

Weight gain of free-ranging beef cattle grazing in the boreal forest of south-eastern Norway



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ABSTRACT

Young forest stands and clearcuts in the boreal forest created by modern forestry practices along with meadows of abandoned summer farms may contribute as feeding areas for beef cattle. The patchy distribution and varying quality and diversity of forage on such unimproved lands may affect cattle productivity. Weight gain of 336 beef cows and 270 calves free-ranging during three summer grazing seasons was monitored in boreal forests of south-eastern Norway, stocked at either high (0.16 cows ha⁻¹) and low (0.04 cows ha⁻¹) stocking densities. We used linear mixed effect models for assessing intrinsic correlates of weight gain in cows and calves in the two areas. Habitat use and home range size of a subsample of 53 cows were monitored by using GPS collars programmed to log locations at 5 min. intervals during the grazing season. Additional extrinsic correlates of weight gain for the subsampled cows using a linear mixed model were also tested.

Average weight gain of beef cows grazing at the low stocking density was positive among cows of early maturing breeds (represented by Hereford) gaining 24 ± 2.8 kg (\pm SE), while cows of late maturing breeds (mainly represented by Charolais) had an average weight loss of 9 ± 8.4 kg. The average weight gain was negative for beef cows of both early (Herefords) and late maturing breeds (mainly represented by Charolais but also Limousin and Simmental) at the high stocking density. Within both breed groups, there was a negative relationship between breed-specific average weight of cows at turnout and weight gain during the grazing period, while a prolonged grazing period was slightly positively related to weight gain. There was no relationship between weight gain and home range size and proportion of grazing habitat for the 53 cows fitted with GPS collars.

Higher weight gains in calves of the low compared to the high stocking density area was found. However, there was no breed effect of weight gain in calves. Across study areas, spring-born suckler calves gained more weight than autumn-born calves (92 ± 1.7 kg vs. 65 ± 4.4 kg). Also, there were higher weight gains for spring-born bull-calves than spring-born heifers (100 ± 2.4 kg vs. 94 ± 2.2 kg).

Overall, the results indicate that it is possible to achieve acceptable weight gains for cattle grazing coniferous forest by finding breeds suitable for these extensive areas and stocking at moderate densities.

1. Introduction

Human population growth is causing an increase in demand for food that is not expected to be met by maximizing agricultural productivity on arable land alone (Godfray et al., 2010). Sustainable food production should be increased by utilizing natural environments at individual sites and managing resources in a way that benefits biodiversity,

ecosystems services, agricultural production and other multiple purposes (Broom et al., 2013). Cattle grazing in forests are utilizing resources that otherwise could not be used as food and are a valuable contribution to global meat and milk production while decreasing the pressure on arable land (Schader et al., 2015). The boreal forests, the second largest biome on the Earth, are mainly managed for the production of timber (Gauthier et al., 2015), but also provide multiple

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ecosystem services as well as grazing for domestic livestock (Bele and Norderhaug, 2013; Kaufmann et al., 2013; Gauthier et al., 2015). However, forestry and livestock farming are not totally compatible. On the one hand, cattle grazing has been associated with damage to young trees by trampling and bedding in areas of regeneration (Hjeljord et al., 2014; Kaufmann et al., 2017) whilst, cattle productivity may be impacted by the forest's heterogeneous environment with a patchy distribution of herbage and quickly declining quality and quantity of forage plants through the grazing season (Garmo, 1986). To assess the sustainability of such grazing regimes in this semi-natural environment, it is important to measure the productivity of cattle in relation to breed and stocking density.

In Norway, forests and alpine areas are abundant whereas only 3–4% of the land area is cultivated. Therefore, livestock grazing in forests and alpine areas (referred to here as “unimproved land”) during the summer has been of great importance for agricultural production in Norway over the past 2000 years (Austrheim et al., 2008). However, during the last part of the 20th century, intensification of dairy production caused a decline in the number of cattle turned out onto Norwegian unimproved land. Today, a growing interest in suckler-based beef production has led to a resurgence in the number of beef cattle grazing on unimproved land during summer (Norwegian Agriculture Agency, 2017). The cattle are a mix of early and late maturing beef breeds. The continental breeds Charolais, Limousin and Simmental are all late-maturing beef breeds bred for intensive meat production and hence adapted to high feed intensities with a demand for energy-dense feed rations (Webster, 1989). British beef breeds are Hereford and Aberdeen Angus, are early-maturing breeds adapted to more extensive production methods based on lower feed intensities and less energy-dense rations (Webster, 1989). In Norway, Charolais and Hereford are the most common breeds and comprise 21% and 14 % of the beef cow population, respectively (Animalia AS, 2019).

In general, the performance of beef cows and their suckling calves depends on the interactions between intrinsic factors, e.g. cattle breeds (Niemelä et al., 2008), time of calving (Casasús et al., 2002b), body size (Demment and Van Soest, 1985) productivity (lactation) (Ferrell and Jenkins, 1985; Montaña-Bermudez and Nielsen, 1990) and extrinsic factors e.g. pasture nutritional quality (Fraser et al., 2009) and availability of the foraging plants (Lowman et al., 1996). The availability of preferred feeding plants and sward heights is dependent on stocking density, and high densities have shown to affect body condition and weight gain of cattle negatively (Wright and Russel, 1987; Senft, 1989; Cornelissen and Vulink, 2015). In addition, the feeding regime during the preceding winter can affect the growth recovery period after turnout to pasture (Hessle et al., 2011). Some studies have reported that weight gain of young weaned cattle on Nordic unimproved land is similar to that on cultivated pastures (Bjørn and Graffer, 1963; Niemelä et al., 2008; Hansen et al., 2009; Steinshamn et al., 2010). However, the feeding regime of suckling calves differs from that of older cattle as their main nutritional intake is provided by milk, and hence the weight gain of these calves depends mainly on the cows' ability to maintain milk production (Wright and Russel, 1987; Casasús et al., 2002b).

