Avdeling for anvendt økologi og landbruksfag, Institutt for skog- og utmarksfag ved Campus Evenstad

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Bachelor thesis

On the search for food: Foraging behavior of beef cattle on forested land in southeast Norway.

På let etter føde: Beiteadferd til kjøttfe på skogsbeite i sørøst Norge.

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Abstract

According to the Optimal Foraging Theory, large herbivores, characterized as quantum feeders, should minimize the time for food search while foraging, in order to maximise food intake. As part of an on-going research project on beef cattle production in the forest, I studied the food search behaviour of cows during foraging bouts. I observed the behaviour of beef cattle on two common lands, Stange-Romedal Almenning (SRA) and Furnes-Vang Almenning (FVA) during summer 2016. The cattle ranges were situated in a heterogenous, forested landscape of the boreal forest zone, with the food distributed in patches on clear-cuts and along forest roads. I predicted that the frequency and time used for search depended on 1) season (spring June/July and fall August/September), 2) lactation status (dry cows and lactating cows), 3) available vegetation composition, measured as ground cover for different species groups, 4) time of day (morning 08:00-14:00 and evening 14:00-21:00), 5) livestock density (FVA high and SRA low density), and 6) breed size (intermediate and large). We monitored randomly selected, foraging cows continuously during sequences of 1 sec to over one hour and registered each change of behaviour with a timer. Search was defined as translocation with head down while not feeding, and did not include walking between grazing patches with head up. The cows used only 3.3% of the total observation time for search. They searched more frequently and longer in fall compared to spring. Lactating cows searched less than dry cows, and search frequency and time decreased with increasing ground cover of grass and herbs. Dry cows searched more in the evening than in the morning, while there was no time-of-day effect for lactating cows. In the high stocking density area FVA, search increased from spring to fall, while there was no relation between search and season in the low stocking area SRA. Search behaviour was not related to breed size in my study. My results combined with those of Dickel (2017) on feeding behaviour of cattle indicate that the heterogenous and patchy environment still allows the cows to feed in long bouts without long and frequent interruptions for food search, and that their behaviour is adapted to their nutritional needs.

Sammendrag

I følge den «optimale beiteteorien» skal store herbivore dyr bruke minst tid på å finne mat mens de beiter, siden de trenger et visst kvantum av mat. Som en del av et større forskningsprosjekt om kjøttfeproduksjon i skog studerte jeg kyrnes søk etter føde under beiting. Jeg observerte adferden til storfe som er nyttet til kjøttproduksjon i to studieområder, Furnes-Vang Allmenninger (FVA) og Stange-Romedal Allmenning (SRA) på utmarksbeite sommeren 2016. Utmarksbeitet er i et heterogent mellomboreal skogslandskap der maten finnes flekkvis på hogstflater og langs skogsbilveier. Jeg forventet at 1) sesong (vår er juni/juli og høsten er august/september), 2) laktasjon (ku med/uten kalv), 3) tilgjengelig vegetasjon målt som dekningsgrad av ulike plantegrupper, 4) tid på døgn (morgen 08:00-14:00 og kveld 14:01-21:00), 5) dyretetthet (FVA høy og SRA lav dyretetthet), og 6) rasestørrelse (mellomstore og store raser) vil påvirke både hyppigheten og tiden som kyrne bruker til å søke mat under beiting. Vi observerte tilfeldige, beitende dyrene kontinuerlig for sekvenser på 1 sekund til over 1 time, og registrerte alle atferdsendringene med stoppeklokke. Søk var definert som forflytning med hode ned uten spising, og ekskluderte forflytning med hode opp. Kyrne brukte bare 3.3% av den totale observasjonstiden til søk. De søkte oftere og lengre om høsten enn om våren, lakterende kyr søkte mindre enn gjeldkyr, søkehyppighet og –tid avtok med økende dekke av grass og urter, gjeldkyr søkte mer om morgen enn om kvelden, mens lakterende kyr hadde ingen forskjell på søk mellom morgen og kvelden, og i FVA (høy dyretetthet) økte søk om høsten mens i SRA (lav tetthet) ble det ikke noen forskjeller mellom sesongene. Størrelsen på rasen hadde ingen innvirkning på søk i dette studiet. Mine resultater sammen med resultatene til Dickel (2017) på beiteadferd til storfe i skogen indikerer at kyrne til tross for det heterogene habitatet klarer å beite på samme flekk uten lange og hyppige avbrudd, og at deres beiteatferd er tilpasset til deres energibehov.

Key words

Cattle	Beef cattle	Bos taurus
Cow	Grazing behaviour	Food search
Feeding behaviour	Day time	Season
Livestock density	Size by breed	Lactation status
Vegetation		

Preface

I thank very much my supervisor Barbara Zimmerman and Morten Tofastrud for their answers to questions and all their time they spent helping me with statistical analyse and support during writing. Many thanks to Lisa Dickel and Morten for the nice fieldwork. Also, many thanks to Lisa, Mélanie Spedener and my parents for helping me with correction of mine language problems and support during writing.

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1. Introduction

1.1. Free-ranging cattle feeding in Norway

The Norwegian law about cattle (*Bos taurus*) farming demands livestock owner to have cattle out on the grassland or the outlying lands during summer. Cattle that are kept in box systems are regulated by law to be outdoors at least 16 weeks and cattle farmed in free systems have to be out at least 8 weeks, to give them opportunity to get more space and exercise. The regulation of keeping cattle is protected by law in Norway (Forskrift om hold av storfe [Farming cattle regulation] 2004, § 10). The Government, Stortinget, decided to have a subsidy tool that motivates to achieve the society's goals of food production (Meld.St. 11, 2016-2017). The aim is to use subsidies to make it profitable for the farmer to have animals on outlying lands (Fylkesmannen, 2017; Landbruksdirektoratet, 2013). The county governor in Hedmark has set the goal to increase beef cattle by 20 % and to increase the use of outlying lands. In Norway, Hedmark county has the highest and still growing beef cattle production, while it is decreasing in the other counties. To increase beef cattle production, the aim is to use more of the outlying lands in forest and mountain during summer (Rekdal & Angeloff, 2016; Ivar Selsjord, 1965). According to TYR (2018) and Nortura (2016) there are three categories of beef cattle breeds for different farming systems: extensive breeds-, intensive breeds- and crossbreeds. Among extensive breeds we find small breeds like Herford and Aberdeen Angus, they are fed with high roughage. Intensive breeds are for example Charolais, Limousin and Simmental, and they are fed with concentrates and lover level of roughage. Crossbreeds are a mix across different breeds to use the heterosis-effect and to maximise positive attributes of beef cattle (Nortura, 2016; TYR, 2018). Worldwide, the most common use of beef cattle breeds is intensive production in commercial farming systems (Shabtay, 2015). However, there are hardly any studies on how adaptive the beef cattle breeds are to outlying lands in heterogenous and low-productive landscapes such as the boreal forest of Fennoscandia.

1.2. Cattle foraging behaviour

Cattle (*Bos taurus*) use the tongue in a rolling technique to collect grass and cut it with the front teeth (Kilgour, Uetake, Ishiwata, & Melville, 2012; Nedkvitne, Garmo, & Staaland, 1995, p. 64). Cattle are grazers and choose mostly herbs and grass (Bjor & Graffer, 1963). When feeding outside agricultural fields they prefer grassland, marshland and riparian habitats (Bailey, VanWagoner, & Weinmeister, 2006; Ivar Selsjord, 1966). Because of the way cattle use their tongue and teeth to feed, they cannot be as selective as sheep. However, they are able to select for the most nutritious plant species or plant parts (Nedkvitne et al., 1995 p.64-66; Ivar Selsjord, 1966). The Optimal Foraging Theory is a complex of different models on how animals decide when foraging: 1) choice of food item, 2) choice of food patch, 3) the time used on a given food patch, and 4) movements characteristics while foraging (Pyke, Pulliam, & Charnov, 1977). Foraging decisions are constrained by an animal's body size, physiological adaptions and social organisation. Large herbivores for example are adapted to maximise the quantity rather than the quality of food and therefore may have an intake of food with low nutritious value (Senft et al., 1987). Calves often adopt their mothers' foraging behaviour and forage patch choice (Bailey, Thomas, Walker, Witmore, & Tolleson, 2010), and in cattle herds, foraging behaviour is often determined by one or a few cows in a herd, referred to as the behavioural syndrome (Wesley et al., 2012).

Other factors influencing foraging behaviour are interactions with other species. Especially avoidance of predation is an important determinant of foraging behaviour. During most of the 20th century, large carnivores occurred at very low densities and were locally eradicated. The carnivore populations are now recovering and Hedmark county has now reproducing populations of all four large carnivores species (Andersen, Linnell, Hustad, & Brainerd, 2003). Cattle may have lost the anti-predator behaviour and may behave in an erratic and inconsistent way to carnivore encounters as a consequence of artificial selection. This has been shown in an experimental study on sheep in Norway (Hansen et al, 2001). However, study in an area where wolves re-established in the US showed that cattle were able to modify their behaviour despite of artificial selection (Laporte, Muhly, Pitt, Alexander, & Musiani, 2010).

