. The model includes the area (Mun), Winter precipitation (Win<sub>P</sub>), May precipitation (May<sub>P</sub>), June precipitation (Jun<sub>P</sub>), July precipitation (Jul<sub>P</sub>), as well as the interaction between municipality and the different weather parameters (Mun\*Win<sub>P</sub>, Mun\*May<sub>P</sub>, Mun\*Jun<sub>P</sub>, Mun\*Jul<sub>P</sub>).

Rank	Mun	Win <sub>P</sub>	May <sub>P</sub>	Jun <sub>P</sub>	Jul <sub>P</sub>	Mun* Win <sub>P</sub>	Mun* May <sub>P</sub>	Mun* Jun <sub>P</sub>	Mun* Jul <sub>P</sub>	ΔAICc	weight
1	x	x	x	x	x	x	-	x	x	0	0.549
2	x	x	x	x	x	x	x	x	x	1.65	0.241
3	x	x	x	x	x	-	-	x	x	3.14	0.114
4	x	x	x	x	x	-	x	x	x	5.15	0.042
5	x	-	x	x	x	-	-	x	x	5.94	0.028

**Table 3.6.2:** Summary of the best ranked model in Table 3.6.1. The Intercept is the estimates at Siljan. The model include winter precipitation (Win<sub>P</sub>), May precipitation (May<sub>P</sub>), June precipitation (Jun<sub>P</sub>) and July precipitation (Jul<sub>P</sub>).

	Estimate (kg)	Standard error	t-value	p-value
Intercept	8.924	0.257	34.725	< 0.001
Ytterøya	-0.801	0.306	-2.621	0.00885
Win <sub>P</sub>	-0.00146	0.00112	-1.306	0.192
May <sub>P</sub>	0.00164	0.000487	3.364	< 0.01
Jun <sub>P</sub>	0.0027	0.000776	3.476	< 0.001
Jul <sub>P</sub>	-0.00215	0.000857	-2.510	0.0122
Ytterøya*Win <sub>P</sub>	0.0027	0.00119	2.268	0.0234
Ytterøya*Jun <sub>P</sub>	-0.00436	-0.00436	-4.541	< 0.001
Ytterøya*Jul <sub>P</sub>	0.00339	0.000916	3.702	< 0.001



**Figure 3.6.1:** Predicted effect of winter precipitation (upper left), May precipitation (upper right), June precipitation (lower left) and July precipitation (lower right) on fawn body mass. Effect at Ytterøya is demonstrated in red color, while the effect on Siljan is in blue. The thick lines show the estimates, while the thinner lines show the standard error for the prediction.

June precipitation and temperature were the variables explaining the variation in fawn weight at Siljan (Table 3.5.3). When running model selection with these variables in interaction with area, the highest ranked model was the full model, i.e. both interactions (Table 3.6.3). The next best model had a  $\Delta\text{AICc}$  of 5.72, and only included temperature in June and its interaction with area. The summary of the top ranked model (Table 3.6.4) was used to predict the effect of the weather variables. The highest ranked model predicted a negative effect of June precipitation at Ytterøya and weakly positive at Siljan (Figure 3.6.2). The effect of

temperature in June had a strong positive effect at Siljan, whereas Ytterøya had a very weak negative effect.