Since the 1950s, forestry in Scandinavia has intensified, becoming dominated by rotational management and clearcutting which creates patches of uniformly-aged forest stands (Aasetre and Bele, 2009). Primarily, the meadows of abandoned summer farms, young forest stands (< 15 years since clearcutting) and clearcuts offer sufficient densities of herbage for foraging cattle (Tofastrud et al., 2019), as these areas are suitable for light-demanding grass species and herbaceous plants (Strand, 1997). Consequently, at a landscape scale, the herbage has a patchy distribution very unlike open grassland pastures. The clearcuts may be in rugged terrain and are often full of obstacles, e.g. stones, tree stumps and logging waste. Such conditions and the need for cattle to move between grazing patches affect energy expenditure and most likely the performance of the animals. The young forest stands are also considered of great importance as feeding resource of the Scandinavian

moose (*Alces alces*) population (Edenius et al., 2002). However, inter-specific interactions (Herfindal et al., 2017) and dietary overlap between moose and livestock are considered as low (Dorn, 1970). Despite the widespread practice of grazing cattle in boreal forests around the northern hemisphere, relevant studies of the performance of improved beef cattle breeds in these extensive conditions are scarce. The last major research on cattle grazing in boreal forests was performed in the 1950s and focused on cows and heifers of dairy breeds (Bjørn and Graffer, 1963).

To fill this knowledge gap, we studied the performance of cows and calves of different beef cattle breeds in free-ranging herds in the boreal forests of south-eastern Norway during summer. We were interested in intrinsic factors, such as breed, age and reproductive status, as well as extrinsic factors, such as stocking density, length of the grazing season, habitat use and home range size. Based on the compiled studies above, we expected higher weight gain in beef cows of early-maturing breeds, dry cows and cows with lower initial breed-specific body weights due to the winter-feeding intensity. Finally, we expected higher live weight gain in spring-born calves based on the importance of milk as a source of energy, in calves of the early-maturing breeds and in bull calves based on their greater ability for energy utilization into weight gain (Turton, 1969; Fraser et al., 2009).

Cattle of early-maturing breeds are more efficient at utilizing energy from poorer quality herbage and therefore probably best suited to grazing these areas (Webster, 1989). Herbivores forage in hierarchies of spatial and temporal scales in daily, seasonal or annual home ranges (Senft et al., 1987; Bailey et al., 1996). Home range sizes of large herbivores vary with habitat and resource distribution (Lazo, 1995; Kie and Boroski, 1996; van Beest et al., 2011), stocking density (Vander Wal et al., 2014) and reproductive status (Saïd et al., 2005; van Beest et al., 2011). Knowledge about the home range size of cattle is important for managing grazing resources and conservation of ecosystems (Ofstad et al., 2016). Little is known about the relationship between weight gain in domestic cattle and home range size but the assumption that home range size is negatively related to the amount and quality of the available herbage appears valid. Therefore, it would be expected that cows with large home ranges would have less weight gain than cows with small home ranges. Expected weight gain in beef cows was hypothesised to be negatively related to the overall stocking density and, at a smaller scale, to the herd size because of intra-herd competition for herbage. Based on studies from other types of un-cultivated land, it was hypothesised that there would be interactions between breed and pasture type.

2. Material and methods

2.1. Study sites

This current study was conducted in two forested areas in south-eastern Norway (60° N, 11° E) (WGS-1984) in Stange - Romedal Almanning (SRA, 150 km²) and Furnes - Vang Almanning (FVA, 100 km²) in the summers of 2015 (SRA only) to 2017. The elevation ranged from 300–600 and 600–700 m above sea level (a.s.l.) in SRA and FVA, respectively. The average ambient air temperature for the study period June–September in the three study years was 13.2°, 14.6° and 13.2° C, and precipitation was 75, 48 and 88 mm in 2015, 2016 and 2017, respectively. The summer of 2016 was warmer and drier, while 2015 and 2017 were slightly colder than normal (Norwegian Meteorological Institute, 2018). The bedrock of SRA and southern FVA is dominated by nutrient-poor acidic rocks such as gneiss and granites, while northern FVA consists of dark sandstone (The Geological Survey of Norway (NGU), 2018).

Typical boreal tree species in Norway include the Norway spruce (*Picea abies*) and Scots pine (*Pinus sylvestris*). Bilberry spruce forest was the dominant vegetation type, covering 58.0% and 44.4% of the area in SRA and FVA, respectively (Rekdal, 2010,2017). The vegetation

types of each study area were mapped by the Norwegian Institute of Bioeconomy Research (NIBIO) in 2010 and 2017 for FVA and SRA, respectively (Rekdal, 2010, 2017). The grazing value of the dominant vegetation types was then estimated by species composition, plant production and the nutrient content of the most important ground layer species of each vegetation type. Consequently, the vegetation types were roughly classified into three foraging classes with differing grazing capacity: Less Good (LG, 0.05–0.08 beef cows ha⁻¹), Good (G, 0.08–0.12 beef cows ha⁻¹) and Very Good (VG, 0.12–0.17 beef cows ha⁻¹) (Rekdal et al., 2000). The assessments concluded that both study areas had a grazing capacity for about 0.11 cows ha⁻¹. However, the stocking densities during this current study were 0.04 (SRA) and 0.16 cows ha⁻¹ (FVA). The utilization of the grazing capacity was therefore estimated to be 38% and 148% in SRA and FVA, respectively (Rekdal, 2010, 2017).

The proportion of young forest stands and clearcuts (0–15 years after clearcutting) in the study areas was 16% and 14% in SRA and FVA, respectively (Tofastrud et al., 2019). The study areas were interspersed by bogs and small summer farm meadows. The meadows made up less than 1 % of the area in both SRA and FVA (Rekdal, 2010, 2017). In general, the grazing value of the coniferous forest was extremely low compared with cultivated pastures (Larsson and Rekdal, 2000). The herbage production of spruce forest on nutritious and moderately nutritious soils have previously been estimated as 2000 kg dry matter (DM) ha⁻¹ and 670 kg DM ha⁻¹, respectively (Hansen et al., 2009). However, measurement of herbage yield in these areas is associated with high uncertainty, caused mainly by their patchy distribution and varying re-growth of the forage plants, dependent on the density of grazing herbivores.