1.3. Plant quality and quantity

Seasonal changes in plant nutritious value is an important factor of beef cattle grazing. Releasing livestock in the spring before plants have recovered from the winter can result in retarded plant maturation, and releasing livestock too late in summer when plants have wilted, makes plants already more resistance to grazing (Histøl, Hjeljord, & Wam, 2012; Larrson & Rekdal, 2000). Therefore, it is important to estimate pasture utilization and feeding capacity measured as the number of animals or as food units (f.u.) before releasing. In general, one dairy cow is considered equivalent to six sheep (Histøl et al., 2012; Larsson & Rekdal, 2000; Rekdal, 2001a), and a beef cattle on 550 kg is required to maintain its bodyweight with 5.5 f.u. per day while a cow of the same weight with a nursing calf is assumed to need 8.5 f.u. per day (Larsson & Rekdal, 2000; Rekdal, 2006b). The most efficient use of outlying lands is reached by mixed stocks of sheep and cattle in equal proportional animal units (Rekdal, 2017). The plant height can also be used as an indicator. At release later in summer, should be 8-10 cm high and for later releasing it should be at 10-15 cm (Nedkvitne et al., 1995, s.64). Baily et al. (2006) observed that some cattle prefer different grass heights. Some only grazed on grass with minimum 13 cm heights and other grazed grass at eight cm in fields where both grass heights were available at the same time. Many articles indicate access to water as an important factor of cattle foraging behaviour (Bailey et al., 2010; Bailey et al., 2006; Kaufmann, Bork, Alexander, & Blenis, 2013; Kilgour, 2012; Wesley et al., 2012). In Norway, water is omnipresent in outlying lands, and this is therefore negligible.

1.4. Main research questions and hypotheses

In my study, I define “foraging” as all behaviour related to food search and intake. “Feeding” is the process of taking bites and chewing. Intake of grasses and herbs is defined as “grazing”, and intake of woody plants is defined as “browsing”. In the framework of the optimal foraging theory, cattle should minimise time for searching and maximise time of food intake during foraging bouts. In forested lands, the habitat is more heterogeneous than in grassland, and the grasses are growing in patches on clear-cuts and along forest roads. Therefore, cattle may have to search more grass than if they were grazing on grasslands.

Time allocated to search for food in outlying lands might negatively affect weight gain, milk production and meet quality.

Many studies have quantified the time cows allocate to feeding, but they usually do not distinguish between search and food intake during the feeding bouts. I have chosen to study how often and how long cows search for food during feeding bouts, and how this varies with available vegetation (trees, raspberry, and grass), time of the day (morning and evening), season (spring and fall), livestock density (below and above carrying capacity), body size of the breed (intermediate and heavy breeds) and lactation status (cow with calf and dry cow). My thesis is part of a research project by the Inland Norway University of Applied Sciences on beef cattle production on forested lands in Hedmark county, and it is closely related to the thesis of Dickel (2017) who looked into determinants of the feeding behaviour of the same cows.

I a-priori set up several predictions:

Prediction 1) Cows search more often/longer for food in late summer (fall) compared to early summer (spring), due to the overall decrease of the nutritious value of plants throughout the summer.

Prediction 2) Cows with calves search less frequent/shorter than dry cows, because lactating cows have higher energy demand and therefore use less time on search, but rather more time on feeding.

Prediction 3) Frequency and time of search decreases with increasing cover of grass and raspberries and decreasing cover of trees, because grasses, herbs and raspberries are the most important forage plants of cows (Dickel, 2017), and a high cover of tree will make occurrence of grass more patchy.

Prediction 4) Cows search more often/use more time for searching late in the day (evening) because they have already been feeding earlier in the day (morning).

Prediction 5) Cows in the area above carrying capacity (Furnes) search more often/use more time for food search because the food is depleted and cows in the area below carrying capacity (Stange) search less often/use less time because the food is abundant.

Prediction 6) Cows belonging to intermediate breeds search more often/use more time on search for food because smaller animals need food with higher nutritious value, while cows

belonging to heavy breeds search less often/use less time on search for food because large animals need a higher quantity of food according to the optimal foraging theory.

2. Material and method

2.1. Study area.

The study was conducted in 2016 on two common lands in Hedmark County, Stange-Romedal Almenning (SRA) and Furnes-Vang Almenning (FVA) (Figure 1). In both areas there is mixed feeding with sheep and cattle (Table 1). Bull calves born before April and older bulls are not allowed to be released because they may mate with the cows or heifers in outlying lands. Livestock males on grassland and outlying lands protected by law in Norway (Hanndyrloven [Livestock-male act] (2003, §3).

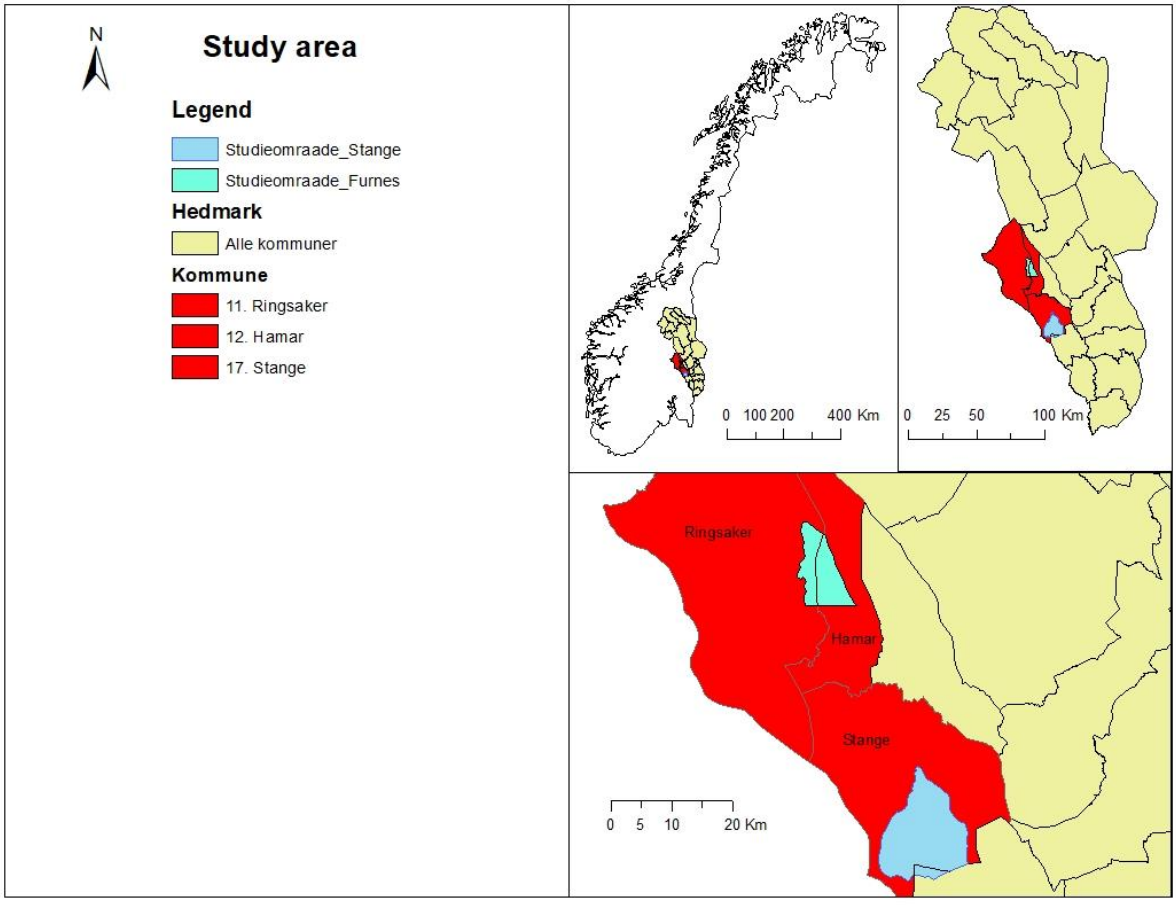

Figure 1. Overview of the study area. The municipalities are marked as yellow, the municipalities in red are where the study took place, and the two areas blue are the study area. The map is made in Esri ArcMap 10.4.1.5686.

Table 1. Overview of the number of owners and animals, the areal of the total outlying lands, the study areas, and the pasture ulization in FVA and SRA (Rekdal, 2016, 2017)

Common lands	Owner Cattle/Sheep	Cattle	Sheep	Total areal	Study areal	Pasture utilization
FVA	8 / 8	232	1 100	116 km^2	90 km^2	140 %
SRA	8 / 4	305	1 200	370 km^2	158 km^2	33 %

Both study areas were in the southern boreal forest and consisted of mainly coniferous and some deciduous trees (Moen, Lillethun, & Odland, 1999, p. 92-93). FVA had more marshland than SRA and both had many clear cuts, a hilly and rugged terrain and forest dominated by spruce (*Picea abies*). The study area has different vegetation categories, mostly different blueberry forest categories. An important pasture plant in the study area is wavy hair-grass (*Deschampsia flexuosa*) (Nesset, 2010; Rekdal, 2010, 2017).

