



# Slaughter weight in relation to calving date

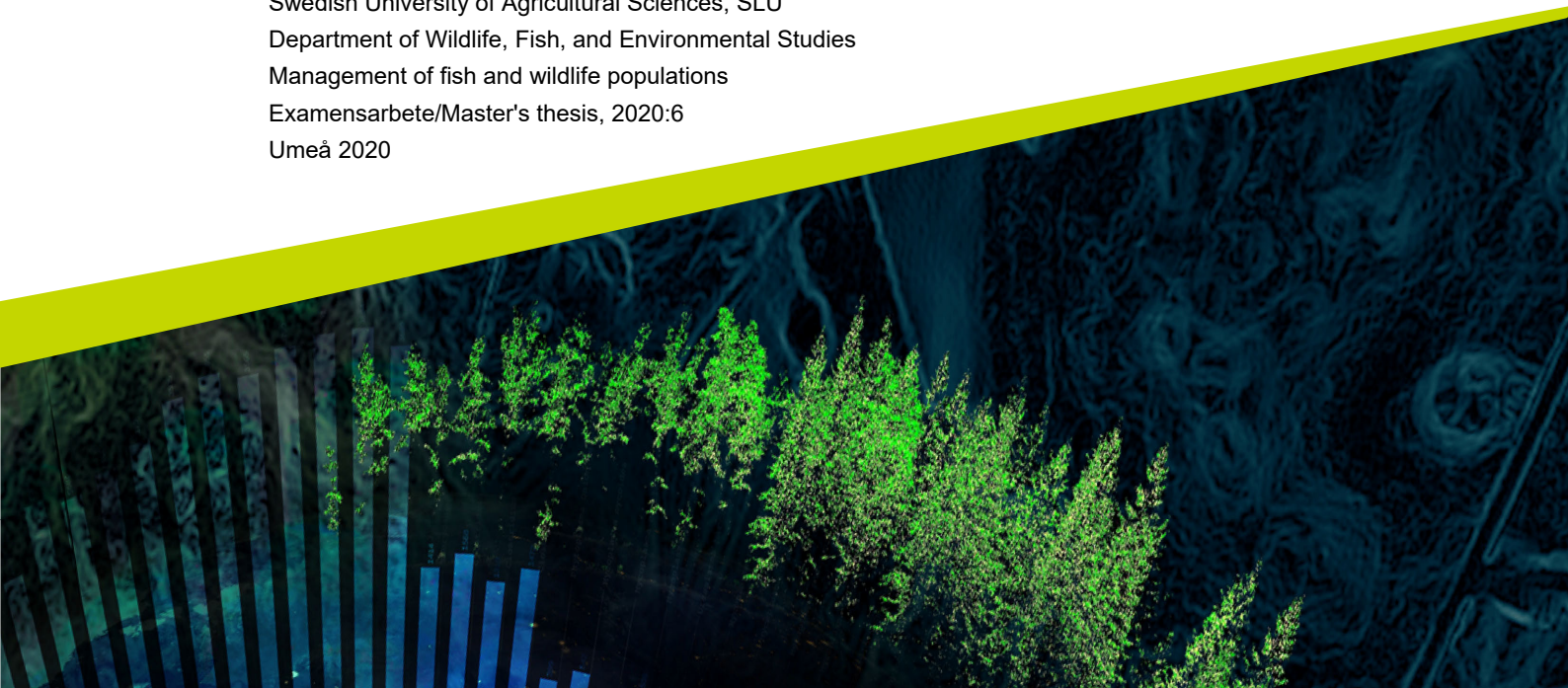
– can area quality compensate for being born late?

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*Slaktvikt i relation till kalvningsdatum – kan områdets kvalitet kompensera för att vara född sent?*

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Master's thesis • 30 credits  
Swedish University of Agricultural Sciences, SLU  
Department of Wildlife, Fish, and Environmental Studies  
Management of fish and wildlife populations  
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## Abstract

The interaction between wildlife and environmental properties such as climate, water and forage availability and competition is a fundamental part when studying wildlife. In ungulates, mortality rates and reproductive success are closely linked to body condition. The trade-offs between energy allocation and reproduction traits can be affected by environmental and climatic factors. In moose (*Alces alces*), the access to high quality habitat affects calf survival, and moose body mass in calves and yearlings correlates to environmental conditions. Recent studies have shown that a diet based on high amounts of broad leaf is positively connected to calf body mass in moose. Also, adult moose has been observed to perform better in higher latitudes in terms of body growth. Female age is also connected to body condition in calves, as calf body weight is suggested to correlate positively to mother age. In younger females, birth date is proposed to be later, resulting in lighter calves as the forage quality is highest in the start of the growing season. In this thesis, I analysed the relationships between area quality, vegetation period, birthdate, female age, and body growth for moose mainly in three areas in Sweden. Latitude, continental climate and forage composition varied among the areas. I found that calves with higher amounts of broad leaf forests in their summer habitat had higher body weight at harvest. I found that length and start of vegetation period also were important for body growth in moose calves, as growth curves were higher for calves in the north where the vegetation period is shorter and starts later than in the south. Surprisingly, I did not find any relationship between calf body weight and female age. Ultimately, based on earlier studies, my results and with a future changing climate that might affect moose negatively, I argue, that it is important to identify the factors affecting body condition in moose in order to sustain a healthy moose population.