2.2. Study animals and intrinsic factors

Cattle from five and four local commercial farms in SRA and in FVA, respectively were used in this current study. Any cattle from the same farm were considered as one herd. The number of animals varied greatly among the herds, from seven up to 98 beef cows of varying ages and reproductive status. Farmers weighed their cattle at turnout and at re-housing and weight gain was calculated (Tables 1 and 2). The weighed animals made up about 40% and 30% of all cattle turned out to SRA and FVA, respectively. During the three year study period, 336 cows (Table 1) and 270 calves (Table 2) were monitored. Eighty-one and eleven cows were studied repeatedly for two and three summers, respectively, whereas 136 cows were studied for one summer only. The cattle were purebred Hereford, Charolais, Limousin, Simmental and crossbreeds of these breeds (34.4% of calves and 23.5% of cows). Hereford and Charolais were the dominant breeds in SRA and FVA, respectively. Simmental and Limousin were only present in FVA, with the exception of one Simmental cow in SRA. Thirteen calves of Aberdeen Angus grazed within SRA. Calves were born either in spring or in autumn. Typical of calves in this part of Norway, spring-born

Table 1

Number of beef cows that grazed in boreal forests of south-eastern Norway, grouped by study area (Stange - Romedal Almanning (SRA) and Furnes - Vang Almanning (FVA)) and by study year (2015–2017)

Study area	SRA			FVA		
Year	2015	2016	2017	2016	2017	Total
Total number of weighed cows	42	58	52	75	109	336
Collared cows	9	12	7	11	14	53
Early maturing breeds ¹ :	39	39	29	2	4	113
Late maturing breeds ² :	3	19	23	73	105	223
Reproductive status:						
Lactating cows	24	35	38	30	20	147
Dry cows	18	23	14	45	89	189

¹ Hereford; ² Charolais, Limousin and Simmental

Table 2

Number of suckling calves reared by either early- or late-maturing breeds and by autumn- or spring-born calves in boreal forests of south-eastern Norway by study area (Stange - Romedal Almanning (SRA) and Furnes - Vang Almanning (FVA)) and year (2015–2017).

Study area	SRA			FVA		
Year	2015	2016	2017	2016	2017	Total
Number of calves	60	65	90	30	25	270
Breed group:						
Early-maturing breeds ¹	24	24	32	1	6	87
Late-maturing breeds ²	36	41	58	29	19	183
Period of birth:						
Spring-born calves	54	59	60	15	22	210
Autumn-born calves	6	6	30	15	3	60

¹ Hereford and Aberdeen Angus;

² Charolais, Limousin and Simmental

calves were born in February – March and autumn-born calves in October – November. All autumn-born calves were suckling heifer calves, as national legislation prohibits turning out bulls older than six months on pastures of communal lands (Ministry of Agriculture and Food, 1970). We divided all animals into categories referred to as ‘main breed’, based on the breed representing the highest proportion of the animal's genotype or, the maternal breed in the case of 50/50 crosses. In addition, cattle were grouped as early and late maturing breeds.

The cattle were continuously grazed and the grazing period varied between herds from 80 to 120 days, from late May to early September. The average number of grazing days (\pm SE) varied between the two study areas, with 122 (1.37) and 96 days (0.87) in SRA and FVA, respectively.

For cows, the individual deviation from the average weight at turnout of animals of the same breed was used to account for variation in both body size and weight caused by the winter-feeding period. The average weight (\pm SE) of the cows at turnout was 602 \pm 8.9 kg and 702 \pm 6.8 kg for early and late maturing breeds, respectively.

2.3. Data collection for extrinsic factors

Habitat use of 53 weighed adult beef cows was monitored using GPS-collars (Tellus Medium plus and Tellus Basic, Followit International AB, Lindesberg, Sweden) (Tofastrud et al., 2019). These consisted of 37.7 % dry cows and 62.3 % lactating cows. The number of GPS collared cows varied between study area and study years due to technical failures or collars that fell off during the grazing season (Table 1). The GPS collars were configured to log positions at 5 min intervals, with the exception of night hours in 2016, when collars were scheduled for 10 min intervals to save battery power. The individual home ranges were defined by creating 100% minimum convex polygons (MCP) which included all positions per animal and year. Herd size was defined as the total number of cattle turned out from a given farm.

ArcGIS 10.6 (Esri, 2017) was used to find the proportion of GPS positions per cow in different vegetation types (Rekdal, 2010, 2017) and forest stands within the home range of each individual. The age of forest stands related to the year of last timber harvesting and was provided by the regional forestry plan service (Allma - Allskog Mjøsen Skog og AT Plan, 2017). The proportion of cow positions located on summer farm meadows and young forest stands < 15 years of age was calculated.

2.4. Statistical analysis

The impact of different variables on weight gain during the summer grazing period in all cows, cows with GPS collars and calves was determined by fitting linear mixed models using the maximum likelihood (ML) procedure within the nlme package (Pinheiro et al., 2018) in R version 3.5.1 (R Core Team, 2018). Since the experimental design was

unbalanced between the study years and areas (Table 1 and 2), we included year as a random effect in the models of all three animal groups. The effects of the following fixed covariates on weight gain in all cows: deviation from the average breed-specific weight (continuous), breed (early- and late-maturing), number of grazing days (continuous), and reproductive status (dry – lactating cows) were determined. The effect of breed groups within low and high stocking density areas was determined from the interaction between breed group and study area.

Individual variation in weight gain of beef cows fitted with GPS collars was determined using the following fixed covariates: home range size (continuous), grazing days (continuous), size of the herd (continuous), and the proportion of cow positions in meadows (continuous) and forested stands younger than 15 years (continuous). All continuous covariates were standardised between 0 to 1 in order to compare the strength of selection among these covariates and achieve a better model performance.

The individual variation in weight gain of the calves was investigated by the following fixed covariates: sex and birth period (spring-born bulls – spring-born heifers – autumn-born heifers), number of grazing days and the interaction between breed groups (early - late-maturing breeds) and study area (SRA – FVA).