FVA is dominated by Ringeriks-quartzite, and the area has limestone, sandstone, shale, alum shale and rhomb-porphyry (NGU, 2017). According to Rekdal (2017), SRA has mostly Øyen-gneiss and granite with some richer lines crossing the area which include: gabbro, amphibolite, micaceous gneiss, -shale, -amphibolite, and -metasandstone.

The study areas are characterized by continental climate, with cold, dry winters and more humid summers. Normal mean summer temperatures measured at a close-by weather station (Løten Id 12270, eklima 2017) was 9.3^o, 14.1^o, 15.1^o and 9.8^o for June, July, August and September, respectively. Normal precipitation during those months was 47, 66, 80 and 70 mm, respectively. For more detail of temperature and precipitation is described in chapter 6.

2.1.1. Human activity in the area.

Both SRA and FVA are used in many recreational activities and different interests like hunting, fishing, hiking, forestry, cabins, and ski tracks. There are built up gathering places like tipis, bonfire, beach, lean-to, floating stage and more. In FVA the landscape is more

intensively used by humans than in SRA. Normally 30 moose are harvested in FVA, compared to 60 moose in SRA (FVA Rinsaker jakt & fiskeområde, 2018; SRA, 2018).

2.2. Material

The equipment used is described in detail in chapter 6.

2.3. Methods

All cattle released in the two study areas were marked with ear tags and some of them had GPS-collars (Telespor and Followit). Id-numbers and colours of the collars and ear tags allowed us to identify individual cows and their owners. Identification however was more difficult later in the season when other animals with similar colours were released. We only observed beef cattle from four breeds and crossbreeds of Herford, Limousine, Charolais and Simmental.

2.3.1. To find cows in the forest, we accessed the most recent GPS-data

Using two web programs: Followit and Telespor. We used binoculars to identify and observe the cattle. All observations were recorded on a tablet with the app WhatISee for IPad. This app registered the time and the GPS-position of the observer, and we categorised the behaviour (Table 2). All observations were sent to a common e-mail server before new observation.

The main goal of the field procedure was to study the cattle feeding behaviour (Dickel, 2017). The idea of studying search behaviour came after the study design was set, and therefore, the “10 seconds rule” may have introduced a slight bias in my thesis. The 10 seconds rule made us stop monitoring if the cow during ten continuous seconds was walking, searching, defecating, or other non-feeding behaviours. A post-hoc analysis showed that in only 9% of all observations, recorded was stopped because the cow searched for more than 10 seconds. We therefore think that we only slightly underestimated the time

cows used for searching. However, we stopped observations for 24% of all registered "walking". We therefore will not use walking in the analyses, despite of the fact that walking might have been part of the search process. Wagon (1963) explained travel as behaviour for search, but that can be for water, feeding locations, and resting locations.

Our rule was to observe an individual cow for 30 minutes before switching to a new cow. Some cows in the study however were not cooperative and constantly fleeing and were excluded from the study. The cooperation of cows can be depended on daily conditions, but in general cows were less cooperative in dense forest, rainy weather, distance from road and how used cattle were to interact with humans.

Table 2. Registered behaviour of cows observed during feeding bouts on forested land in southeast Norway.

Grazing grass	The cow is grazing on sedge family (*Carex*), sweet grasses (*Pocaceae*) and rush family (*Juncaceae*).
Browsing shrubs	The cow is feeding on raspberry (*Robus idaeus*), ferns (*Polypodiopsida*), juniper (*Juniperus communis*).
Heather	The cow is feeding on European blueberry (*Vaccinium myrtillus*), cowberry (*Vaccinium vitis-idaea*), bog bilberry (*Vaccinium uliginosum*), black crowberry (*Empetrum nigrum*), heather (*Calluna vulgaris*) and other species in *Erica* family.
Browsing trees	The cow is feeding on spruce (*Picea abies*), pine (*Pinus sylvestris*), birch (*Betula ssp.*)
Stop	When we do not see the cow, or after ten seconds continuous of the behaviour search, dropping, walking and other.
Search	The cow is looking for food low movement speed and head down. The cow does not feed or chew.
Dropping	The cow is defecating.
Walking	The cow is moving with raised head.
Other	The cow does other behaviour that is not mention, for example: licking, staring, ruminating, tingling and socialising.

2.3.2. Vegetation registration.

After having observed individual cows on a plot on given day, we registered the vegetation on the plot where they had been feeding. Each plot was given an id-number and coordinate. Later in the season the cattle had been observed repeatedly close by previous plots. If the distance between the new and the old plot was > 50m, we redid the vegetation registration. We entered vegetation registration data directly in Excel and stored it in Dropbox by the help of a tablet.

On each plot, we randomly selected 10 sample squares of 40x40 cm by throwing a metal frame within 3 – 15 m from the centre of the plot.

On the sample squares, we recorded the vegetation in per cent coverage: Grass, Herbs, Raspberry, Ferns, Trees, Heather, and Moss (Table 3). Later we added a separate category for horsetails (*Equisetum*) because it was occurring in huge amounts and it was not referable to any of the other plant groups.

We excluded lichen and fungus in the vegetation registrations, because we assumed that cows did not forage those (Table 3).

To describe the cutting class, we assume classes by taking a practical review by looking at the tree height and the overview of the plot.

Table 3. Categorises the plant group and the explanations (Dickel, 2017).

Name of plant group	***Explanation of the plant group***
Grass	All species belonging to *Poacea, Juncaceae* and *Cyperaceae.*
Moss	All mosses including *Spangnum sp.* and lichen.
Trees	Seedlings and trees up to height of ~ 1.50 meters.
Heather	*Ericaceae*, i.e. genus *Vaccinium* with the species *myrtillus, vitis-idaea* and *uligunosum* and *Empetrum nigrum.*
Herbs	Not-woody which do not belong to one of the other groups, including e.g. *Fabaceae* as *cloverbut,* also *Urtica dioica*.
Rubus species	Plants belonging to the *Rubus*, particularly *rubus idealis* and *rubus chamaemorus*.
Ferns	Ferns and *Lycopodiopsia.*
Equisetum species	Plants belonging to the genus *Equisetum*.
Uncovered	No vegetation, bare soil, stones, wood etc.

2.3.3. Standardizations of the data and data analyses.

I cleaned the data in Microsoft Excel by defining sequences as maximum 10 minutes of continuous feeding and maximum 30 minutes between consequent observations. For the analyses I used R (Rcmdr) 3.3.2 (2016-10-31) Sincere Pumpkin Patch, Rstudio 3.3.2, R Commander Rcmdr (2016-10-31) and R package "nlme". To map the study area, I used Esri ArcMap 10.4.1.5686.

I used general linear nixed models GLMM to model the search behaviour. Search was expressed with different response variables: 1) Frequency of search (min^{-1}), 2) time used for search (sec/min), 3) the log-transformed ratio of time spent searching to time spent feeding, and 4) proportion of time spent searching. Explanatory variables were Study area (SRA or FVA); Season divided into spring (6 June – 12 July) and fall (1 August – 8 September); Time of day divided into morning (08:00 – 14:00) and evening (14:00 – 21:00); % cover of grasses and herbs; % cover of raspberries; % cover of trees; Lactation status (lactating or dry cows); Size

by breed divided into intermediate (Herford and related mixed breeds) and large breeds (Limousin, Simmental, Charolais and related mixed breeds).

All beef cattle were supposed to be weighted before they were released into the forest in spring and after they were collected in fall. Unfortunately, we had some problems collecting these data and I could not use the real body weight. Instead I used the size of the breed.

Cow-id nested in herd was entered as random factor, to correct for uneven sample size and individual behaviour. I weighted each observation sequence with length of observation, in order to give more weight to long than short sequences. Before analyses, I checked for collinearity between explanatory variables by using a correlation matrix with a threshold of $r < 0.6$.

I backward selection by p-value and AIC model selection to find the best model. The explanatory variables retained in the best model were reported in the results with significant (<0.050), tendency (0.051 - 0.100) and non-significant (>0.100) models.

3. Results

In total, we observed 173 cows during 445 foraging sequences of 1 second – 1.11 hours. In 85% of the time, cows were feeding, mostly on grass and herbs (Figure 2). They searched for forage with head down in 3.3% of the total observation time (Figure 2).