*Keywords:* moose, slaughter weight, birth timing, area quality

# Preface

With this thesis I finish my studies at the Swedish University of Agricultural Sciences and my master in Management of Fish and Wildlife Populations.

I would like to give a special acknowledgement to my supervisor, Wiebke Neumann, for encouraging and supporting me during this process.

I would also like to give an acknowledgement to my assistant supervisor, Fredrik Widemo, for helping me to get different perspectives on the moose topic.

All my fellow students are also worthy of a special thanks. To all those small but important moments that made this journey.

# Table of contents

<b>1. Introduction.....</b>	<b>9</b>
1.1. Purpose and Hypothesis .....	12
<b>2. Material and Methods.....</b>	<b>13</b>
2.1. Study area .....	13
2.2. Data .....	15
2.3. Spatial data – area quality .....	16
2.4. Statistical analysis .....	17
<b>3. Results.....</b>	<b>20</b>
<b>4. Discussion.....</b>	<b>23</b>





# 1. Introduction

The interaction between wildlife and environmental properties such as climate, shelter and forage availability, water and competition is a fundamental part when studying wildlife. How the environment affects a single individual or a whole population or vice versa is the base of ecology (Cain, 2014). With natural changes in the environment, climate change or land use, wildlife species need to adapt. Moose (*Alces alces*) is one of the most important wildlife species in Sweden. Both economic, cultural and social values are connected to moose. Yet, at the same time, the species creates damage to forestry when browsing in young pine stands (Widemo et al., 2019). Additionally, Sweden contains one of the densest populations of moose worldwide (Pfeffer et al., 2018, Wallgren, 2016) and the recent warm and dry summers in Sweden have increased mortality in moose calves (Sveriges Lantbruksuniversitet, 2018). However, moose have been shown to perform different on a geographical scale (Allen et al., 2017). At low altitudes, moose have been observed to reach better body condition in terms of body mass due to longer growing season (Ericsson et al., 2002). Simultaneously, moose have been observed to perform variably depending on different latitudes, in coastal or inland areas, and where body mass becomes larger with higher latitudes (Herfindal et al., 2006b).

In ungulates, mortality rates and reproductive success are closely linked to body condition (Allen et al., 2017, McLoughlin et al., 2007, Sand, 1996, Solberg et al., 2007). The trade-offs between energy allocation and reproduction traits can be affected by environmental and/or climatic factors (Gaillard et al., 2010, Sand, 1996, Milner et al., 2013). In elk (*Cervus canadensis*), the access to low nutritional forage during summer results in lower pregnancy rates compared to populations with access to higher quality forage (Proffitt et al., 2016). Similarly, the access to high quality moose habitat affects calf survival (Allen et al., 2017), and moose body mass in calves and yearlings has been suggested to correlate to environmental conditions (Herfindal et al., 2014). Traits that explain forage quality could be availability, nutrient content or type of plant species. Herfindal et al. (2006a) separate forage quantity and forage quality and suggest that forage quality in spring and summer correlates to autumn body mass in young moose, while forage quantity does not. Thus, forage resources could impact an individual in the long term.

Solberg et al. (2008) studied moose on an island in Norway and found that males and females have different growth rates. Body growth for males was observed to be faster than for females. However, body mass for males in this population was the highest reported in Norway. In roe deer (*Capreolus capreolus*), lifetime reproductive success correlates positively with habitat quality (McLoughlin et al., 2007). Also, length of growing season was found to be an important mechanism to determine calf body weight in moose (Ericsson et al., 2002). In addition, forage plants have been shown to contain higher proportion of valuable nutrients in the start of the growing season (Klein, 1990, Pettorelli et al., 2011). Danell et al. (2011) presented that for moose calves, the best summers are rainy and cloudy summers, as they give better forage quality because plants do not produce fibre as quickly. Although, at the moment of calving, the calf only indirectly benefits from the high quality forage through the milk of the female. Additionally, recent studies suggests that a varied diet with relatively high proportion of broadleaf positively affects calf body mass in moose (Felton et al., 2020).

Moose parturition dates differ somewhat in relation to start of the growing season, depending on female body condition and age, where young and old females has been observed to ovulate later than females in their reproduction peak (Garel et al., 2009). Malmsten et al. (2014) observed similar patterns in moose where oestrus period for heifers occurred later than for cows, supporting the idea of calves born by heifers or younger cows are born later compared to calves with older mothers. Moreover, the same study proposed that high carcass weight increased probability of first ovulation. For female roe deer, parturition date was suggested to have strong correlation to winter body condition (Plard et al., 2015). Offspring that were born early in the season had better body condition the following winter compared to the rest. Likewise, a moose calf born right before the start of the growing season should have an advantage when it comes to availability of forage of high quality and achieve better body condition before the winter compared to someone who is born later. Thus, the relationship between age of the females, parturition date and calf body weight could be somewhat complex, as calf body mass also has been suggested to correlate positively with mothers age (Solberg et al., 2008, Solberg et al., 2007). Moose calves continue to grow throughout September with the body growth stopping in October, and may even decrease during the winter (Danell et al., 2011).