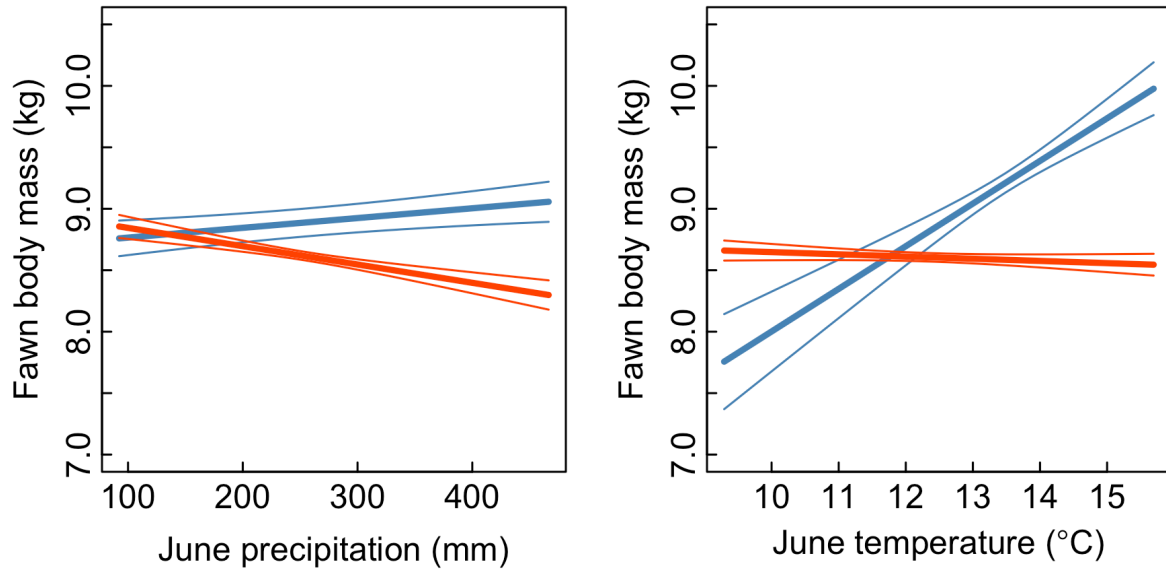
**Table 3.6.3:** Ranking of models explaining variation in autumn fawn weight, only including the parameters found to be of most importance at Siljan. The models include factor of municipality (Mun), the precipitation in June (Jun<sub>P</sub>), the temperature in June (Jun<sub>T</sub>), as well as the interaction between municipality and the weather variables (Mun\*Jun<sub>P</sub>, Mun\*Jun<sub>T</sub>).

Rank	Mun	Jun <sub>P</sub>	Jun <sub>T</sub>	Mun*Jun <sub>P</sub>	Mun*Jun <sub>T</sub>	ΔAICc	weight
1	x	x	x	x	x	0	0.912
2	x	-	x	-	x	5.72	0.052
3	x	x	x	-	x	6.75	0.031
4	x	x	-	x	-	11.25	0.003
5	x	x	x	x	-	13.18	0.001

**Table: 3.6.4:** Summary of the best ranked model in Table 3.6.3. The Intercept is the estimates at Siljan. The model include the precipitation in June (Jun<sub>P</sub>) and temperature in June (Jun<sub>T</sub>).

	Estimate (kg)	Standard error	t-value	p-value
Intercept	4.323	1.196	3.614	< 0.001
Ytterøya	4.897	1.251	3.913	< 0.001
Jun <sub>P</sub>	0.000796	0.000554	1.435	0.151
Jun <sub>T</sub>	0.347	0.0904	3.839	< 0.001
Ytterøya*Jun <sub>P</sub>	-0.00229	0.000772	-2.96	0.003
Ytterøya*Jun <sub>T</sub>	-0.3649	0.0936	-3.9	< 0.001





**Figure 3.6.2:** Predicted effect of June precipitation (left) and June temperature (right) on fawn body mass. Effect at Ytterøya is showed in red color, while the effect at Siljan is in blue. The thick lines show the estimates, while the thinner lines show the standard error for the prediction.



## 4 Discussion

By using data on autumn fawn body mass from two roe deer populations, there was found contrasting effects of weather on this important life history trait. At Ytterøya, roe deer fawns were mainly affected by precipitation during winter and summer, whereas roe deer fawns at Siljan were strongly affected by summer conditions, particularly June temperature. This suggests that conditions both before and after birth affect fawn body mass. However, the importance of these factors differs between the populations.

According to the univariate model, snow conditions was not found to be important for roe deer at Siljan, whereas at Ytterøya this variable was highly significant showing negative effect of snow depth in all winter months. However, when also accounting for other variables, snow depth was not in the best model whereas winter precipitation was included. When investigating the correlation between months and weather effects, it was found a high correlation between snow depth in all winter months. Similarly, when examining the monthly correlations, it was apparent that snow depth was significantly correlated with temperature, that again was correlated with precipitation. This suggests that effect of weather is more complex, and more than one parameter is of importance. The model implies that precipitation during the winter months may be a better variable to use when predicting differences in body mass, rather than snow depth as first predicted.