To select the most plausible models with the optimal structure of fixed effects Akaike's information system criteria (AIC) was used (Burnham and Anderson, 1998). A full model set was generated by using the dredge function in the MuMin package in R for the interpretation of all models with $\Delta\text{AIC} < 2$, thereafter, the conditional model averaging approach was used to construct model-averaged estimates of the parameters (Grueber et al., 2011). Confidence intervals of 95% were used to identify uninformative parameters (CIs which included zero) and evaluate the relative importance of potential predictor variables (Arnold, 2010). Fixed predictors were checked for collinearity using a Pearson correlation coefficient $r_s < 0.6$ and plots of factorial variables.

3. Results

On average, early maturing breeds of beef cows in the low stocking density area (SRA) were the only group of cattle that gained weight during the grazing season (24 ± 2.8 kg (mean \pm SE), $n = 107$) (Fig. 1). Early maturing breeds in FVA and of late maturing breeds in SRA and FVA were housed with an average weight loss of -58 ± 16.6 kg ($n = 6$), -6 ± 8.5 kg ($n = 45$), and -22 ± 3.7 kg ($n = 178$), respectively. Average weight gain of dry cows of early and late maturing breeds were 29 ± 4.6 and -13 ± 4.6 kg, respectively. During grazing season, the average weight of both dry and lactating cows of early maturing breeds increased with 29 ± 4.6 kg ($n = 44$) and 14 ± 4.4 kg ($n = 69$), respectively. Contrary, dry and lactating cows of late maturing breeds had an average weight loss of 13 ± 4.6 kg ($n = 145$) and 30 ± 4.3 kg ($n = 78$) kg, respectively.

The best-ranked models explaining weight gain for all studied beef cows included the coefficients individual deviation from mean breed-specific turnout weight, number of grazing days, reproductive status and the interaction between breed groups and study areas (Tables 3 and 4). Weight gain of cows was positively correlated to number of grazing days and negatively correlated to deviation from breed-specific average turnout weight (Table 4). In general, weight gain was lower for lactating than for dry cows. The interaction between breed group and study area indicated that early maturing breeds in SRA (low stocking density) had highest weight gain, and that weight gain was lower in FVA (high stocking density), with a less pronounced difference between breed groups (Fig. 1, Table 4). The confidence interval of the interaction term overlapped 0 marginally, while the single terms overlapped strongly, indicating a weak relationship between weight gain and breed/study area.

The best-ranked models used to explain weight gain in the

subsample of 53 cows equipped with GPS included the covariates grazing days, home range size and the use of summer farm meadows (Table 6). As in the models above, weight gain increased with the length of the grazing period. Average weight gain was negatively related to home range size and the proportion of time spent on summer farm meadows, but these relationships were weak (95% CI including 0). The mean (\pm SE) home range size of GPS collared cows was 39.7 ± 3.7 km² and 23.7 ± 2.4 km² in SRA and FVA, respectively. The mean (\pm SE) proportion of time spent on summer farm meadows was $13 \pm 0.01\%$ and $9.4 \pm 0.01\%$ for cows in SRA and FVA, respectively. Size of the herd (number of cattle turned out per farm) and the use of forested stands younger than 15 years were not retained in the three best-ranked models.

The two best-ranked models ($\Delta\text{AIC} < 2$) used to explain variation in weight gain in suckling calves contained the combination of sex and birth period and study area as the strongest predictors (Tables 7 and 8). Across all three study years, mean (\pm SE) weight gain of calves of early and late maturing breeds was 104 ± 2.6 kg and 86 ± 1.7 kg in the low stocking density area (SRA) and 77 ± 7.2 kg and 57 ± 5.2 kg in high stocking density (FVA) (Fig. 2). The mean (\pm SE) weight gain of autumn-born heifer calves was lower and varied more across study areas, 78 ± 3.4 and 32 ± 8.4 kg in SRA and FVA, respectively. The number of grazing days was less important for weight gain in suckling calves (CI slightly overlapped zero). The mean (\pm SE) number of grazing days for SRA and FVA were 108 ± 1.0 and 90 ± 1.5 days, respectively.

Spring-born bull calves showed the highest weight gain (99 ± 2.3 kg) during the summer grazing period followed by spring-born heifers (88 ± 2.2 kg) over autumn-born heifers (64 ± 4.4 kg). The interaction between breed group and study area was included in the models but did not explain weight gain in suckling calves as the confidence interval overlapped zero and the relative variable importance was very low (Table 8).

4. Discussion

In this current study, weight gain in beef cows and their calves on forest pastures across two study areas with differing stocking densities, breeds, reproductive status of cows, age of calves, and years were evaluated. Generally, cows grazing in the low stocking density area (SRA) gained more weight than those of the high stocking density area (FVA; Fig. 1). The majority of both dry and lactating cows lost weight in both study years. As predicted from the Ideal free distribution theory (Fretwell and Lucas, 1969), Tofastrud et al. (2019) previously found an increased use of sub-optimal habitats by the cows in FVA, eventually combined with consumption of less nutritious herbage. Therefore, it is assumed that the high stocking density influenced sward height and availability of preferred feeding plants in the area and thus further negatively influenced weight gain in cows (Cornelissen and Vulink, 2015). However, no measurements on herbage availability were conducted in this current study to validate this assumption. Although cattle have the opportunity to increase the time spent grazing to compensate for the smaller bites when grazing shorter swards, they may still be unable to fulfil their nutritional requirements (Chacon et al., 1978). Hence, sward height and stocking density can have a strong effect on feed intake and performance of both grazing beef cows and their suckling calves (Wright and Russel, 1987; Wright et al., 1994). Since breed composition and number of grazing days differed between the two study areas, direct comparisons of weight gain between the two study areas are however limited and need to be interpreted with caution.

