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Clover (Trifolium spp) gamefields: Forage production, utilization by ungulates and browsing on adjacent forest

Karl Komstedt

Sveriges lantbruksuniversitet
Fakulteten för skogsvetenskap
Institutionen för vilt, fisk och miljö
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Viltåker med klöver (Trifolium spp): Foderproduktion, klöverviltets utnyttjande och påverkan på omgivande skog

Karl Komstedt

Keywords: *Trifolium repens*, browsing, gamefields, forage availability, ungulates

Handledare: Jean-Michel Roberge och Johan Månsson
Examinator: Göran Ericsson

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SLU, Sveriges lantbruksuniversitet
Fakulteten för skogsvetenskap
Institutionen för vilt, fisk och miljö

Swedish University of Agricultural Sciences
Faculty of Forestry
Dept. of Wildlife, Fish, and Environmental Studies

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Sammanfattning

Viltet är en värdefull och förnyelsebar resurs som genererar många olika förtjänster, såväl ekonomiska och ekologiska som sociala värden. Dessa är betydelsefulla för utveckling och bibehållande av en levande landsbygd. Ökande klövviltspopulationer har emellertid medfört ökat betestryck på värdefulla trädslag och grödor. Tidigare studier nämner stödutfodring och viltåkrar som metod för att styra om klövviltets födosök och minska betesskador genom att tillhandahålla attraktiva foderresurser. Kvantitativa skattningar på möjlig biomassaproduktion av olika viltåkergrödor tillsammans med betestryck på omgivande skog saknas. Inom temaforskningsprogrammet Vilt och skog har det därför genomförts ett treårigt projekt som ska utvärdera fodermärgkål, klöver och foderraps som viltåkergrödor och betestrycket i skog närliggande till viltåkrarna.

I denna studien har biomassaproduktionen av klöver (*Trifolium* spp.) i viltåkerblandning utvärderats på viltåkrar insådda 2008 och 2009 i studieområdet Misterhult i södra Sverige. Detta har gjorts med inhägnade ytor med tillhörande kontrollytor slumpmässigt spridda över 8 viltåkrar Eftersom klövervallarna putsas under säsongen har klippningarna förlagts omedelbart före varje klippning samt en sista gång före vegetationsperiodens slut. Betestrycket på omgivande skog har undersökts med hjälp av fyra stycken 500 meters transekter från varje viltåker, en längs varje väderstreck. På transekterna har provytor lagts ut på avstånden 0, 50, 100, 200, 300, 400 och 500 meter från viltåkern.

Studien visade på en hög biomassaproduktion på viltåkrarna. Emellertid var det stora variationer i produktion mellan viltåkrarna, men även under vegetationsperioden. Dessutom visade studien på stora skillnader i biomassaproduktion mellan viltåkrar insådda 2008 och 2009. Viltåkrar insådda 2008 kunde producera mellan 100 gram och 656 gram torrvikt klöver per m² med den aktuella viltåkerblandningen under vegetationsperioden. Det motsvarar en medelproduktion på 3040 kg klöver per hektar. Den korresponderande klöverbiomassan i kontrollytorna var 48 gram och 331 gram torrvikt per m². Det fanns signifikanta skillnader i tillgänglig och betad biomassa. Viltobservationer som utfördes under fältarbetet i studieområdet visar på att viltåkrarna frekventerades av främst rådjur och hare, men även av älg, dovhjort, kronhjort och vildsvin.

Studien visade även att olika lövbärande träd och buskar förekom i varierande grad i förhållande till viltåkrarna med mer allmän förekomst i kantzonen intill viltåkern. Betestrycket i kantzonerna var högt på de flesta lövbärande träd och buskar men avtog med ökande avstånd till viltåkern med vissa undantag.

Att bibehålla ett öppet landskap med betade bryn och kantzoner tillsammans med fleråriga och begärliga grödor på viltåkrarna kan ge möjligheter att styra viltet och betestrycket i landskapet. I förlängningen ger detta de nödvändiga verktyg som behövs i en ekosystembaserad viltförvaltning.