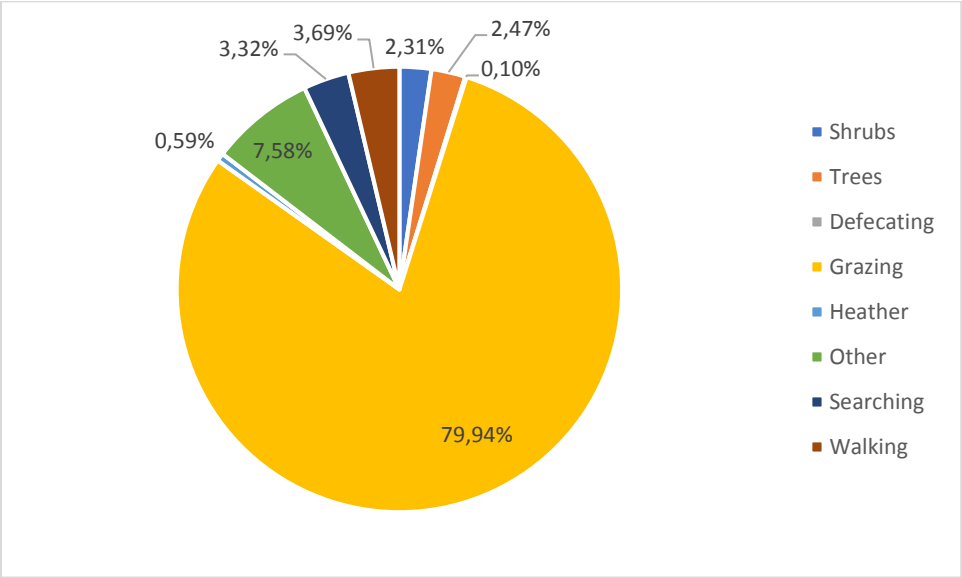

Figure 2. Percentage of different time used on differ behaviour cattle did during the foraging bouts 2016.

Frequency of search (number of search events per minute) varied with the coverage of raspberry ($F_{1.240}$ = -6.43, p < 0.005), season ($F_{1.240}$ = 5,39, p <0.005), time of day ($F_{1.240}$ = -2.88, p = 0.043), and the interactions of season and lactating status ($F_{1.240}$ = -3.40, p <0.005) season and coverage of grass ($F_{1.240}$ = -2.40, p = 0.016), lactation status and time of day ($F_{1.240}$ = 2.59, p = 0.010) (Figures 3 – 6, Table 4). Cows searched more often for food in fall than in spring (Figure 3), and dry cows searched more often in the morning than in the evening, while there was no clear difference in time of day for lactating cows (Figure 5). Search frequency decreased with increasing cover of grass, and the decrease was stronger in fall than in spring (Figure 5 and 6).

Table 4. Model coefficients for the best model explaining frequency of search during foraging for cows on forested land in south-east Norway.

	Value	Std.Error	DF	t-value	p-value
(Intercept)	1.3122060	0.3285613	240	3.993793	0.0001
Raspberry	-0.1044520	0.0162337	240	-6.434278	0.0000
PeriodLate	2.0763876	0.3851928	240	5.390516	0.0000
ReprodY	-0.0458818	0.2877902	150	-0.159428	0.8735
Grass	-0.0087854	0.0060350	240	-1.455760	0.1468
TimeondayLate	-0.6496844	0.2254952	240	-2.881145	0.0043
PeriodLate:ReprodY	-1.1346970	0.3336793	240	-3.400562	0.0008
PeriodLate:Grass	-0.0189816	0.0078896	240	-2.405917	0.0169
ReprodY:TimeondayLate	0.8964560	0.3460187	240	2.590773	0.0102

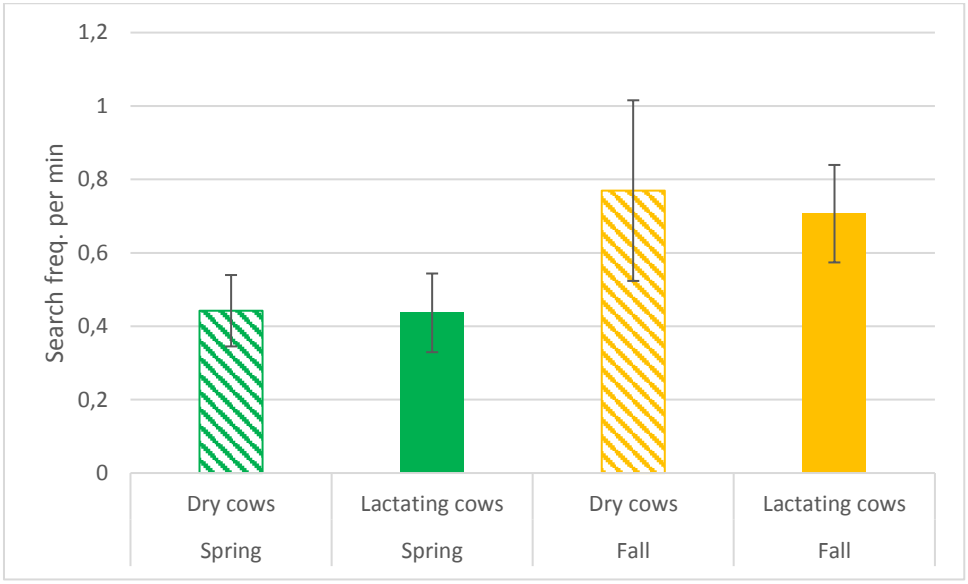

Figure 3. Search frequency per minutes per season and lactation status.

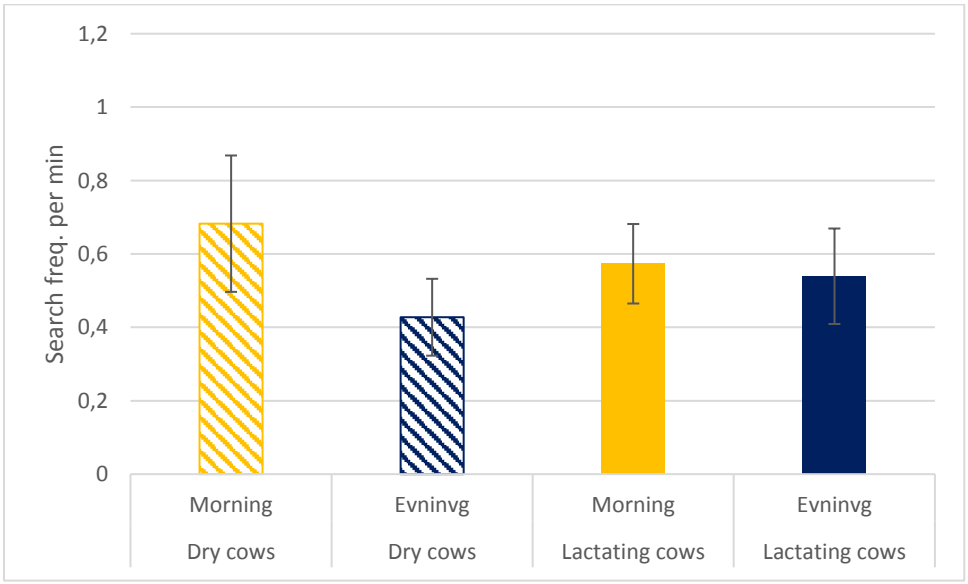

Figure 4. Search frequency per minutes per lactation status and time on day.

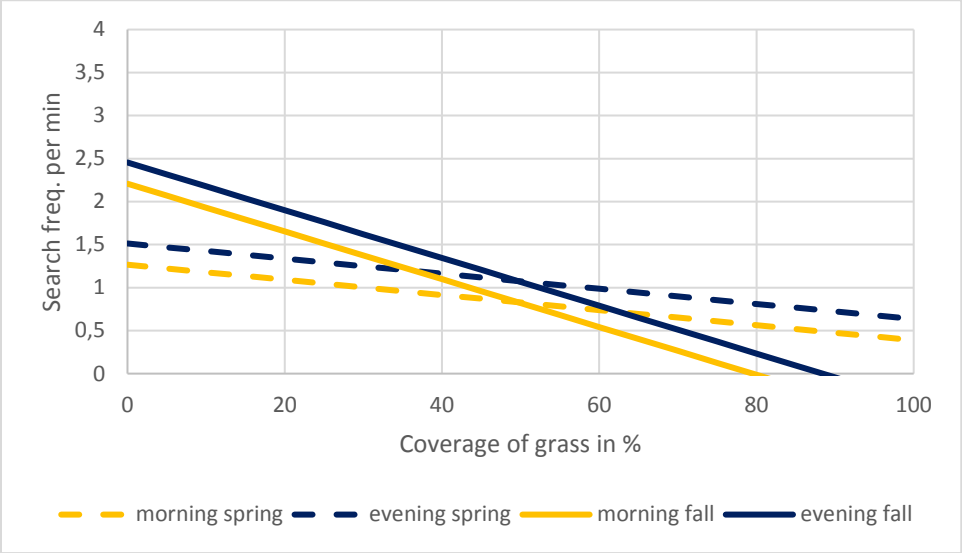

Figure 5. Frequency search per minutes and coverage of grass in season and for the different time of day lactating cows.