Timing of calving might be thus crucial for determining body condition throughout lifetime. A study on big horn lambs (*Ovis canadensis*) in Alberta, US, found that the lambs cannot compensate for being born late and negative effects of this was stronger for male lambs than for female lambs (Feder et al., 2008). Likewise, small

moose calves were observed to not be able to compensate for the loss of growth those first months in life, being smaller than average throughout their lifetime (Solberg et al., 2008). Accordingly, a poor start in life may result in higher mortality and reduced fecundity.

## 1.1. Purpose and Hypothesis

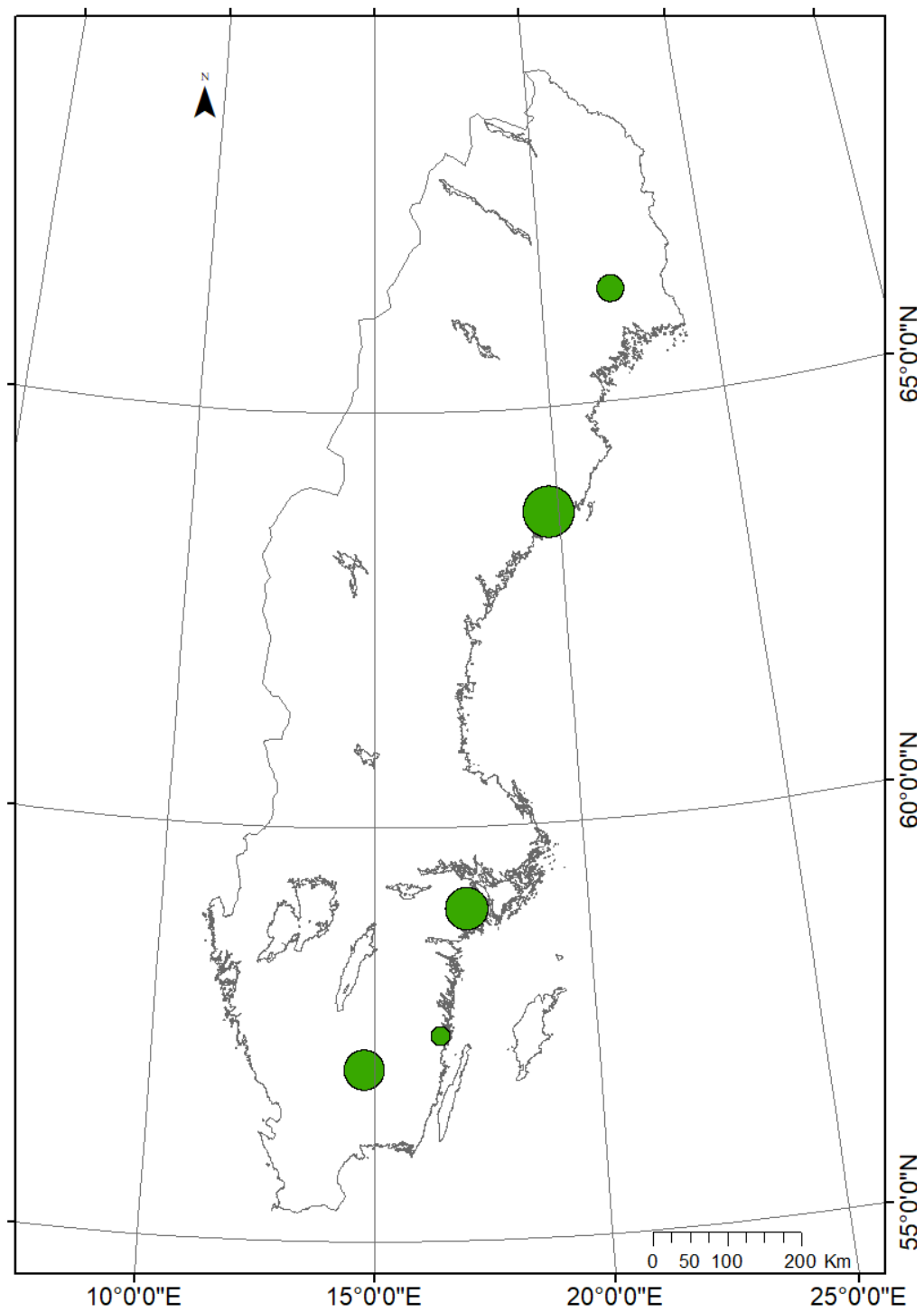
In this thesis, I analyzed the relationship between birth date of moose calves, calf body mass of calves shot in the fall during the hunting period and quality of forage in areas where female moose with calves have been located during the summer/growing season from the calves' birth to the fall. Based on literature, I tested the following hypotheses.