Previous studies of beef cows kept on unimproved land have shown factors such as cow size, milk yield potential and variation in maintenance requirements to be important for weight gain (Wright et al., 1994; Casasús et al., 2002a). In general, large herbivores are better adapted to low quality forage than smaller ones because of the relationship between the body size and the digestive tract, which in turn

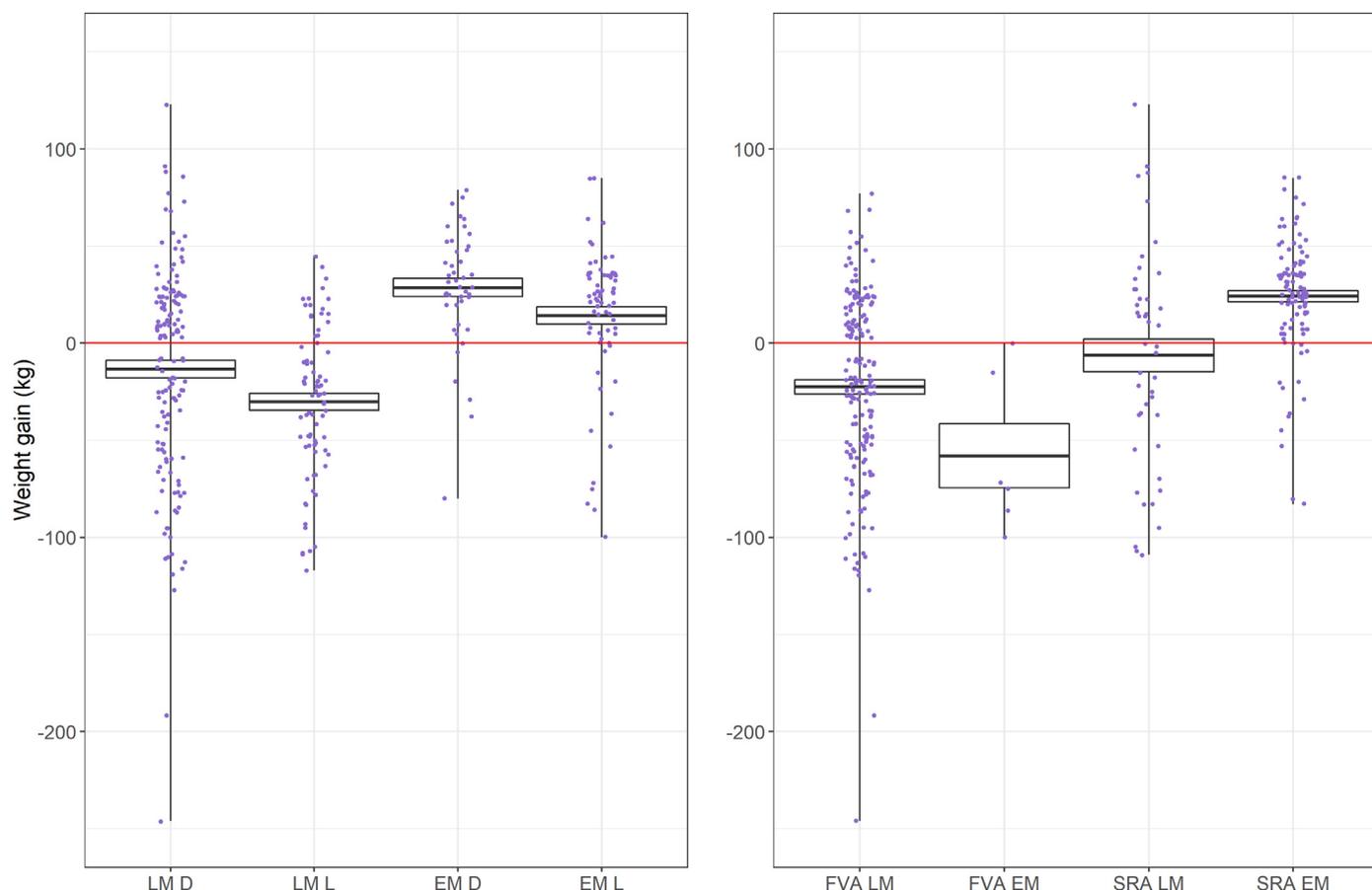


Fig. 1. Boxplots highlighting average weight gain (horizontal middle line inside boxes), standard error (upper and lower lines of the boxes) and the distribution of observations (dots and vertical lines), for beef cows grazing in boreal forests in south-eastern Norway during 2015 to 2017. The cows were divided into late (LM) and early maturing (EM) breeds and dry (D) and lactating (L) cows (left), and in areas of low (SRA) and high stocking density (FVA) (right).

enables extended microbial activity and thus more energy obtained from the plant material (Demment and Van Soest, 1985). On the other hand, early maturing beef breeds, mainly represented by Hereford in this current study, were originally bred for lower-quality nutritional environments than those of late maturing breeds, resulting in differences in maintenance and growth requirements (Webster, 1989). The Norwegian Hereford breeding goal of today is still emphasizing a more extensive production rather than those of late maturing breeds (TYR, 2016). As a result, cattle of early-maturing breeds are more efficient in utilizing energy in low quality forage, whereas late-maturing breeds are more efficient when fed rations with a high energy density (Webster, 1989). Hence, early-maturing breeds, often with a smaller body size, are believed to be better suited to nutrient-poor pastures (Osoro et al., 1999), whereas animals with a genetic potential for high productivity may be less suitable for grazing such nutrient-poor environments (Ferrell and Jenkins, 1985). This is supported by the study of Fraser et al. (2009) who reported higher weight gain of steers of an early-maturing native beef cattle breed over Charolais/Limousin crosses on semi-natural grassland, whereas the crosses gained more

weight on improved pastures. Alternatively, Hesse et al. (2008) could not find any significant effect of breed when comparing weight gain in heifers of a native breed and Charolais. Also, Hansen et al. (2009) reported no difference in daily weight gain of heifers of different breeds grazing in boreal forests of Norway. The number of animals was low in both studies. Therefore, we assume that the early maturing breeds are better adapted to meet their nutritional needs for maintenance and growth on unimproved pastures than those of late maturing breeds. In accordance with the results of previous studies (Braghieri et al., 2011; McCabe et al., 2019), no differences in time spent on grazing between GPS-collared cows of early and late maturing breeds were found in the current study (Tofastrud et al., 2018).