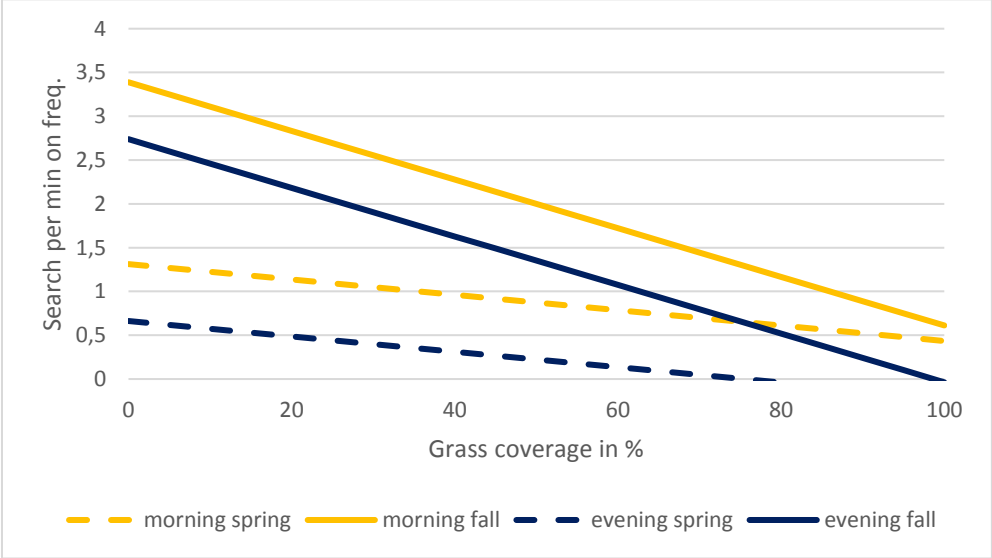

Figure 6. Frequency search per minutes and coverage of grass in season and for the different time of day dry cows.

Time used for search (seconds per minute) varied with the coverage of raspberry ($F_{1.241}$ = -2.58, p = 0.010), coverage of trees ($F_{1.241}$ = -2.58, p = 0.010), coverage of grass ($F_{1.241}$ = -2.96, p < 0.005), season ($F_{1.241}$ = 3.19, p <0.005) and the interactions of area and season ($F_{1.241}$ = -2.63, p = 0.008), and a tendency in interactions of season and lactation status ($F_{1.241}$ = -1.95, p = 0.051) (Figures 7 – 10, Table 5).

Search for food in per cent varied with the coverage of raspberry ($F_{1.242}$ = -2.94, p < 0.005), the coverage trees ($F_{1.242}$ = -2.78, p = 0.005) and the coverage of grass ($F_{1.242}$ = -3.11, p <

0.005), season ($F_{1.242}$ = 2.66, p = 0.008), and interaction between area and season ($F_{1.242}$ = -2.39, p = 0.017) (Figures 11 and 12, Table 6).

Cows used more time on searching for food in fall than in spring (Figures 7 and 11), while there was no clear difference in lactating cows (Figure 8). Search time decreased with increasing cover of grass, and the decrease was stronger differ in FVA in fall than in spring (Figures 9 – 10 and 12).

Table 5. Model coefficients for the best model explaining frequency of search during foraging for cows on forested land in south-east Norway.

	Value	Std.Error	DF	t-value	p-value
(Intercept)	6.835483	2.2611361	241	3.023030	0.0028
Raspberry	-0.281892	0.1090709	241	-2.584479	0.0103
Trees	-0.263750	0.1019469	241	-2.587133	0.0103
AreaS	2.210708	2.5347036	6	0.872176	0.4166
PeriodLate	6.837365	2.1367528	241	3.199886	0.0016
ReprodY	2.063945	1.8369023	150	1.123601	0.2630
Grass	-0.087341	0.0294481	241	-2.965916	0.0033
AreaS:PeriodLate	-5.958328	2.2579077	241	-2.638871	0.0089
PeriodLate:ReprodY	-4.396963	2.2465657	241	-1.957193	0.0515

Table 6. Model coefficients for the best model explaining frequency of search during foraging for cows on forested land in south-east Norway.

	Value	Std.Error	DF	t-value	p-value
(Intercept)	0.11614454	0.02782757	242	4.173722	0.0000
Raspberry	-0.00520578	0.00176812	242	-2.944238	0.0036
Trees	-0.00460255	0.00165365	242	-2.783263	0.0058
Grass	-0.00147004	0.00047224	242	-3.112901	0.0021
AreaS	0.04016504	0.02898576	6	1.385682	0.2152
PeriodLate	0.07412562	0.02784073	242	2.662489	0.0083
AreaS:PeriodLate	-0.08702152	0.03638213	242	-2.391876	0.0175

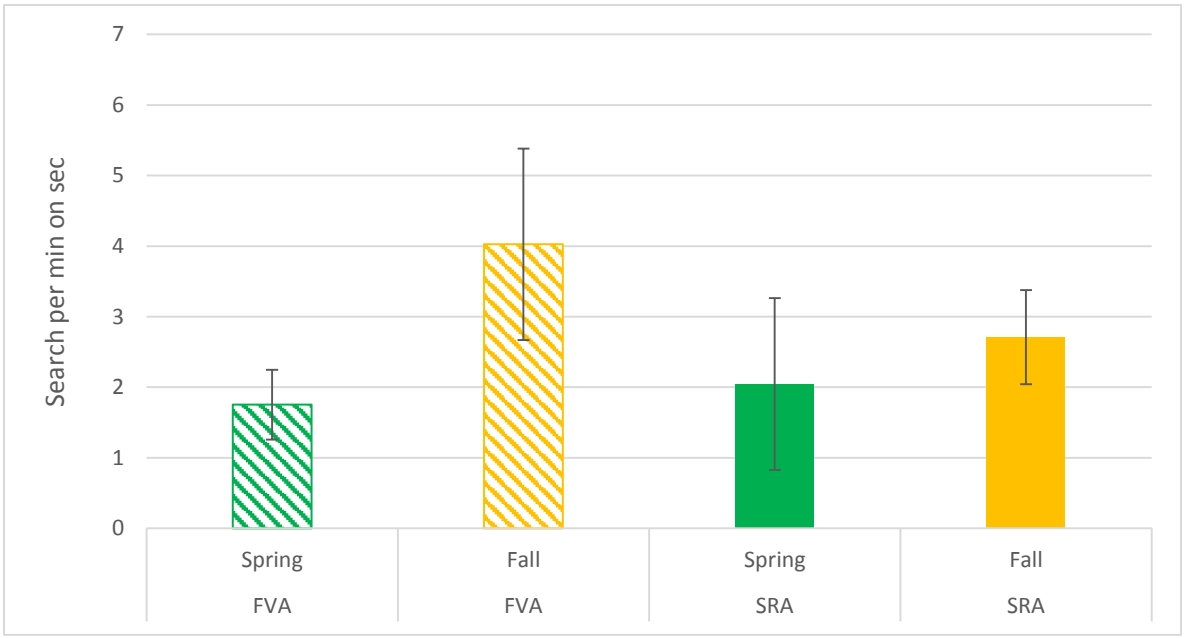

Figure 7. Search per minutes on time after food in Furnes and Stange, and per season.

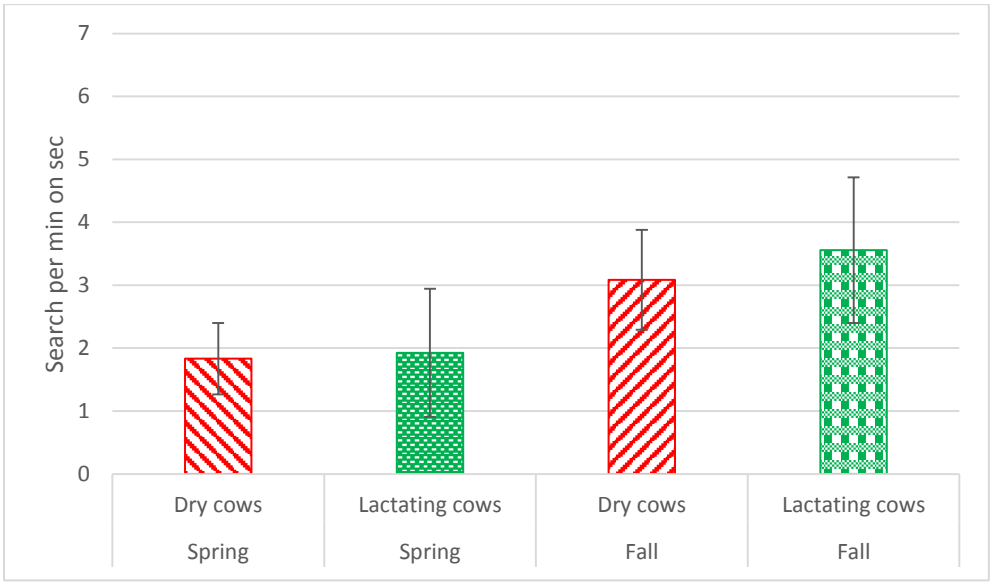

Figure 8. Search per minutes in seconds in spring and fall by different lactation status.