Abstract

Wildlife is a valuable and renewable resource that promotes economical, ecological and social values. These values are important for developing and maintaining many rural societies. However, growing ungulate populations have led to increased browsing pressure on valuable forest trees and crops. Previous studies have proposed supplementary feeding and gamefields as potential methods for controlling the ungulate foraging and reducing browsing damage by providing other attractive food resources. However, quantitative estimates of potential biomass production of various gamefield crops and browsing pressure on the surrounding forest have been lacking. Within the thematic research program "Wildlife and Forestry" a three-year project was therefore initiated to evaluate marrow-stem kale, clover and rapeseed as gamefield crops together with browsing pressure in forests adjacent to the gamefields.

In this study, the biomass production of clover (*Trifolium* spp) in a gamefield mixture has been evaluated on 8 gamefields sown in 2008 and 2009 in the study area Misterhult in southern Sweden. This was done with fenced plots and with associated control plots randomly distributed across the gamefields. Since clover leys are trimmed down during the season, the biomass assessments had to be conducted immediately before each of the trimmings, and one last time before the end of the vegetation period. Browsing pressure on the adjacent forests was investigated using four 500-meter transects from each gamefield, one in each cardinal direction. Plots were laid out on the transects at distances of 0, 50, 100, 200, 300, 400 and 500 meters from the game field.

The study showed a high biomass production on gamefields. However, there were large variations in production between the gamefields, but also during the growing season. The study also showed large differences in biomass production between the gamefields sown 2008 and 2009. Gamefields sown in 2008 were able to produce between 100 grams and 656 grams and with a mean production of 304 grams dry weight of clover per m² with the current gamefield mixture during the growing season. This is equivalent to 3040 kg dry weight of clover per hectare. The corresponding clover biomass at the control plots was 48 grams and 331 grams dry weight per m². There were significant differences in available and grazed biomass. Game observations conducted during the fieldwork in the study area showed that the gamefields were frequented mostly by roe deer and hares, but also moose, fallow deer, red deer and wild boar.

The study also showed that different deciduous trees and shrubs were present in varying degrees relative to the gamefields with higher prevalence in the border zones next to the gamefield. Browsing pressure in the edge-zones was high on most deciduous trees and shrubs but decreased with increasing distance from the game field with some exceptions.

Maintaining an open landscape with browsed edges along with perennial and highly palatable crops on gamefields can provide opportunities to manage wildlife and browsing pressure in the landscape. In due course, this provides the necessary tools needed in an ecosystem-based wildlife management.

Introduction

Wildlife development and collisions with human interests

Wildlife is a valuable and renewable resource. Utilization of wildlife through recreation and hunting generates expenditures which can be beneficial to local economies, especially in rural communities (Mattson 1990, Storaas *et al*. 2001; Willebrand *et al*. 2001; Alatalo 2003; Gordon *et al*. 2004). But expenditure data alone underestimates the value of wildlife to society. The human benefits associated with wildlife, such as public health and naturalistic values, are not always taken into account (Heberlein 2005). Although valuable, wildlife has an impact on other values such as economical, ecological, socioeconomical and other values. Ungulate populations have locally led to conflicts concerning damages caused by browsing and grazing on forests and crops and through traffic incidents (Alverson *et al*. 1988; Gill 1992b; Hörnberg 2001; Storaas *et al*. 2001; Gordon *et al*. 2004; Andreassen 2005). The forestry industry suffers from decreased wood quality and growth by damages and plant suppression due to ungulate browsing (Gill 1992a; Gill 1992b; Bergström & Danell 1995). Agriculture suffers from browsing and grazing damages on crops and plantations and decreased fodder value due to soil mixture into silage, mainly caused by wild boars (West *et al*. 2009). Traffic incidents cause economic and human casualties yearly (Andreassen 2005). Since the development of the large herbivore populations in Sweden have shown steady growth, many stakeholders are affected (Bergström & Danell 2009). Hence, management of wildlife emerges as an important strategy to avoid collisions of different interests. To manage wildlife in a sustainable and prosperous way requires an increased understanding of the dynamic interactions in the habitats and ecosystems. The amount of forage that is available, together with forage quality and food plant distribution, has big impact on how the ungulates search for forage, move in the landscape and how they choose browsing patterns (Fryxell 1991; Gordon *et al* 2004; Gundersen *et al*. 2004; Eklund 2009; Nilsson 2009; Lidberg 2011). Since wildlife activity influences several ecosystem processes through browsing, grazing, trampling and faeces, they can change the appearance and composition of plant species, clearings, pathways, soils and conditions (Pastor & Naiman 1992; Reimoser & Gossow 1996; Gill & Beardall 2001; Edenius *et al*. 2002; Gordon *et al*. 2004; De Jager & Pastor 2008). Management or nursing of wildlife can contribute to substantial secondary values and synergies, and minimize the conflicts amongst stakeholders (Heberlein 2005).