1. Late born moose calves can compensate their body growth when having larger access to good quality habitat.
2. Calves at higher latitudes have a steeper growth curve than calves at lower latitudes.
3. Calves that are born late have an advantage of having an older mother.

## 2. Material and Methods

### 2.1. Study area

I analysed slaughter weights in relation to date of birth of 76 moose calves that were offspring to GPS-marked female moose ( $n = 50$ ) in five areas in Sweden (Fig. 1). The three main areas were Nordmaling ( $64^{\circ}\text{N}$ , onshore), Östermalma ( $58^{\circ}\text{N}$ ) and one inland area close to Växjö ( $56^{\circ}\text{N}$ ) (Fig. 1). Additionally, data was collected in Niemsele ( $66^{\circ}\text{N}$ ) and Oskarshamn ( $57^{\circ}\text{N}$ ). The climate varied among the areas. The northern study areas were characterized by a temperate and sub-polar continental climate with rather warm and short summers, such as 140-160 days vegetation period and cold, long winters with 70-90 cm of snow (Beck et al., 2018, SMHI, 2017). The southern study areas were characterized by a mild-humid continental climate with mild winters with 20-40 cm of snow, longer and warmer summers and 180-190 days vegetation period (Beck et al., 2018, SMHI, 2017). The forest at the study site Växjö was damaged severely by a storm in 2005 and 2007, resulting in large areas of young forest and thus really successional forage available in this region (Svensson et al., 2011).



*Figure 1. Location of the main study areas in three larger circles. Nordmaling in Norrbotten county, Östermalma in Södermanland county and Växjö in Kronoberg county in Sweden (north to south). Smaller circles is Niemsele (most north, Norrbotten county) and Oskarshamn (Kalmar county).*

## 2.2. Data

During the period of May 2012 and September 2019, 50 female moose were monitored through GPS-tracking devices. The females were monitored throughout the calving period, and the birth of 76 calves were documented. Out of these 76 calves, 48 calves were ear-tagged and birth weight was collected shortly after birth (Table 1). Data on slaughter weight was collected between 2012 and 2019 during the hunting season, which lasted from the first Monday in September to 31 of January in the northern region and from the second Monday in October to the end of January in the southern region. Consequently, calves that were tagged and then harvested in the autumn were included in this data set.

I analysed data on birthdates, slaughter weight and slaughter date for 76 calves that were offspring from 50 different female moose. To each calf, I linked the GPS position data from its mother. The female data consisted of age and position data during the time the calf was alive. Female age at parturition (hereafter referred to as female age) varied between 3 to 17 years (mean age =  $7.97 \pm 3.2$  years). I used slaughter weight as proxy for body weight and will use the term body weight henceforth.

Table 1. Composition of the dataset; total number of calves, number within a given sex class, number of calves with birth weight collected at birth, number of females, and mean female age at parturition at each study site . Missing info about sex for 6 calves.

	<i>Calves</i>	<i>Female calves</i>	<i>Male calves</i>	<i>Birth Weight</i>	<i>Females</i>	<i>Mean female age (SD)</i>
Total	76	31	39	48	50	7.97 (±3.2)
Niemsele	6	4	2	4	6	7.3 (±2.5)
Nordmaling	16	6	9	8	12	5.75 (±1.5)
Östermalma	23	6	13	13	15	9.2 (±3.5)
Oskarshamn	1	-	1	1	1	-
Växjö	30	15	14	22	16	8.3 (±3.3)

### 2.3. Spatial data – area quality

To estimate vegetation period for each study site, I analysed daily ambient temperature data from the nearest weather station from the Swedish Meteorological and Hydrological Institute (SMHI, 2019). I defined vegetation period onset as the first day of 14-day period with a daily mean temperature  $>7^{\circ}\text{C}$  (Allen et al., 2017, Karlsen et al., 2007). I defined the autumn onset as the first day of five with daily mean temperature  $<10^{\circ}\text{C}$ , which is the meteorological definition for autumn onset (SMHI, 2019).

To estimate access to forage quality, I estimated females' home range for the period between the birth of the calf and its death using four positions per day from the GPS position data for each female (R package `adehabitatHR`; (Calenge 2006)). I



assumed that the calf had the same movement as their mother during this time. I used the Brownian bridge kernel method for home range estimation, which takes the trajectory and time elapsed between two locations into account. I calculated two probability levels of home range size. One larger area with 95% of the positions from GPS position data that represents the area the animal move through and a smaller one, 50%, which represents the core of the home range.

I estimated area quality using the National Vegetation Map of Sweden (Swedish Environmental Protection Agency; (Naturvårdsverket, 2019)). The map was produced during 2017-2019 and consists of 25 thematic classes. The map is in raster format with pixel size of 10 x 10 meters. I extracted vegetation information for every home range using the R package raster (Hijmans, 2019). I connected the extracted information to every individual calf and calculated the percentage of each vegetation cover classification within a given home range. I summarized individual vegetation classes to eight habitat classes: arable land, broadleaf dominated forests, mixed forests, pine dominated forests, spruce dominated forests, open land, temporarily non-forest, and wetland (water and “other” areas like, roads, houses etc. was also individual classes).