At Siljan the predicted effect of winter precipitation was negative, while it was positive at Ytterøya. As the lowest temperature at Siljan is lower than at Ytterøya and mean snow depth is quite a bit higher, it is possible that more of the precipitation result in snowfall at Siljan whereas the outcome may be more rain at Ytterøya. Larger snow depth result in a shorter growing period as well as the animals having to use more energy on movement (Parker et al., 1984). This could affect the maternal body weight, which then again would affect the body mass of fawn as females should supply energy according to their fat reserves during lactation (Andersen et al., 2000).

The mean snow depth at Ytterøya is significantly lower than at Siljan (46.6 cm > 11.7 cm,  $p = 0.001$ ). According to the univariate model, temperature in January and February was found to have a positive effect on fawn body mass. The correlation between temperature and snow depth during winter was also found to be negative and indicates that warmer temperatures result in less snow. Accordingly, a warm winter does not necessarily have to have the same outcome in two different areas. In some places a warm winter could result in rain, whereas it

also could result in snowfall (Mysterud et al., 2000). It is therefore likely that precipitation during winter at Ytterøya is rain, this could contribute to snow melt, and consequently a longer growing period (Nielsen et al., 2012, Pettorelli et al., 2005). As the mean snow depth is quite low, the precipitation that is snowfall probably do not affect the cost of movement greatly. It is rather a possibility that snowfall at Ytterøya can contribute to a prolonged period where the plants are at an early phenological stage where they are rich in nutrients (Lenart et al., 2002). As a result, both maternal body mass and fawn body mass could increase as the quality and digestibility of plants is very important early in the growing season (Langvatn et al., 1996).

The fact that there were significant differences among the populations in how body mass was related to winter conditions indicates that there are some differences between the populations that causes animals to respond differently to winter weather. The effect of winter weather on autumn fawn body mass at Ytterøya can be explained by its effect on the mothers of the fawns. Increasing maternal body weight could result in a higher prenatal care, thus heavier fawns (Andersen et al., 2000). Consequencely, if the increased amount of snow resulted in decreased maternal body weight, smaller fawns would be born. Snow conditions can also affect onset of spring and the length of growing season, which also affect body mass of herbivores (Ericsson et al., 2002, Herfindal et al., 2006b). The results found in this study also indicate that this is the case, as larger snow depth often result in a shorter growing period (Klein, 1970).

A possible explanation to why winter conditions were not significant at Siljan could be that roe deer at Siljan is more accustomed to large snow depths, as there is usually more snow at Siljan than Ytterøya. During the study periods, Ytterøya and Siljan had a mean snow depth of respectively 11.7 cm and 46.6 cm between January and April. Therefore, it may be that the population at Siljan won't be as affected by differences in snow depth, as every additional cm of snow won't be a huge percentage increase. It may also be that the possibility to migrate between favorable winter areas are larger at Siljan than at the island Ytterøya, and that winter conditions at Siljan not necessarily represent the conditions experienced by roe deer. Moreover, the food availability may not be as affected at Siljan as Ytterøya if they exploit more twigs and bark on trees, and it is also a possibility that locals feed the roe deer more in some areas, and they will therefore be less affected by the loss of forage opportunities. The result is however still somewhat surprising, as it should be expected that the cost of

movement should increase with snow depth (Parker et al., 1984) and that years with larger amount of snow is associated with a shorter growing season (Klein, 1970).

Weather during spring and early summer is important for the quality and quantity of plants as forage for herbivores (Lenart et al., 2002). Whereas a warm spring can give earlier onset of spring, a warm summer often reduce the quality of the plants that forage, and accordingly, I predicted differential effects of spring and summer conditions on fawn body mass. The results show a difference in weather effects during spring and summer, but precipitation was found to be a better explanatory variable than temperature. The effect between the two localities also differs, which can suggest differences in onset of spring and summer between the two areas.