Using gamefields to support high ungulate densities and minimize conflicts

Increased supplies of forage distributed away from sensitive plantations or roads can lead to a decreased browsing intensity at a given density of ungulates or fewer collisions (Putman *et al* 1996; Hörnberg 2001, Andreassen 2005). Creating suitable habitats away from roads, productive forests or valuable crops might also make it possible to keep high densities of ungulates and still avoid conflicts between stakeholders (Gundersen *et al* 2004; Nilsson 2009; Lidberg 2011). Gamefields are commonly used to provide a high quality forage and to create such suitable habitats in an otherwise monocultural forest landscape (Jensen 2001; Bergqvist *et al* 2009). Many different crops are used such as sunflower (*Helianthus annuus*), millet (*Panicum miliaceum*), marrow-stem kale (*Brassica oleracea* var. *medullosa*), rapeseed (*Brassica napus*) and clover (*Trifolium* spp.), but also gamefield mixes containing a variety of legumes, grasses and weeds (Jensen 2001). Previous studies within the thematic research program “Wildlife and Forestry”(in Swedish: Temaforskningsprogrammet “Vilt och Skog”) have evaluated marrow-stem kale (Nilsson 2009) and rape seed (Lidberg 2011) and the effects on forests adjacent to the gamefields. The main findings in these studies reveal a high utilization of the gamefields and notable edge-zone effects to the gamefields. However, quantitative knowledge of forage production of clover and utilization by ungulates and the effects on adjacent forests have been lacking.

Objectives of this study

In the light of previous year’s studies of marrow stem kale and rape seed, this study will evaluate gamefield seed-mix as game field crops. With focus on clover (a component in the gamefield seed-mix that is extensively utilized) as supplemental forage crop, a quantitative study of biomass production and forage utilization during the vegetation period was made, similar to the previous studies. The principal aim of the study was to assess how much forage that was produced and to what extent it was utilized by ungulates. An additional aim was to see if the clover pastures could have any effect on the summer browsing and rooting in the adjacent and surrounding forests. Furthermore, the species utilizing the pastures were to be observed in order to get an understanding of the distribution and forage pattern of the ungulates.

Four specific questions were:

1. What is the available biomass of clover and weeds on the game fields during the vegetation period and to what extent is it utilized by herbivores?

2. How much does the available biomass of clover and weeds differ between game fields sown 2008 and 2009?

3. How are the ungulates utilizing forests adjacent to the clover gamefields?

4. Which ungulate species are utilizing the clover fields and to what extent?

Methods

Study area

This study was conducted in an area comprising 43 km² owned by the state forest enterprise Sveaskog. The area is located in south-eastern Sweden, near Misterhult (57˚ 27´N, 16˚ 32´E). The study area is located in the hemiboreal zone and consists of 80 % forest land with a large element of rocky forests, 9 % bare rock, 3 % mire, 2 % pasture land and the rest is arable land, water and other land cover types (Sveaskog 2009). The forest stands consist of Scots pine (*Pinus sylvestris;* 57%), Norway spruce (*Picea abies*, 24%), birch (*Betula* spp; 12%), other broad leaved trees 7%. The other broadleaved trees mainly consist of oak (*Quercus robur*), aspen (*Populus tremula*), rowan (*Sorbus aucuparia*) and willows (*Salix* spp) (Sveaskog 2009). The site quality and forest production is varied dependent of the topography. There are both fertile and barren soils present, where the fertile soils are dominated by Norway spruce and different deciduous trees, the barren soils often more dominated by Scots pine. The mean wood volume production in the area is 5-6 m^3sk/ha/year. The major revenue from the area comes from forestry and to some extent also sports hunting (Sören Pedersen, Sveaskog, pers. comm.).