As the hunting season starts about one month earlier in the north of Sweden, only data on body weight in September were available from the northern region. Previous research show that moose calves stop growing around the end of September (Danell et al., 2011), affecting body weight analyses when not correcting for differences in harvest dates. On average, calves grow with 430 g per day throughout September (personal communication F. Widemo<sup>1</sup>). Consequently, I corrected the body weight data from the calves harvested in September. For every calf harvested in September, I added 430 g for every day left in September after harvest date for that individual. For all my analyses, I used the corrected body weight.

## 2.4. Statistical analysis

I applied linear mixed-effects model fitted with REML in my analysis (Pinheiro and Bates, 2000). The linear mixed-effects model function is related to a linear model but combines fixed effects and random effects. It can handle unbalanced data, and accounts for auto-correlated data such as repeated measures. The data included repeated measures as it included several calves born by the same female, either the same or different years. To account for this autocorrelation, I assigned female ID as random effect in all models.

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<sup>1</sup> Fredrik Widemo, SLU, Fredrik.Widemo@slu.se, 2019-12-16

To test my three hypotheses, I included female age, birth date, area quality and length of vegetation period as fixed effects (Table 2). I used calf body weight as the response in the first and the third hypotheses. To test the second hypothesis, I used the difference between calf body weight at harvest and birth weight as response variable using thus a subset of my data. I decided to include female age as fixed effect in each model based on previous studies (Solberg et al., 2008, Solberg et al., 2007). To test for the effect of habitat quality on calf body weight in hypothesis 1 and 2, I used the percentage of deciduous dominated forests within the females' home range (both at 95 % and 50 % estimates), as I assumed that this habitat type reflects superior quality forage during this period (Felton et al., 2020). Length of vegetation period varied considerably across latitudes and thus my study areas (Fig. 1). I thus did not include region as random effect in my second hypothesis as I used vegetation period as fixed effect. To test my second hypothesis, I first used interaction between area quality and length of vegetation period. The interaction term, however, was not significant, and I thus removed it to simplify the model. To test my third hypothesis, I added one model with female age as response variable and region as fixed effect.

I considered a level of significance of  $p \leq 0.05$ .

Table 2. Structure of the linear mixed-effects model to test my three hypotheses. I tested the first and the second hypothesis for both home range levels, 95% and 50% (core area).

H	Response variable	Fixed effects	Random effects	Home range
1	Body Weight <sup>1</sup>	Female Age <sup>2</sup> + Birth Date + Quality Habitat <sup>3</sup>	Region <sup>4</sup> / Female ID	95%, 50%
2	Body Weight <sup>1</sup> – Birth Weight	Female Age <sup>2</sup> + Quality Habitat <sup>3</sup> * Veg Per. <sup>5</sup>	Female ID	95%, 50%
2b	Body Weight <sup>1</sup> – Birth Weight	Female Age <sup>2</sup> + Quality Habitat <sup>3</sup> + Veg. Per <sup>5</sup>	Female ID	95%, 50%
3	Body Weight <sup>1</sup>	Female Age <sup>2</sup> + Birth Date	Region <sup>4</sup> / Female ID	-

<sup>1</sup>corrected calf body weight; <sup>2</sup>female age at parturition; <sup>3</sup>percentage of deciduous forest within the home range; <sup>4</sup>northern or southern Sweden; <sup>5</sup>length of the vegetation period

### 3. Results

*H1: Late born moose calves can compensate their body growth when having larger access to good quality habitat.*

Both within the 95% and 50 % home range, calf body weight decreased significantly with later birth date (95 %:  $t$ -value = -3.39,  $p$ -value = 0.003, 50 %:  $t$ -value = -3.61,  $p$ -value = 0.002). Female age and area quality had no significant effect on body weight (female age: 95%:  $t$ -value= 4.99,  $p$ -value = 0.51; female age: 50%:  $t$ -value = -0.77,  $p$ -value = 0.45; area quality: 95%:  $t$ -value = 1.62,  $p$ -value = 0.12; area quality: 50%:  $t$ -value = 1.34,  $p$ -value = 0.19).

*H2: Calves at higher latitudes have a steeper growth curve than calves at lower latitudes.*

Within the 95% and 50 % home range, I did not find any support for an effect of female age (95%:  $t$ -value = 0.3 ,  $p$ -value = 0.07, 50%:  $t$ -value = 0.1,  $p$ -value = 0.9), area quality (95%:  $t$ -value = 0.9,  $p$ -value = 0.4, 50%:  $t$ -value = 1.07,  $p$ -value = 0.3) or length of vegetation period (95%:  $t$ -value = -0.9,  $p$ -value = 0.4, 50%:  $t$ -value = -1.13,  $p$ -value = 0.3), nor interaction between area quality and length of vegetation period (95%:  $t$ -value = -0.6,  $p$ -value = 0.5, 50%:  $t$ -value = -0.9,  $p$ -value = 0.4) on calf body weight.