In our current study, lactating cows had a higher average weight loss than dry cows of the same breed group. Previous studies have shown that lactating cows lose (Montaño-Bermudez and Nielsen, 1990) and gain weight (Wright et al., 1994; Casasús et al., 2002b) on unimproved land. These contrasting results are most likely because of variations in cattle breeds and pasture quality. A comparison of the time budget of GPS-collared lactating and dry cows showed that lactating

Table 3

Predictors and Akaike information criterion (AIC) values (degrees of freedom (d.f.), Log-Likelihood, AICc, ΔAIC and AIC weights) of best-fitting (ΔAIC < 2) linear mixed models of weight gain for suckler cows in boreal forests of Stange and Romedal almenninger (SRA) and Furnes and Vang almenninger (FVA) in south-eastern Norway during 2015 to 2017.

Model	Grazing days	Dev. turnout weight/breed	Reproductive status	Breed	Study area	Breed * Study area	d.f.	Loglik	AICc	ΔAIC	Weight
1	+	+	+	+	+	+	9	-1698.49	3415.54	0.00	0.54
2	+	+	+	+	+		8	-1700.28	3416.99	1.45	0.26
3	+	+		+	+	+	8	-1700.54	3417.52	1.98	0.20

Table 4

Model-averaged coefficients, 95% confidence intervals (CI), standard errors and relative importance of variables included in three models with Δ AIC (Akaike information criterion) < 2 for independent variables explaining the variation in individual weight gain of beef cows grazing at low and high stocking density in boreal forests of Stange and Romedal almenninger (SRA) and Furnes and Vang almenninger (FVA) in south-eastern Norway during 2015 to 2017. References are for late maturing breeds, dry cows for reproductive status, and FVA for study area.

Model coefficients	Estimate	CI (2.5% – 97.5%)	S.E	Relative importance
Intercept	-106.46	(-142.37, -70.54)	18.26	
Grazing days	0.93	(0.58, 1.27)	0.18	1.00
Dev. turnout weight of the breed	-0.18	(-0.22, -0.13)	0.02	1.00
Reproductive status (Lactating)	-10.55	(-20.35, -0.75)	4.98	0.84
Breed (Early maturing)	-7.80	(-45.67, 30.07)	19.28	1.00
Study area (SRA)	7.96	(-6.86, 22.78)	7.54	1.00
Breed (Early maturing) * Study area (SRA)	35.00	(-0.20, 70.19)	17.89	0.74

cows spent on average 30 minutes more per day grazing (Tofastrud et al. 2018) and therefore compensated for the higher energy demands of raising a calf. Including information about the sex and birth date of the calf would have been useful, but this data was unfortunately not available, as these factors affect the amount of milk produced by the cow (Espasandin et al., 2016).

When cattle are turned out to pasture, their feed type changes dramatically, and this is associated with changes in diet digestibility and intake and accompanied by losses in intestinal fill, which constitutes a considerable part of live weight (Spörndly et al., 2000; Hesse et al., 2007). The feeding regime before the grazing period affects weight loss during the recovery period, measured as live weight. Weight loss of up to 30-40 kg has been reported during the first weeks on pasture and, in general, a reduction in weight is greater for cattle having had higher levels of indoor feeding (Hinks et al., 1999; Hesse et al., 2011). In our study, the winter-feeding regimen was not recorded but instead we used individual deviation from the mean breed-specific weight to measure individual weight variation at turnout date. Cows that were heavier than the average at turnout gained less weight than those being below average. This is in accordance with previous studies where weight gain in cattle grazing on unimproved areas was found to be negatively correlated with body weight at turnout date (Bjørn and Graffer, 1963; Hesse et al., 2011). We therefore argue that farmers should maintain a moderate feeding regime during the winter in order to enable effective grazing during summer. In addition to differences in winter-feeding intensity, deviation from the mean breed-specific weight might be caused by both individual variation in body size or feed intake capacity of the individual cow caused by genetic variations (Herd et al., 2004).

Several studies (Casasús et al., 2002b; Hansen et al., 2009; Steinshamn et al., 2010) reported year as a source of variation in weight gain for cattle. Studies have shown a relationship between weather conditions in the grazing season and the feeding value of forage plants (e.g.; Sæther, 1985; Steinheim et al., 2004). Low summer temperatures appear to have a positive effect on quantity and quality of the herbage and subsequently the weights of northern ungulates. During our three-year study period, the summer of 2016 was warmer and drier than the summers of 2015 and 2017, respectively. In this current study, the effect of year was a random effect to correct for unbalanced numbers of study years between the two areas, but also to correct for annual differences in temperature and precipitation (Tables 1 and 2). The effect

Table 5

Predictors and Akaike information criterion (AIC) values (degrees of freedom (d.f.), Log-Likelihood, AICc, Δ AIC and AIC weights) of best-fitting (Δ AIC < 2) linear mixed models of weight gain for suckler cows fitted with GPS collars in boreal forests of Stange and Romedal almenninger (SRA) and Furnes and Vang almenninger (FVA) in south-eastern Norway during 2015 to 2017.

Model	Grazing days	Loc. meadows	Home range size	d.f.	Loglik	AICc	Δ AIC	Weight
1	+			4	-278.40	565.62	0.00	0.55
2	+	+		5	-277.99	567.25	1.62	0.24
3	+		+	5	-278.12	567.52	1.89	0.21

Table 6

Model coefficients, 95% confident intervals (CI), standard errors and relative importance of variables included in three models with Δ AIC (Akaike information criterion) < 2 affecting weight gain in beef cows grazing boreal forests in south-eastern Norway during 2015 to 2017 in areas of low stocking density in Stange and Romedal almenninger (SRA) and high stocking density in Furnes and Vang almenninger (FVA).

Model coefficients	Estimates	CI (2.5% – 97.5%)	S.E	Relative importance
Intercept	-21.96	(-39.47, -4.45)	8.73	
Grazing days	35.97	(21.03, 50.92)	7.46	0.55
Home range size	-1.80	(-21.01, 6.15)	4.60	0.24
Summer farm meadows	-1.13	(-20.18, 9.53)	4.04	0.21

of year may also be because the individual animals were not exactly the same between years and there were differences in winter feeding regime between the years.