Period of vegetative growth (days with a mean temperature exceeding 5˚ C) in this area starts in the middle of April and continues until the end of October (Wastenson *et al* 1990; Ottosson Löfvenius and Perttu 2006).

The area holds high densities of large herbivores. Five ungulate species are found within the Misterhult area (Månsson *et al* 2008; Roberge *et al* 2009; Nilsson 2009; Lidberg 2011) and have been estimated to the following winter densities by pellet group counts in a study conducted in April 2008; moose (*Alces alces*) 17.8±1.3/10 km^2 (±SD), roe deer (*Capreolus capreolus*) and fallow deer (*Dama dama*) 141.3±22.7/10 km^2, red deer (*Cervus elaphus*) 4.4±1.0/10 km^2, and wild boar (*Sus scrofa*). Svensk Naturförvaltning AB conducted a faecal count in 2007 estimated the densities of wild boar to 3.4-6.7 /10 km^2. In addition to the large herbivores, the European hare *(Lepus europaeus*) is abundant in the area.

During the hunting season 2009/2010 in the area, 20 moose (2 moose below license), 5 red deer, 7 fallow deer, about 45 roe deer and about 100 wild boar were harvested (Kent Nilsson, 2009, pers. comm.).

Assessment of biomass on clover gamefields
To be able to study of clover as a gamefield crop, eight clover fields where the size ranges between 1700-11000 m^2 have been evaluated (Fig. 1) during April to November 2009. The clover fields were distributed over the study area. In all of the gamefields, a gamefield-mixture containing several different herbs, grasses and legumes were used. The gamefield-mixture, called "Jägarblandning Extensiv" is provided by the company Skånefrö AB and is composed with 20% Red fescue (*Festuca rubra*), 13% White mustard (*Sinapis alba*), 13% Meadow fescue (*Festuca pratensis*), 12% Timothy-grass (*Phleum pratense*), 10% Ryegrass (*Lolium spp.*), 10% Phacelia (*Phacelia tanacetifolia*), 8% Alfalfa (*Medicago sativa*), **5% Red clover** (*Trifolium pratense*), **5% White clover** (*Trifolium repens*), 4% Chicory (*Cichorium intybus*). Red clover and White clover are hereafter together referred to as "clover". All species not recognized as clover are hereafter referred to as "weeds".

Thirty four exclosures, each 1.6x1.6 m, were randomly distributed on the eight clover fields to exclude grazing by large herbivores. Twenty of the 34 exclosures were placed on five clover fields that had been sowed in May one year before the study (2008). Fourteen of the 34 exclosures were placed on clover fields that had been sown in June the same year the study was conducted (2009). The original plan was to have 20 exclosures on five newly sown fields, but due to bad weather conditions with much precipitation, there were only three fields available. The number of exclosures at each game field was dependent of the size of the game field and ranged from 2-7 per game field.

The game fields were fertilized with manure with a quantity of 20 tonnes/ha spreading 30 kg of nitrogen per ha before, or in case of very wet soil conditions, right after ploughing.

Assessments of biomass were conducted during three occasions in 2009: June 10-18th, August 27th- September 28th and October 26th- November 5th. During the vegetation period, the clover fields sown 2008 were trimmed down two times in order to sustain clover flowering and to suppress weed-growth. Fields sown 2009 were not trimmed due to late establishment. To get as accurate estimations of biomass production as possible, the surveys were conducted immediately before each of the trimmings. To be able to study utilization of the crop an unfenced control sample plot was pair-wise linked to each exclosure. The unfenced control plot was placed five metres northwards from the northwesternmost corner of the exclosure. In both the exclosure and control plot average height of the clover was estimated before collecting the biomass within. All of the above ground biomass was collected and sorted into weeds and clover. The total fresh biomass was weighed on scales to nearest gram. To assess the dry matter quotas, samples of 500 grams were collected from clover and weeds both from within the exclosures and in the unfenced plots. If the samples contained less than 500 grams, the available biomass was collected. The clover and weeds were dried separately until constant weight was confirmed before the final weighing.