Excluding the interaction between area quality and length of vegetation period, however, I found that within the 95% home range, area quality and calf body growth correlated positively ( $t$ -value = 2.41,  $p$ -value = 0.04). My results also showed a negative effect of length of vegetation period on calf body growth ( $t$ -value = -2.97,  $p$ -value = 0.02; Fig. 2). Female age had no significant effect on calf body growth ( $t$ -value = 0.39,  $p$ -value = 0.7). Within 50% home range, length of vegetation period had a negative effect on calf body growth ( $t$ -value = -2.92,  $p$ -value = 0.02), whereas female age ( $t$ -value = 0.25,  $p$ -value = 0.8), and area quality had no effect on body growth ( $t$ -value = 1.57,  $p$ -value = 0.15).

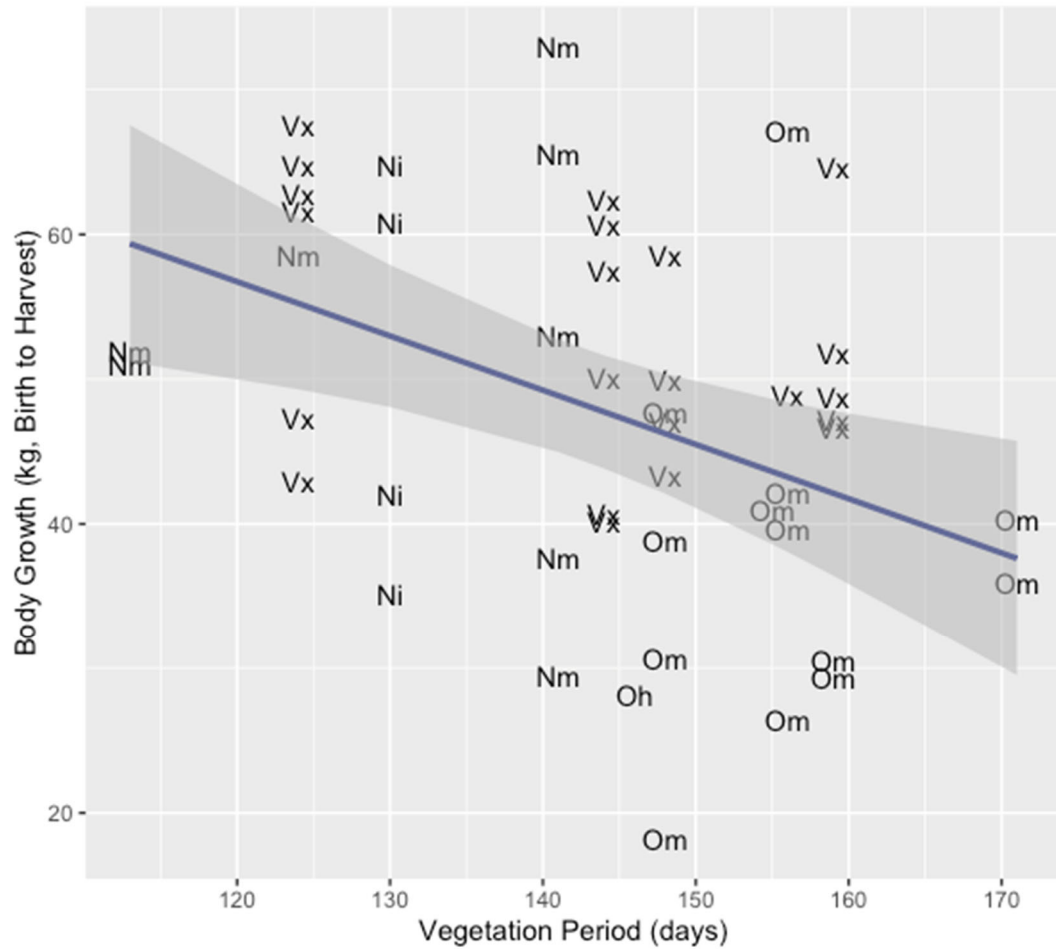
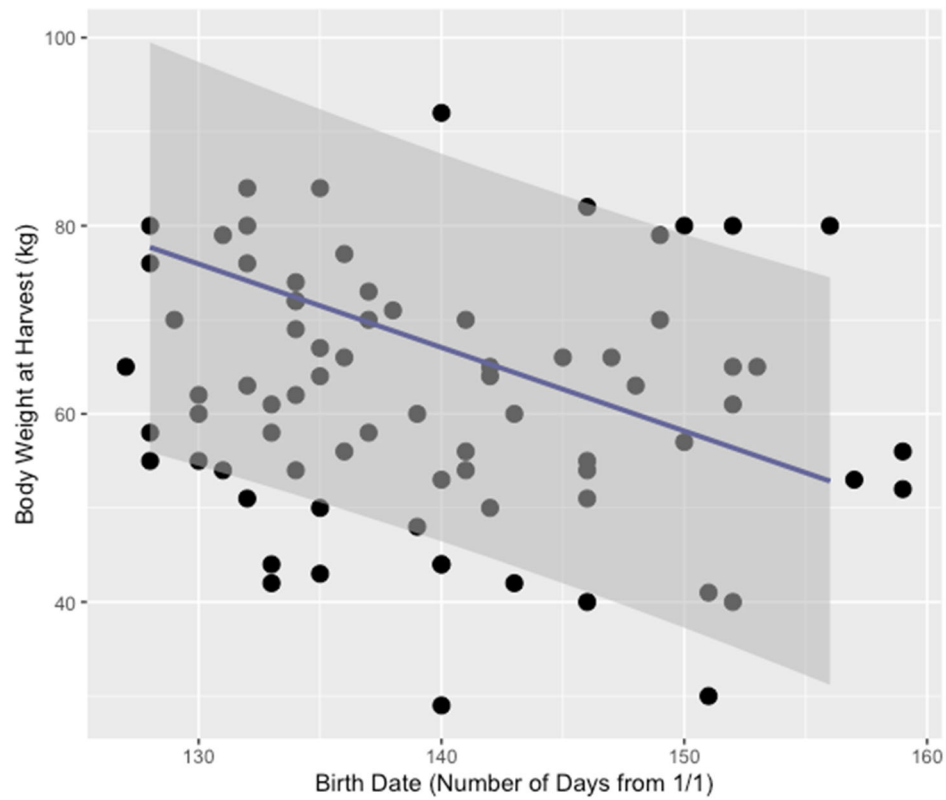