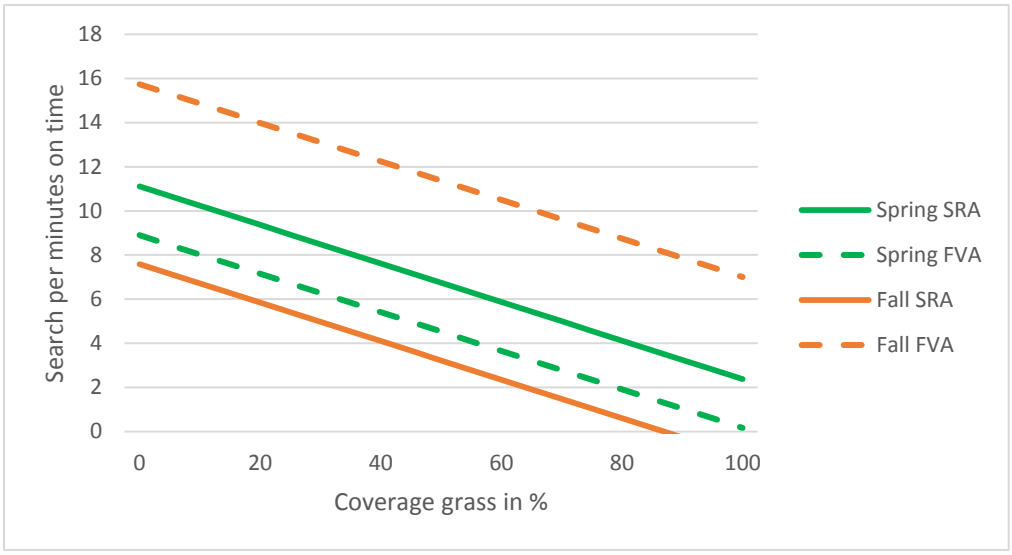

Figure 9. Search per minutes on time with coverage of grass in per cent and lactating cows in area and season.

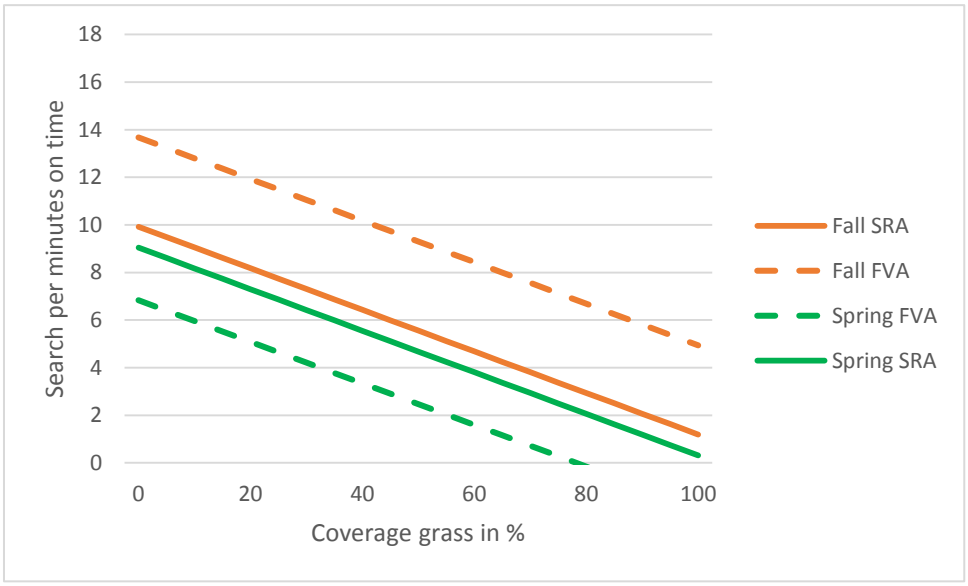

Figure 10. Search per minutes on time with coverage of grass in per cent and dry cows in area and season.

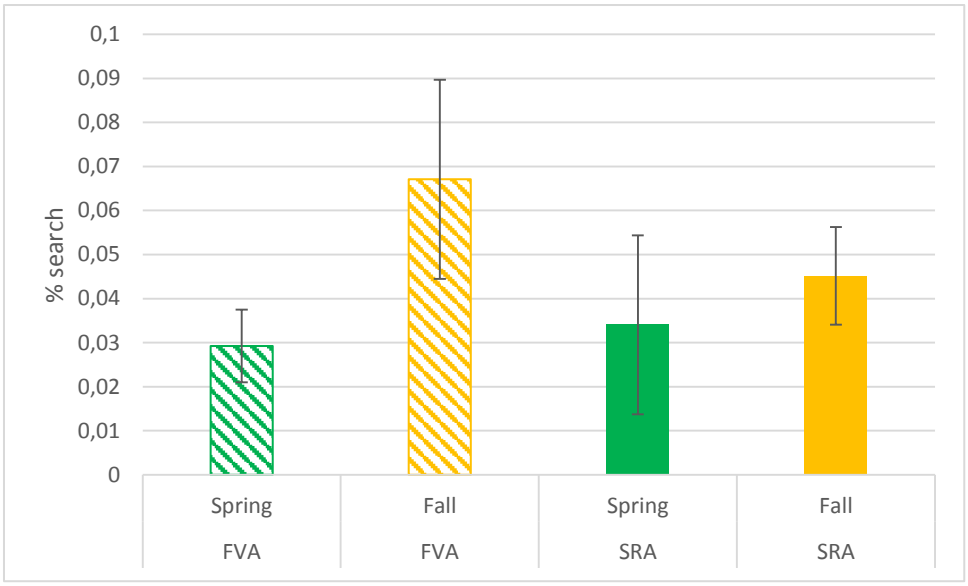

Figure 11. Search time for food in per cent for both areas per seasons.

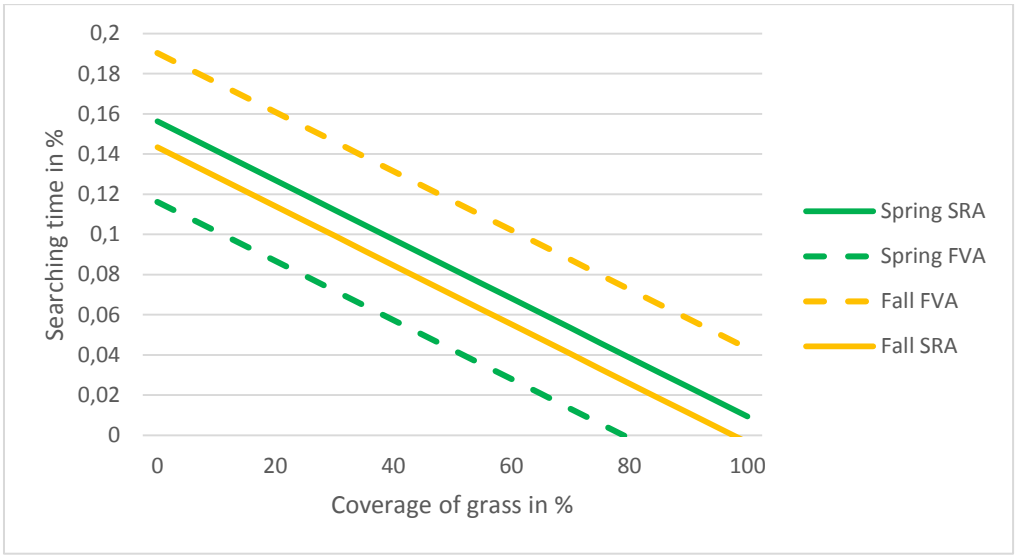

Figure 12. Search time in per cent with coverage of grass in per cent per area and season.

The ratio of the time used for searching and time used for feeding was correlated with the coverage of grass ($F_{1.235}$ = 2.72, p = 0.006), coverage of raspberry ($F_{1.235}$ = -2.42, p = 0.016), season ($F_{1.235}$ = 4.09, p < 0.005), time of day ($F_{1.235}$ = -2.79, p = 0.005), and the interactions between season and time of day ($F_{1.235}$ = 2.22, p = 0.027), and season and coverage of grass ($F_{1.235}$ = -4.31, p < 0.005), area and season ($F_{1.235}$ = -2.40, p = 0.017), season and time of day ($F_{1.235}$ = 3.11, p < 0.005), and time of day and lactation status $F_{1.235}$ = 2.26, p = 0.024) (Table 7, Figure 13). Cows had a higher ratio of search/feeding in spring compared to fall in areas with intermediate to high grass cover (Figure 13). They also had a higher ratio of searching/feeding in the evenings compared to mornings, independent of season and grass cover. In the evenings, lactating cows had a higher ratio of searching/feeding than dry cows, but in the mornings, the ratio was slightly lower for lactating than dry cows. On FVA cows generally had a lower ratio of searching/feeding in spring and higher in fall (Figure 13).