Browsing pressure on forests adjacent to the gamefields

To evaluate the summer browsing pressure in relation to distance from the gamefields, the survey was planned and conducted at the end of September 2009. The intention was to execute it before frost and leaf fall, but in this case there had been a couple of early frost nights. Transects of a total distance of 500 meters were distributed from the most northern, southern, eastern and western edge of each of the eight gamefields. If lakes, wetlands or other game fields were coming across the transect it was excluded. Pairwise sample plots of 20 m^2 each were then distributed along the transects at each of the distances 0, 50, 100, 200, 300, 400, 500 meters (Fig. 1). Determining the distances was facilitated by a handheld GPS. The first sample plot on the transects was taken at the edge-zone between gamefield and forest, defined as the first tree or shrub next to the game field. The border of the sample plot closest to the game field included all twigs of the tree or shrub closest to the field. The first plot was always placed on the transect while the second was placed 20 m to the left of the transect. The mean value of the two paired sample plots was used in the statistical analyses to avoid pseudo-replication.

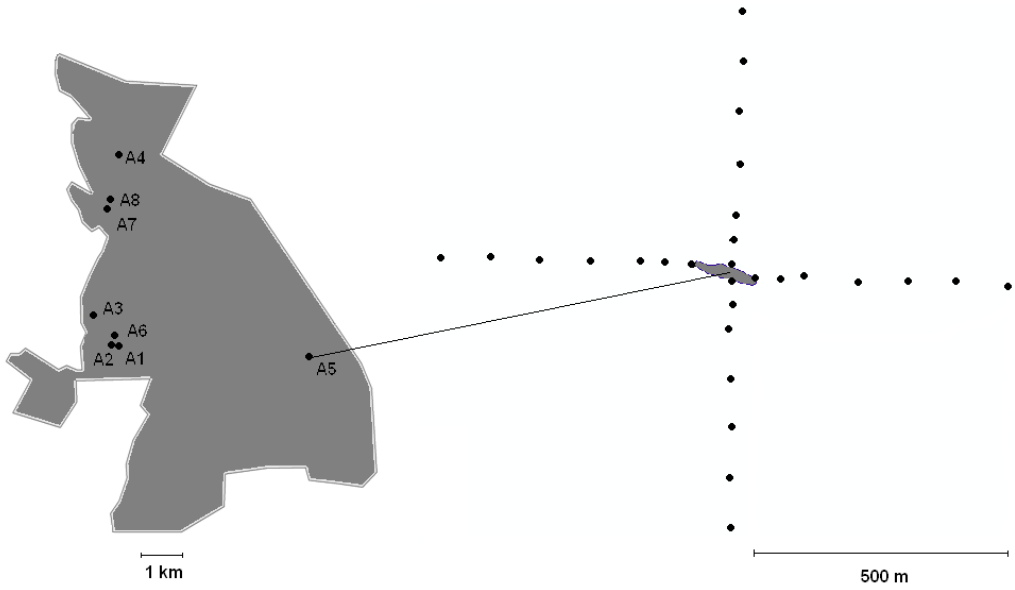

Figure 1. Overview of the study area where clover fields A1-A8 are pointed out. Clover fields A1-A5 were sown 2008, whilst A6-A8 were sown 2009. Gamefield with four 500 m transects and sample plots at each distance on the transect.

In each sample plot the total number of trees, number of trees with bites, number of trees with stripped leaves and the number of trees with both stripped leaves and bites were counted. The assessments were conducted for silver birch (*Betula pendula*), downy birch (*Betula pubescens*), rowan (*Sorbus aucuparia*), aspen (*Populus tremula*), penduncculate oak (*Quercus robur*), linden (*Tilia cordata*), maple (*Acer platanoides*), ash (*Fraxinus excelsior*), hazel (*Corylus avellana*), willows (*Salix* spp), alder buckthorn (*Frangula alnus*) and blackthorn (*Prunus spinosa*). Only trees with leaves within the height interval of 0.5-2.5 m were included. The different tree species were grouped similar to the previous studies by Nilsson (2009) and Lidberg (2011).

Rooting and soil disturbance by wild boar

Rooting was assessed as a proportion of disturbed ground layer of the area in the survey plots. Only the ground disturbance that could be connected to the rooting behavior of wild boar was assessed. Other disturbances such as human impact or disturbance due to other ungulate behavior, i.e. rutting pits was not taken into consideration. The rooting was measured in the same plots as the browsing pressure.