The number of grazing days varied both between individual cows and between farms, and in general the length of the grazing period was positively correlated with weight gain in cows (Tables 4 and 6). As the time for re-housing cattle in September is strictly regulated because of the start of hunting season, variations were mainly caused by a delayed turnout date. Some cows gave birth in late spring, which delayed their turnout, as the farmers wanted to check the next gestation before turnout to the forest. Pasture herbage grows very rapidly in early spring with a subsequent decline in growth rate in the late season (Nams and Martin (2007). At the end of the grazing period, night frost may occur in September, which causes stagnation in plant growth and reduces the cow's rumen and intestinal fill. As in our study, Nams and Martin (2007) found lower weight gain of Canadian beef cattle turned out to pastures later in the season and explained this as a loss of grazing time in the period of maximum growth potential. As stated above, cattle lose weight during their first weeks on pasture and need a recovery period while adapting to the new regime before reaching a net gain in weight (Nams and Martin, 2007). Cows with a short grazing period will therefore lose weight over a greater proportion of their grazing period and, hence, have fewer days available for positive weight gain before housing.

Home range size in our study was much larger than reported in previous studies of free-ranging cattle on unimproved lands

Table 7

Predictors and Akaike information criterion (AIC) values (degrees of freedom (d.f.), Log-Likelihood, AICc, ΔAIC and AIC weights) of best-fitting (ΔAIC < 2) linear mixed models of weight gain for suckling calves in boreal forests of Stange and Romedal almenninger (SRA) and Furnes and Vang almenninger (FVA) in south-eastern Norway during 2015 to 2017.

Model	Grazing days	Sex/birth period	Breed	Study area	Breed * Study area	d.f.	Loglik	AICc	ΔAIC	Weight
1	+	+	+	+		8	-1211.70	2439.96	0.00	0.62
2	+	+	+	+	+	9	-1211.14	2440.97	1.01	0.38

Table 8

Effects of parameters, 95% confident intervals (CI), standard errors and relative importance of the variables included in two models with Δ AIC (Akaike information criterion) < 2 on weight gain for suckling calves in boreal forests of Stange and Romedal almenninger (SRA) in south-eastern Norway during 2015 to 2017. References are autumn-born heifers for sex and birth period, late-maturing breeds for breed, and FVA for study area.

Model coefficients	Estimates	CI (2.5% – 97.5%)	S.E	Relative importance
Intercept	17.40	(-6.91, 41.71)	12.34	
Grazing days	0.25	(-0.01, 0.49)	0.12	1.00
Sex and birth period				1.00
Spring-born heifers	25.87	(18.74, 33.00)	3.62	
Spring-born bulls	32.56	(24.33, 40.78)	4.18	
Breed (Early-maturing)	12.87	(-1.75, 27.47)	7.43	1.00
Study area (SRA)	19.17	(11.13, 27.20)	4.08	1.00
Breed (Early maturing) * Study area (SRA)	10.20	(-8.95, 29.35)	4.08	0.38