Figure 2. Effect of the length of vegetation period on body weight at harvest for moose calves in Sweden. The line represents the predicted values given by the linear mixed-effects model (95% home range, Hypothesis 2, Table 1). The points represent the observed values with name of the study sites; Ni is Niemsele, No is Nordmaling, Om is Östermalma, Oh is Oskarshamn and Vx is Växjö.

*H3: Calves that are born late have an advantage of having an older mother.*

My results showed a negative relationship between calf birth date and body weight at harvest as calf body weight decreased significantly with later birth date ( $t$ -value = -3.51,  $p$ -value = 0.002, Fig. 3). I found no effect of female age on calf body weight ( $t$ -value = -0.93,  $p$ -value = 0.36). Yet, female age was higher in the southern region than in the northern one (mean age: north =  $6.2 \pm 1.9$ , south =  $8.6 \pm 3.4$ ,  $t$ -value = 3.31,  $p$ -value = 0.002).



*Figure 3. Effect of birth date on body weight at harvest for moose calves in Sweden. The points represent the observed values and the line represents the predicted values with confidence intervals given by the linear mixed-effects (95% home range, Hypothesis 3, Table 1).*

## 4. Discussion

In this thesis, I analyzed the relationships between birth date, birth weight, female age, body weight at harvest and habitat quality for moose calves using a linear mixed-effects model. I found that calf body weight at harvest decreased with later birth date. My results showed a negative relationship between calf body growth and length of vegetation period and a positive relationship between calf body growth and amounts of broad leaf forest in habitat. Surprisingly, however, my results also suggested no significant relationship between calf body weight and female age.

My results confirmed that late-born calves have a disadvantage in terms of body weight at harvest. In moose, birth date is suggested to correlate to mother age with young and old females giving birth later than females at their reproduction peak (Garel et al., 2009, Malmsten et al., 2014). Malmsten et al. (2014) also suggests that high female body weight increased probability of first ovulation, and thereby determining parturition date. Additionally, calf body weight is proposed to correspond to female age (Solberg et al., 2008, Solberg et al., 2007). My results showed no effect of female age on calf body weight at harvest. Alternatively, benefits of female age may mainly manifest themselves from an earlier parturition date. However, based on previous studies, I think that female age is an important parameter to have included in my analysis. My dataset is relatively small, and thus might not detect any correlation. Mean age for females in the southern region was higher than in the northern region, suggesting that most females in the north are at their reproduction peak (Ericsson et al., 2001, Malmsten et al., 2014). Calves may be negatively affected in the southern region, thus parturition date might occur later, consequently affecting my analysis.

Birth date is crucial for calves' chances of accumulate body mass, as at the start of the vegetation period, the forage plants are more nutrient rich and develop more fiber later, and thus hold the highest forage quality for herbivores (Herfindal et al., 2006a, Klein, 1990, Pettorelli et al., 2011). Concerning area quality and forage quality, my analyses showed different results. Thus, in my first hypothesis when considering female age, birth date and area quality as fixed effects, I did not find any significance for the amounts of broad leaf forest in the home range affecting calf body weight at harvest, which contradicts recent studies (Felton et al., 2020).