Observations

In order to be able to assess what species that utilize the gamefields, observations of wildlife were carried out 1 hour at sunrise and 1 hour at sunset each day throughout the fieldwork period. A gamefield was not visited two days in a row. Most of the gamefields had one or more hunting towers in close vicinity which facilitated the observations. To minimize disturbance to wildlife, the wind direction was always taken into account when approaching the gamefields. During the observation, number of individuals of each utilizing species was noted.

Statistical analyses

Paired t-test was used to statistically test if there were any differences:

1) In available biomass of clover and weeds between the exclosures and the unfenced control plots,
2) In clover height between the exclosures and the unfenced control plots.
3) between gamefields sown 2008 and 2009.

One-way ANOVA analyses were used to statistically test differences in:

1) available biomass of clover and weeds in June, August and October
2) browsing intensity patterns in relation to distance from the gamefields.

The browsing pressure is expressed as a proportion of browsed and stripped trees and to avoid problems with non-normality the variable was arcsine-transformed (Krebs 1999). The analyses were executed in SAS statistical program JMP.

Results

Assessment of biomass on game fields

On gamefields sown year 2008, the mean available biomass (fresh weight) of clover within the exclosures was (±SE) 668±94 g/m² in June, 820±80 g/m² in August and 21±6 g/m² in October. The corresponding figures for clover biomass in the unfenced plots were 453±111 g/m² in June, 391±39 g/m² in August and 12±3 g/m² in October.

On gamefields sown 2009, the available biomass of clover was assessed in October and was found to be 85±11 g/m² mean dry weight in the exclosures and 7±1 g/m² in the unfenced plots (dry weight).

The available dry biomass of clover in the game fields sown 2008 differed significantly between the exclosures and the unfenced plots in June (paired t-test; t=2.56, p=0.019, df=19), August (t=6.11, p<0.0001, df=19) and October (t=2.47, p=0.023, df=19)(Fig. 2-3, Table 1). The available dry biomass of weeds on the game fields sown 2008 showed significant differences between exclosures and unfenced plots in August (t=3.25, p=0.0042, df=19), whilst there were no significant differences found in June (t=1.4, p=0.17, df=19) or October (t=0.61, p=0.54, df=19; Table 1). Furthermore, the height of clover within exclosures and unfenced plots differed significantly (June: t=6.5, p<0.0001, df=10; August: t=16.35, p<0.0001, df=19; October: t=8.95, p<0.0001, df=19; Table 2).

For the game fields sown 2009, both the available biomass of clover and weeds (dry weight) differed significantly between the exclosures and the control plots (clover; t=7.08, p<0.0001, df=13; weeds; t=8.65, p<0.0001, df=13). There was also significant differences regarding height of clover (t=8.32, p<0.0001, df=13; Fig. 4, Table 2).

Table 1. Mean dry matter quotas for clover and weeds in exclosures and in the unfenced control plots for gamefields sown 2008 and 2009.

		Exclosures		**Unfenced**	
		Clover	Weeds	Clover	Weeds
2008	June	16%	24%	16%	26%
	August	23%	27%	19%	29%
	October	20%	25%	20%	27%
2009	October	19%	17%	18%	15%