Table 7. Model coefficients for the best model explaining the ratio of the time used searching to the time used feeding for cows on forested land in south-east Norway.

	Value	Std.Error	DF	t-value	p-value
(Intercept)	-4.881345	0.4681374	235	-10.427163	0.0000
Raspberry	-0.053283	0.0219985	235	-2.422096	0.0162
AreaS	0.363545	0.3577250	6	1.016270	0.3487
PeriodLate	2.348385	0.5732072	235	4.096921	0.0001
TimeondayLate	-0.886008	0.3171226	235	-2.793897	0.0056
Grass	0.021981	0.0080577	235	2.727911	0.0069
ReprodY	-0.394719	0.3375926	150	-1.169216	0.2442
AreaS:PeriodLate	-1.059813	0.4412162	235	-2.402027	0.0171
PeriodLate:TimeondayLate	1.404464	0.4506432	235	3.116575	0.0021
PeriodLate:Grass	-0.046070	0.0106828	235	-4.312533	0.0000
TimeondayLate:ReprodY	1.021207	0.4514100	235	2.262260	0.0246

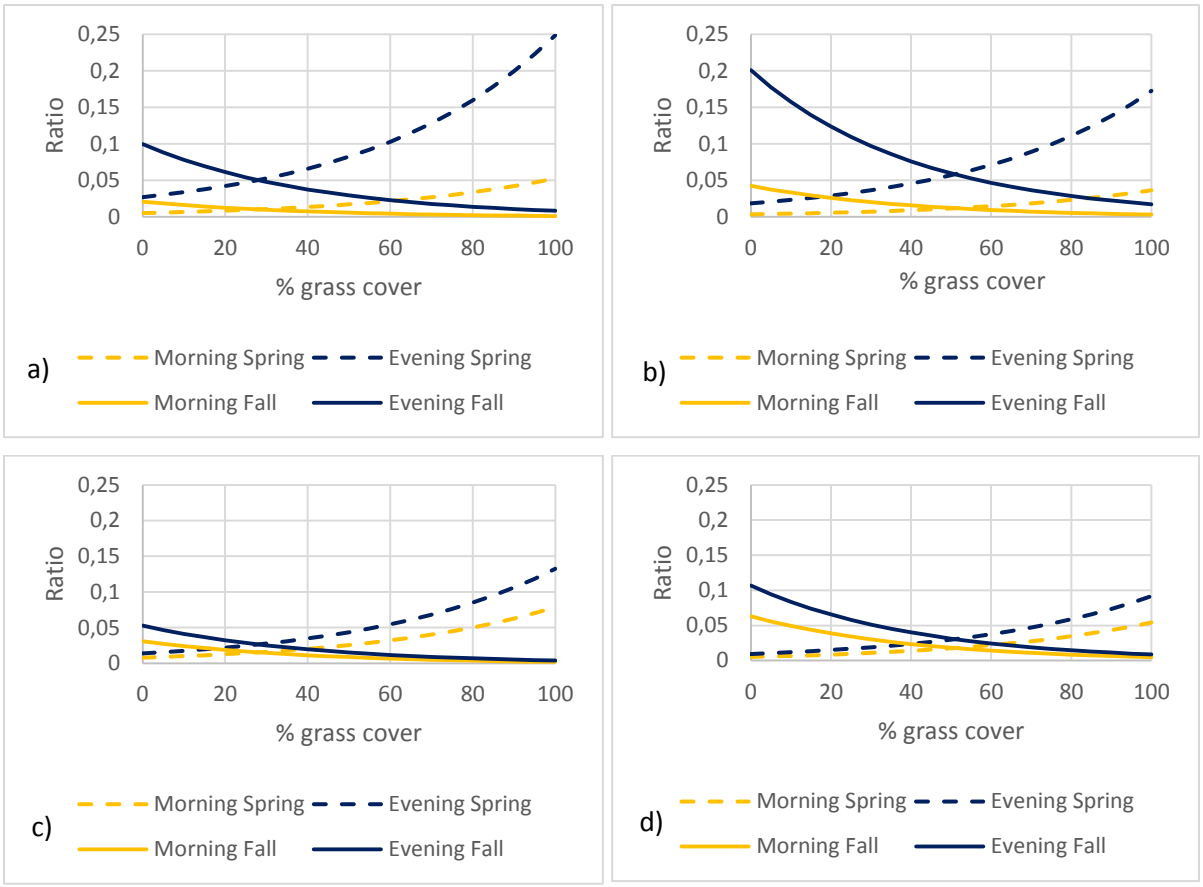

Figure 13. Ratio between search time and the time spent on feeding with the coverage of grass per season and time of day. a) Lactating cows in SRA, b) lactating cows in FVA, c) dry cows in SRA, and d) dry cows in FVA.

4. Discussion

The aim of this study was to analyse the search behaviour of cattle during feeding bouts. I found support for five of six original hypotheses, predicting that search behaviour differs with 1) season, 2) lactation status, 3) available vegetation composition, 4) time of day, and 5) areas with different livestock densities. I found no support for my hypothesis that search behaviour depends on the size of the breed 6). A potential reason for this is that the size of the cattle varied within each breed. In other studies, body weight was found to be correlated with intake of dry matter (Funston, Kress, Havstad, & Doornbos, 1991; Histøl et al., 2012; Rekdal, 2006a). The real body weight of the cows would have been a better variable to include in the models, but was however not available at the time of analysis.

4.1. Search behaviour as a function of season and area

Cattle in the study were observed to search more and longer in fall than spring. After flowering, plants reduce their nutritious value in the above-ground biomass (Larsson & Rekdal, 2000). Cows may therefore in fall search more intensively for plants with highest nutritious value, often combined with best taste (Rekdal, 2001b; Ivar Selsjord, 1965, 1966). Dickel (2017) observed that cows instead of grazing only on grass, they increased to browse more on trees in fall.

In fall the cows searched differently in the two study areas characterized by different animal densities. They searched more frequently and longer in FVA where livestock densities are above the carrying capacity. Furthermore, in fall, the ratio of searching/feeding was higher in FVA than in SRA. This may indicate that available vegetation was lower in fall in FVA, and in SRA the cattle had better access to the available vegetation throughout the season. In spring however, the ratio of searching/feeding in areas with limited grass cover was lower in FVA than in SRA. This might indicate that the grass in FVA produced new nutritious shoots continuously as a consequence of grazing, while in SRA grasses more quickly matured, thereby loosing nutritional value (Larsson & Rekdal, 2000).

Mobæk et al. (2009) found for sheep, that they changed micro-habitat selection during feeding season. The sheep changed from using high to low productive vegetation types

(Mobæk, Mysterud, Egil Loe, Holand, & Austrheim, 2009). This might have happened in FVA in fall according to Dickel (2017). Grasses might have been grazed so hard that they became too short for cattle to reach in parts of FVA (Bailey et al., 2006; Mysterud, 2006).

4.2. The influence of lactation status on search behaviour

Lactating and dry cows had similar search behaviour in spring, but in fall, dry cows searched more frequently and longer than lactating cows. The highest frequency of search was registered for dry cows in the morning hours in fall. This indicate that dry cows can use more time find to more high-valued plants in fall rather than to find a high quantity of low-valued plants (Nedkvitne et al., 1995, p.64-65; I Selsjord, 1968). When they finally found the plants they wanted, they probably used more time feeding than searching (Austrheim, Solberg, & Mysterud, 2011). Histøl et al. (2012) found that cattle per 100 kg in forest need to graze 3 kg dry matter daily to maintain their bodyweight (Histøl et al., 2012; Rekdal, 2006a). Furthermore, the need of extra nutrition depends on which lactation status cows are in and weaning of the calves (Adams, Clark, Klopfenstein, & Volesky, 1996).
Cattle need different amounts for nutrition according to what they must produce, for example production of milk, gestation, weaning of calves and when cattle do not produce anything (Herd & Sprott, 1998). In a follow-up study, it could be interesting to compare the search and feeding behaviour for all these different reproductive stages.

4.3. Available vegetation composition

According to Larsson & Rekdal (2000; 2001), the use of pasture in outlying lands is limited by three important factors: 1) production of pasture plants, 2) nutritional value of plants and, 3) utilization scale. For the feeding intake of cattle, micro-habitats which are rich in grass are important (Bjor & Graffer, 1963). In my study, cows in general searched less with high coverage of grass, and with low coverage of raspberry and of trees. In fall, cows searched more in FVA, the area with high stocking densities.
The vegetation on a given plot was only registered once, when cattle were observed in a plot for the first time. Therefore, it might not account for eventual vegetation change during the seasons. To check this, we should register the vegetation on all possible plots and vegetation

heights for each different category before releasing and after gathering of animals. Furthermore, we did not collect data to analyse the nutritional composition of available and eaten plants throughout the season. That might have helped to explain some of the observed changes in search frequency and time in our study.