However, when I tested for the effect of vegetation period on body growth as the response variable in my second hypothesis and at the larger estimated home range level (95%), I found a positive relationship between amounts of broad leaf forests and body growth, suggesting that good area quality is positive for body growth in moose calves in combination with a short vegetation period. I did not find the same relationship for the core home range level (50%), however, which means that on a larger scale, a higher percentage of high quality habitat (% deciduous forest) resulted in higher calf body weights, whereas the habitat quality at a smaller scale was not important. At the same time, as the raster I used to estimate habitat quality was based on the vegetation in 2017-2019, it may not reflect the vegetation conditions in the home ranges for the calves that lived earlier than 2017. Thus, it could have been more accurate to use vegetation information from the actual years the calves lived. Spitzer (2019) also implies that moose consume more pine (*Pinus sylvestris*) than *Vaccinium* spp. in areas with high densities of other deer species, thus changing their feeding behavior. Therefore, moose in these areas might be affected by interspecific competition and leave the good quality forage resources, as all these areas are multi-ungulate areas, in particular Östermalma and Nordmaling. Therefore, it would have been an advantage to use other parameters to estimate habitat quality, like field layer information, than exclusively forest type.

Herfindal et al. (2006b) suggests that body mass for moose increases with latitude. Similarly, my analyses showed that a shorter vegetation period (i.e. higher latitude) results in higher growth rate for calves from birth to fall. I found a negative relationship between the length of vegetation period and calf body growth, suggesting a steeper growth curve in the northern areas where the vegetation period was shorter. A shorter vegetation period and colder ambient temperatures could lead to plants accumulate less fiber during the whole season, and therefore constitute better quality forage for moose (Danell et al., 2011). My results suggested that calves' benefits from the nutrient rich forage at the start of the vegetation period, given the larger body mass gain in the northern areas. In the southern areas where the vegetation period was longer the difference between birth weight and body weight at harvest was less, suggesting that birth date in relation to vegetation period on-set is an important factor determining calf body weight at harvest.

Danell et al. (2011) suggest that moose calves continue to grow throughout September and then body growth stops in October, because forage plants lose nutritional content and the lactating period ends. Consequently, a calf born later will have less time to accumulate body mass before winter. At lower altitudes, moose have been suggested to reach better body condition in terms of body mass, because of the longer growing season (Ericsson et al., 2002). This is somewhat contradictory to my results. A possible argument could be that a short vegetation period and lower ambient temperature is positive for calf body growth, as long as



it is not too short. However, the individuals in my data does not live at higher altitude as all range were in the inland or along the coast, but in southern and northern Sweden, suggesting that a shorter vegetation period is positive for calf body growth.

Danell et al. (2011) suggested that the best summers for calf body growth are cloudy and relatively cold summers, as the forage plants do not accumulate fiber as fast. As the summers are colder in the north, the forage plants might contain less fiber during the whole growing season than in the south. This also connects to what Herfindal et al. (2006a) suggests regarding area quality and quantity and that area quality is more important for body growth in moose. Thus, there might be access to more forage in the south, as the vegetation period is longer, but the quality of the forage is better in the northern areas in my analysis because of the colder summers (Beck et al., 2018, Danell et al., 2011). I did not include those kind of weather parameters in my analysis, but recent summers have been somewhat warm and dry, which has affected calf survival negatively (Sveriges lantbruksuniversitet, 2018). Consequently, I think that it would be necessary to further evaluate the effects of additional climatic factors, like temperature, on calf body weight which was not included in my analysis.

Furthermore, the storms that affected the southern areas may have led to an increase in forage quality and forage quantity (Svensson et al., 2011), thus, affecting the population in Växjö positively. Yet, the northern populations in my analysis are, nevertheless, growing faster due to better forage as a result of a shorter vegetation period. Further, a changing climate and an advanced vegetation on-set could result in an increase in temporal deviation between calving date and vegetation on-set (SMHI, 2019). As my analysis showed and former studies on moose suggest, that a longer vegetation period and a late birth date in relation to the start of the vegetation period is disadvantageous for calf body growth, this would impose that calves would be negatively affected in a future changing climate, especially in the southern Sweden.

There are some constrains when dealing with a small dataset, which makes me interpret the results of my analyses with caution. For example, there could be some differences in body growth between male and female calves, as previous research show that male and female moose have different growth rates (Ericsson et al., 2002, Solberg et al., 2008). Nevertheless, I did not include calf sex in my models as I needed to create simple models as possible with regard to the small data set. Given the fact that some of my results are in line with most of the earlier studies, however, I feel slightly more confident that some of my results are correct and reliable.

Body mass is connected to reproduction rates and mortality rates in moose, it thus is crucial and an essential part to understand when studying and managing ungulates (Allen et al., 2017, McLoughlin et al., 2007, Sand, 1996, Solberg et al., 2007). Consequently, calf slaughter weight is a predictor of population condition and future growth in moose management and there are several important mechanisms affecting body condition and survival in ungulates (Allen et al., 2017, Ericsson et al., 2002, Herfindal et al., 2014, Herfindal et al., 2006a, Herfindal et al., 2006b). Ultimately, based on previous studies and my analyses, I think that the relationship between area quality and body condition in moose is more complicated than I have been able to model. Thus, I argue that an ability for moose to compensate body growth when having access to better quality forage could exist. Yet, more research must be done and, as calf mortality has increased during the recent hot summers (Sveriges lantbruksuniversitet, 2018), and with a future changing climate that might affect moose negatively, I argue, that it is important to identify the factors affecting body condition in moose in order to sustain a healthy moose population.

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