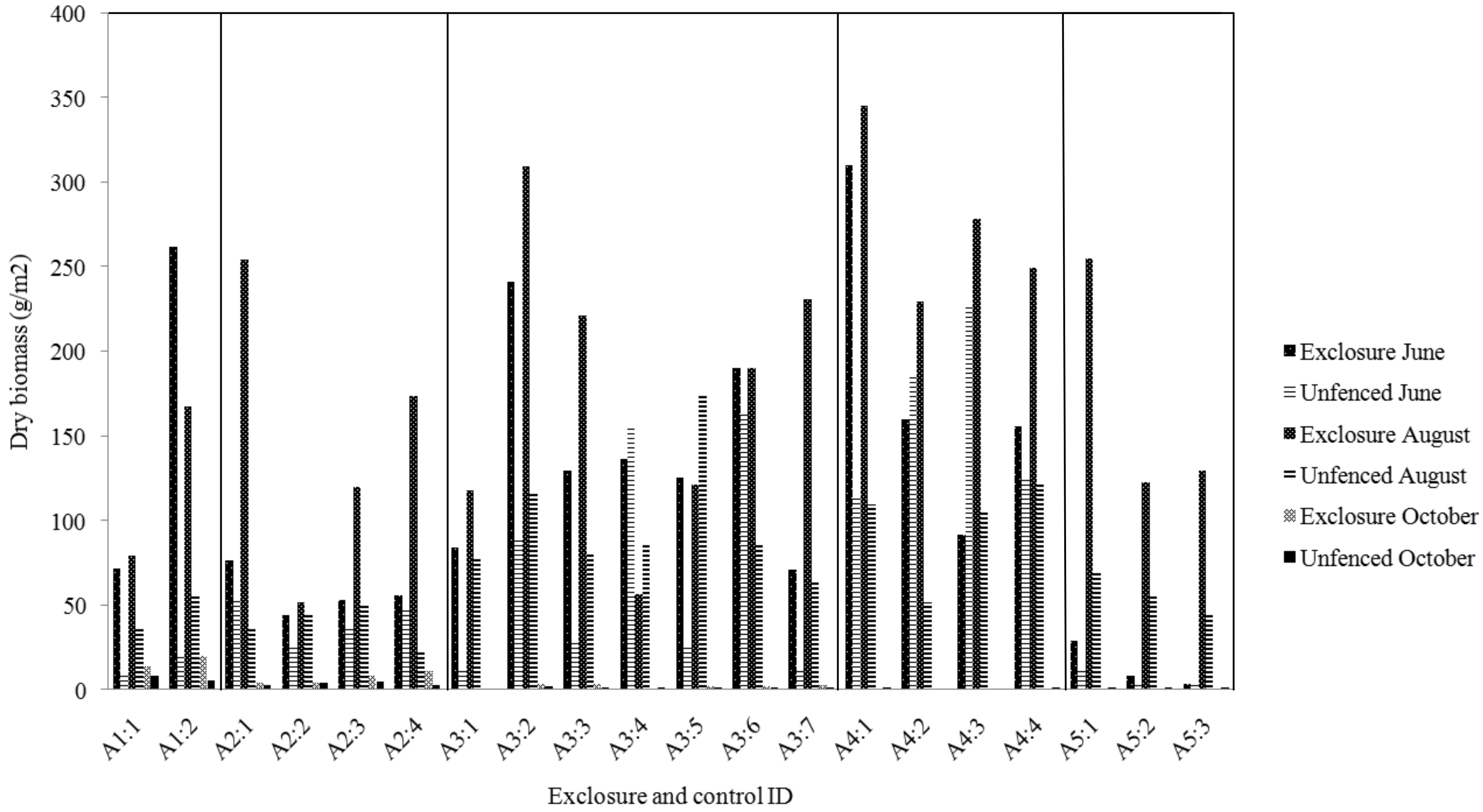

Figure 2. Dry biomass (g/m²) of clover in exclosures and unfenced control plots on game fields sown 2008, assessed in June, August and late October. The x-axis represents the exclosure and unfenced plot identity number at game fields A1-A5 (Fig1).

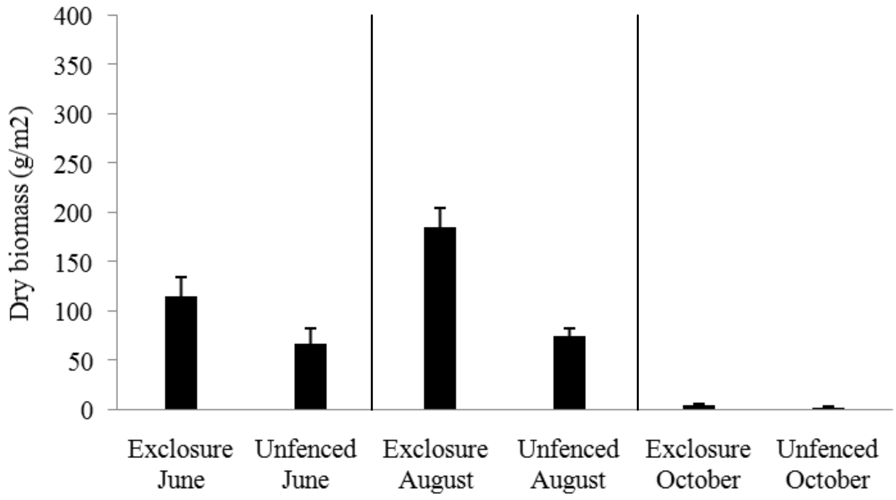

Figure 3.Mean (±SE) dry biomass production of clover (g/m²) on game fields sown 2008 assessed in June (n=20), August (n=20) and October (n=20).