Cow prefer some species over other, often coupled with nutritious value and taste, such as *Agrostis capilaris.* This species is the grass of highest pasture value in forest (Larsson & Rekdal, 2000; Ivar Selsjord, 1965, 1966). Larsson and Rekdal (2000) describe for livestock foraging in boreal forest that raspberry, broadleaved trees, and heather are important plants. The vegetation composition can change by trampling by livestock, especially of heavy animals Bjor and Graffer (1963). Cattle use of outlying lands might be different, since cattle split up in different herds and of different size (Histøl et al., 2012), which might cause variable impact on locations of different vegetation composition (Mysterud, 2006). Furthermore, using outlying lands for livestock foraging might be in conflict with forestry aims (Histøl et al., 2012) because of the damage on roots and trunk (McLean & Clark, 1980). McLean and Clark (1980) observed that wrong management of land use resulted in weight loss of cattle during foraging in forest. Clear-cuts in the transition stage of cutting classes 1 and 2 are favoured micro-habitat, and livestock feeding holding vegetation height down, thereby opening up for more light available for the young trees (Bjor & Graffer, 1963). Bjor and Graffer (1963) observed that the soil changed to be richer if it was exposed by livestock foraging. However, the weather might have an impact on the soil and vegetation (McLean & Clark, 1980; Nedkvitne et al., 1995, p. 65).

4.4. The change of search during day time.

Dry cows searched more often in morning and less in evening. Lactating cows did not change search time or frequency throughout the day. The ratio of searching/feeding was generally higher in the evening than in the morning, and dry cows had a slightly lower ratio of searching/feeding than lactating cows during foraging bouts. Gregorini et al. (2005) found that heifer grazing time decreased at evening and increased in idling at evening. Evening generates more intense and longer grazing events when the vegetation quality was higher (Gregorini et al., 2005). This might happen because of phenology of plants, change of fresh plant materials and daily grazing (Eirin et al., 2005). The rumination of the food occurs at

dusk, when the dry matter and the carbohydrates concentration are increased in the plants (Eirin et al., 2005). However, the grazing intake by heifers studied by Eirin et al. (2005) did not differ the between morning and evening. Furthermore, heifer have shown an indication that they avoided foraging in darkness in order to minimize predation risk (Hessle, Rutter, & Wallin, 2008) and therefore light conditions might impact foraging behaviour (Eirin et al., 2005; Wagon, 1963).

4.5. Conclusion

This study is one step towards the understanding of beef cattle behaviour on outlying lands in the southern boreal forest. In this study I found that search time and frequency changed with season, lactation state, available vegetation, and area. Since search represents only a small amount of time used compared to other foraging behaviour, it is questionable how much inference can be drawn from this result. The results may be the biased due to our 10 seconds rule, i.e. to stop observations after 10 seconds of continuous non-feeding behaviours. This rule was used due to a different focus of the initial study. I do not recommend using this rule in further studies. Still, I think that my study can be seen as a pilot for further exploration of the subject. My results combined with those of Dickel (2017) on foraging behaviour of domesticated herbivores on low-productive outlying lands indicates that cattle will try to find the best plant materials of what is available and what nutrition they need to produce during season.

In the future it might be important to understand more of “the secret life of beef cattle”, the biodiversity, the impact on wildlife and comparison to socially goals to reach better management of free-ranging cattle.

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6. Attachments

6.1. Table of hypotheses, formulation, and analysing

Table 8. Shows the formulation, analyse and variable of the main issue and hypotheses.

	Formulation	**H_0 & H_1**	**Analyse & variable**
Main issue	*Does the frequency and time of search for food in beef cattle vary with season (spring and fall), lactation status (with- and without calves), available vegetation (trees, raspberry, and grass), time on day (morning and evening), density of animals (area) and the size of the breed (small and large)?*	H0 = No difference or correlating	Linear model
		H1 = It is a difference or correlating	X-variable: Season + lactation-status + vegetation cover + time of the day + areas + size by breed.
			Y-variable: Search time/frequency of sequence, Search % of tot, relations S/pasture
Hypotheses 1	*Cows search more often/use more time for food in late summer (fall) compared to early summer (spring).*	H0 = No difference in time or frequency between the periods.	T-test: two-way t-test with assumed two different variations.
			X-variable = Early summer and late summer
		H1 = It is a difference in time or frequency between the periods.	Y-variable = Frequency and time
Hypotheses 2	*Time and/or frequency differs between cows with and without calves.*	H0 = No difference with calf or not.	T-test: two-way t-test with assumed two different variations.
			X-variable = with calf and not.
		H1 = It is a difference with calf or not.	Y-variable = Frequency and time.
Hypotheses 3	*Search frequency/time depends on available vegetation composition.*	H0 = No difference in time or frequency depended on available vegetation composition.	Linear regression
			X- variable = Vegetation cover.
		H1 = It is a difference in time or frequency depended on available vegetation composition.	Y- variable = Frequency and time.
Hypotheses 4	*Cows search more often/use more time late at the day then early at the day.*	H0 = No correlation in time or frequency between time on day.	T-test: two-way t-test with assumed two different.

			X- variable = Time of the day.
		H1 = It is a correlation in time or frequency between time on day.	Y- variable = Frequency and time.
Hypotheses 5	*Cows in Furnes (high density) search more often/use more time for food search than those in Stange.*	H0 = No difference in time or frequency between the study area.	T-test: two-way t-test with assumed two different variations.
			X-variable = Stange og Furnes.
		H1 = It is a difference in time or frequency between the study area.	Y-variable = Frequency and time.
Hypotheses 6	*Cows in a small breed search more/use more time on searching for food than cows in a large breed.*	H0 = No difference in time or frequency between the breeds size.	T-test: two-way t-test with assumed two different variations.
		H1 = It is a difference in time or frequency between the breeds size.	X-variable = Size of breed
			Y-variable = Frequency and time.

6.2. Temperature and precipitation

Table 9. Normal mean temperature in °C per month for the period of 1961-1990 from five weather stations in Hedmark for the months the cattle was at outlying lands (eklima, 2017).

Study area	Station	June	July	August	September
Stange	*Sand i Nord-Odal Id 5340*	9.5	14.2	15.3	14.0
	Staur forsøksgård Id 12090	13.8	15.1	14.1	9.8
For both	*Løten Id 12270*	9.3	14.1	15.1	13.6
Furnes	*Brumunddal Id 12340*	9.5	14.0	15.5	14.5
	Rena flyplass Id 7950	13.3	14.4	12.5	7.2

Table 10. Normal precipitation in mm per month for the period of 1961-1990 from five weather stations in Hedmark for the months the cattle was at outlying lands (eklima, 2017).

Study area	Station	June	July	August	September
Stange	*Sand i Nord-Odal* *Id 5340*	55	74	80	85
	Staur forsøksgård *Id 12090*	56	68	66	57
For both	*Løten* *Id 12270*	47	66	80	70
Furnes	*Brumunddal* *Id 12340*	45	63	77	74
	Rena flyplass *Id 7950*	77	73	73	70

6.3. Equipment list

6.3.1. Field equipment

GPS-collars, GPS, collars with bells, tablet, camera, five meters long rope, 40x40 cm iron-frame, flora books, car, binocular, telescope, magnifying glass.

6.3.2. General programs

Dropbox, Microsoft Office: Excel and Word, Mailbox, Garmin BaseCamp, GeoFollowit, Telespor, Rcmdr, Rstudio, Erisi ArcMap.

6.3.3. Programs to the tablet

Ipad: WhatISee, Mail, Note, Dropbox, Microsoft Office Excel

6.4. Observing table

Table 11. WhatISee app outlook and cattle behaviour categories. X can be moved to the observed behaviour.

Cow number: KY0094	
Grazing grass	X
Browsing shrubs	
Heather	
Browsing trees	
Stop	
Search	
Dropping	
Walking	
Other	

6.5. Vegetation table

Name	Waypoint							Date observation			
								Date vegetation			
	1	2	3	4	5	6	7	8	9	10	SUM
Grass	0	0	0	0	0	0	0	0	0	0	0
Herbs	0	0	0	0	0	0	0	0	0	0	0
Heather	0	0	0	0	0	0	0	0	0	0	0
Raspberry	0	0	0	0	0	0	0	0	0	0	0
Trees	0	0	0	0	0	0	0	0	0	0	0
Ferns	0	0	0	0	0	0	0	0	0	0	0
Equisetum	0	0	0	0	0	0	0	0	0	0	0
Moss	0	0	0	0	0	0	0	0	0	0	0
Coverage	0	0	0	0	0	0	0	0	0	0	0
V. hight	0	0	0	0	0	0	0	0	0	0	0
Sp. number											

Tree counting 100m2	
Number	Middle hight

Veg. type	
Clearcut: age	
Comments	

Figure 14. Vegetation table used in fieldwork.