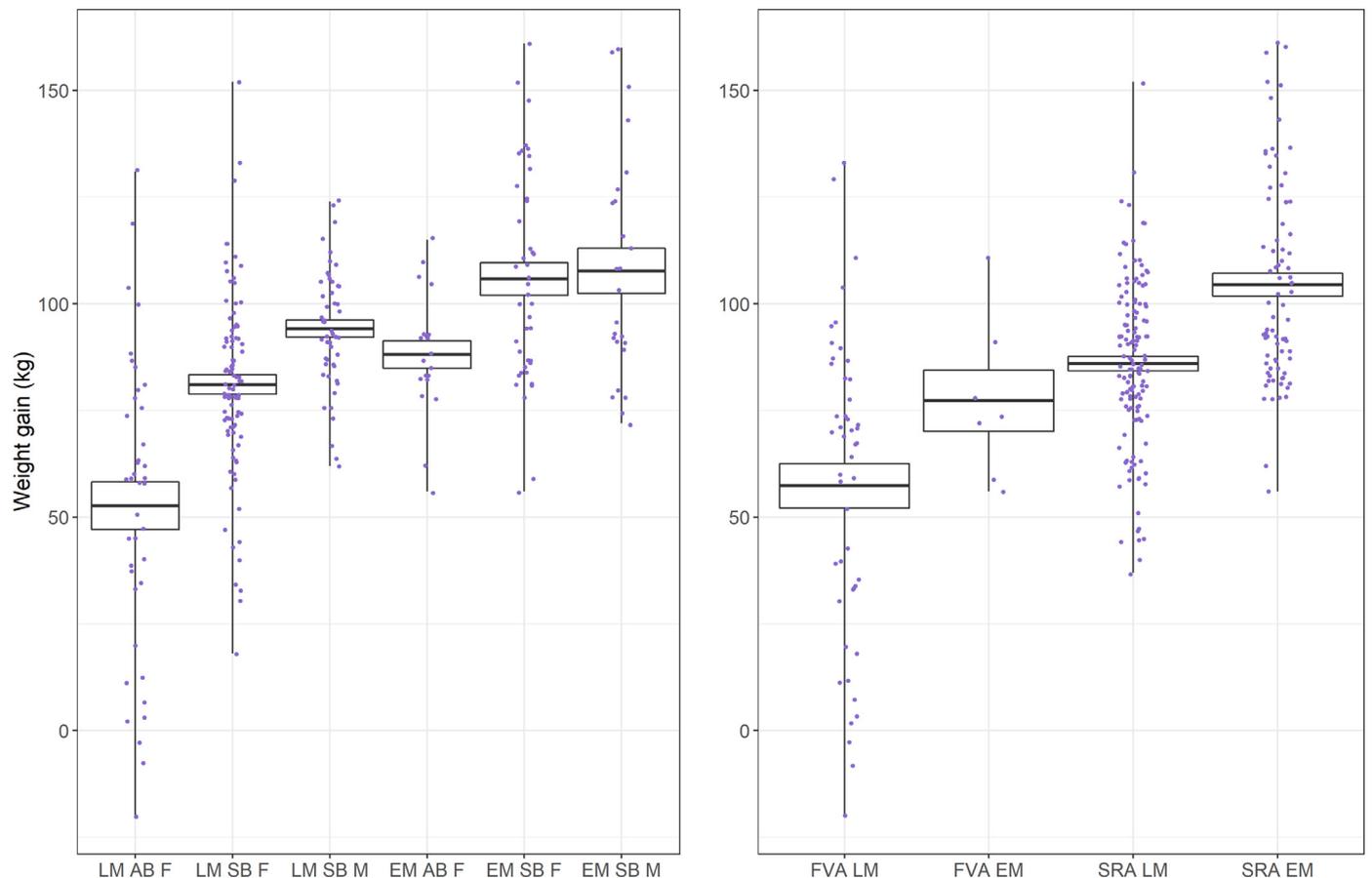


Fig. 2. Boxplots highlighting average weight gain (horizontal middle line inside boxes), standard error (upper and lower lines of the boxes) and the distribution of observations (dots and vertical lines), for beef suckler calves grazing boreal forests in south-eastern Norway during 2015 to 2017. The calves were divided into late (LM) and early maturing breeds (EM) and autumn-born (AB) and spring-born (SB) calves and, female (F) and male (M) calves (left), and in an area of low (SRA) and high stocking density (FVA) (right).

(Lazo, 1995; Howery et al., 1996; Kie and Boroski, 1996). As found in the studies of Roath and Krueger (1982), home range size of individuals and herds were stable from year to year (Tofastrud, unpublished data). A possible explanation may be that the size of the home range depends on the availability of resources (van Beest et al., 2011) and the

phenology of foraging plants (Lazo, 1995; Ofstad et al., 2016), but may also result from social learning in young calves from following their mother (Howery et al., 1998) and spatial memory of foraging sites (Launchbaugh and Howery, 2005). Bjor and Graffer (1963) observed intense use of summer farm meadows early in the season, followed by a

decreasing use through the summer. In contrast, we observed cattle gathering in large herds on the meadows of abandoned summer farms throughout the season. This may be explained by antipredator behaviour related to disturbances by human activity or the presence of large carnivores which were frequently observed in these areas. No effect of the use of forest stands younger than 15 years or herd size on weight gain in beef cows was found in our study. We assume that several factors might have influenced this result; there were a relatively low number of collared cows in this current study, the variation in weight gain was relatively high and there was low prevalence of preferred foraging habitats in the coniferous forest.

Weight gains of suckling calves in the present study (Fig. 2) was similar to results from Niemelä et al. (2008) and Steinshamn et al. (2010) who found daily weight gain of suckling calves grazing coastal meadows and mountains pastures at 1000 and 900 gram, respectively. Weight gain of young calves has been shown to be dependent on the milk production of the cow (Wright et al., 1994), where 60% of the variance of the gain in suckling calves can be attributed directly to the effect of the cow's milk yield (Rutledge et al., 1971). For all heifers, our spring-born calves gained more weight than autumn-born calves (Table 7). A possible explanation is that the autumn-born suckling calves needed a higher proportion of nutrient intake from the herbage as their mothers were at the end of their lactation period and their milk production was low (McDonald et al., 2011). Previous studies have shown that high feed intake from pasture may be demanding for young cattle even on cultivated pastures (Wright and Russel, 1987; Spörndly et al., 2000; Blanco et al., 2014). Wright and Russel (1987) showed that suckling beef calves compensated for reduced access to milk by increasing their grass intake, but this compensation is dependent on the availability of nutritious herbage. On average, the weight gain in autumn-born calves was notably lower in the high compare to the low stocking density area of this current study. We assume that the high stocking density may have led to reduced sward heights in these nutrient poor pastures and consequently increased the risk of not meeting the feeding requirements for growth in young calves.

As a result of early maturing breeds' superior ability to utilize the feed resources in the area of low stocking density (SRA), the weight gain of calves of early-maturing breeds was higher than those of the late-maturing breeds (Table 7). Obviously, this capability surpassed the fact that Hereford cows, which represent all early maturing cows in this current study, are known as a breed with low milk production potential (Montaño-Bermudez et al., 1990). As expected, bull calves grew more than heifers because of their higher feed efficiency caused by growth of muscle mass rather than fat (Turton, 1969) (Table 7). The growth potential of bull calves is effectively realized as long as the mother's milk production meets their needs, which seemed to be the case especially for the Hereford cows. However, some farmers claimed weight gain of bull calves was not satisfactory and kept them at the farm on higher feed intensities.

5. Conclusion

Forest habitats in Northern Scandinavia were found to be valuable grazing resources for free-ranging beef cattle, with acceptable weight gain of spring-born calves in accordance with previous studies. Weight gain in beef cows varied widely among individuals and breeds, but the relatively small weight reduction found in adult cows of this current study is likely to be quickly recovered after housing. Differences in weight gain between the study sites were found, and indicating a potential negative relationship between weight gain and stocking density. To reach economic and ecological sustainability, stakeholders should cooperate to find the optimal stocking density based on the grazing value of the area.

We also found higher weight gain in both calves and cows of early compared to late maturing beef breeds. Although the interest of using

late-maturing beef breeds, suitable for intensive production, is growing among Norwegian farmers, our results show that cattle production based on early-maturing beef breeds is likely to be more suitable for unimproved land and in particular, in systems with spring calving.

6. Management implications

Our results show that farm operation management, including calving period, winter-feeding regime and cattle breed, are crucial factors for an efficient utilization of unimproved land and should be considered in the context of grazing low-quality pastures in the boreal forest. This current study was based on a limited number of animals, but indicates opportunities for identifying various factors related to operational management and relevant genotypes of cattle related to effective grazing.

Because the length of the study period is positively related to cattle growth and defined by the turn-out date rather than the date of housing (onset of moose hunting season), we suggest early turn-out to optimize access to energy-rich plant shoots in the spring. Turn out and housing is laborious for farmers, therefore, an extended grazing will be advantageous and also lead to less use of the farm's winter fodder.

This current study shows that autumn-born calves have limited opportunities to realize their growth potential. This is also known by the farmers who rely on the potential for compensatory growth and turnout these heifer calves as an important social learning practise, in preparation for the day they will graze the forest as adult cows.

Declaration of Competing Interest

No potential conflict of interest was reported by the authors.

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