Precipitation in May had similar effect at the two locations. This could be because most fawns in Norway are born during May or the first weeks following in Norway (Andersen et al., 2004). As a result this period should be of importance at both locations as resources during lactation is of most importance for an income breeder (Andersen and Linnell, 2000). As water can be a limiting resource for plant growth (Langvatn et al., 1996), the precipitation during onset of spring could be detriment of the plants available. A higher level of precipitation is also often associated with lower temperature, which results in a higher level of nutrition as well as a lower level of defense against herbivores in plants (Lenart et al., 2002).

The effect of precipitation in June was found to be negative at Ytterøya, while it was positive at Siljan. The same effect was found when investigating the effect of June temperature. However, the effect of precipitation in July was opposite, where the effect was positive at Ytterøya and negative at Siljan. This difference could be because Ytterøya is further north than Siljan, and may have a later vegetational phenology. The geographic differences between the two places, could make the onset of spring different. Differences in growing season and plant development seems to be a reasonable explanation to the variation in autumn fawn body mass. This also coincides with the fact that roe deer should be more affected by the food intake during the reproductive period as they are income breeders (Hewison and Gaillard, 2001, Andersen et al., 2000). At Siljan precipitation may be of importance as it can increase the quality of plants when it is cloudy. The positive effect observed at Ytterøya in July could be due to the same increase in plant quality, but that the effect will be seen later than at Siljan.

As mentioned, Siljan had a positive effect of temperature in June, whereas Ytterøya had a weak negative effect. Higher air temperatures could decrease nutrient concentration and increase defense against herbivores in some plants and therefore decrease the quality of the plants (Lenart et al., 2002, Nielsen et al., 2012). However, as the quantity of plants increase with higher air temperatures (Lenart et al., 2002), thus, a warmer summer could also result in higher abundance of plants. It is also likely that a warmer summer can reduce the thermoregulatory cost of the fawns, and as a result the effect of digested biomass will be higher as less energy will be utilized to keep warm (Descamps et al., 2008).

Density was not included in this study, as it has been observed to have a larger impact on survival rather than a direct effect on body mass. (Andersen and Linnell, 2000). However, it has been shown to affect fawn body mass (Pettorelli et al., 2002, Andersen et al., 2000, Sæther, 1997, Mysterud et al., 2002), as it has a large impact on resource availability (Linnell et al., 1998b). Thus, increasing density can lead to less prenatal care, resulting in reduction in fawn weight at birth (Andersen et al., 2000). Density may also interact with the climatic effect, typically the effect of severe winter conditions can increase if there also is a high density (Mysterud and Østbye, 2006). Thus, it might be a factor worth including in further studies.

As the data is collected from harvested fawns, it is a possibility that the hunters have had a bias towards collecting larger animals (Mysterud et al., 2006). However, it is not as likely that this regard the harvesting of fawns in the same degree as harvesting of adults (Nilsen and Solberg, 2006). It is also worth mentioning that the data was collected over a period of 20 years at Ytterøya, whereas only 6 years at Siljan. This results in a much lower sample size at Siljan, making the results not as reliable as the ones at Ytterøya as there is a larger possibility that some of the results is random as a every year would have a larger effect on the results. Biological patterns are also harder to detect when sample size is lower. It would therefore be advantageous to have a larger sample size in future studies. The time periods at the two locations did not overlap for the entire period. This is not favorable as it will be harder to detect yearly effects. The effect of temperature in June coincides with the results in the univariate model previously discussed at Siljan. June temperature had a small negative effect at Ytterøya in the model, suggesting that precipitation in June is of more importance than the temperature at Ytterøya.

Even though there was a somewhat small sample size in this study, the result is still quite clear. There were observed weather effects on fawn body mass, and the effects differed at the two locations Siljan and Ytterøya. This is an indication that one cannot generalize weather effects over larger areas as local differences is of importance. As a result, one should take local differences into consideration when working with management of roe deer.





## 5 Acknowledgements

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