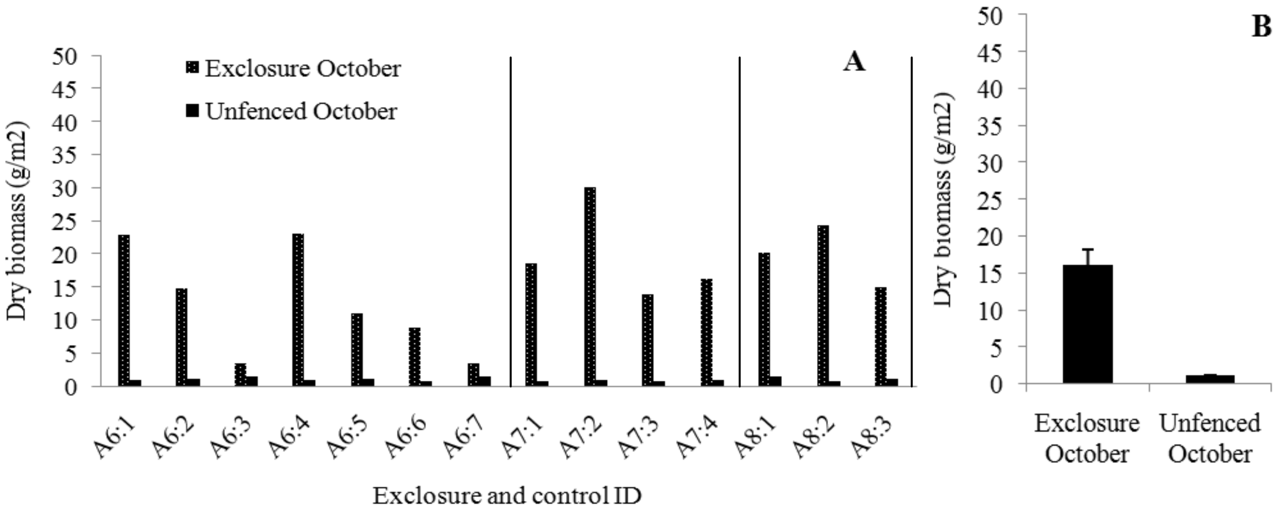

Figure 4.(A) Dry biomass (g/m²) of clover in exclosures and unfenced plots on game fields sown 2009, assessed in late October. The x-axis represents the exclosure and unfenced plot identity number at game fields A6-A8 (Fig1). (B) Mean (±SE) dry biomass production of clover (g/m²) on the game fields sown 2009, assessed in late October (n=14)

The available biomass (dry weight) of clover within the exclosures differed significantly between June, August and October (ANOVA; $F=34.9$, $p<0.0001$, $df=2$). On game fields sown 2008, the available dry biomass of clover within the exclosures peaked in August i.e. significantly higher in August compared to both June (Tukey's HSD; $p=0.0059$) and October ($p<0.0001$) (Fig 2-3, Table 2a).

No clear peak was found for the available dry biomass of clover within the unfenced plots, although October differed from both June and August (ANOVA; $F=15.4$, $p<0.001$, $df=2$).June and August did not differ (Tukey's HSD; $p=0.88$) while a higher availability was found in August compared to October ($p<0.0001$; Fig 2-3, Table 2a).

Regarding the available biomass of weed within the exclosures, there were differences between June, August and October (ANOVA; F=56.5, p<0.0001, df=2), however no significant difference was found between June and August (Tukey's HSD; p=0.287) but still between August and October (p<0.0001), where the weed biomass was significantly higher in August. In the unfenced plots there was a clear peak in August, with significantly higher biomass (dry weight) of weeds compared to both June (p=0.0211) and October (p<0.0001) (Table 2a).

Table 2a. Mean (± SE) biomass production dry weight (g/m²) of clover and weeds and height (cm) of clover in exclosures and unfenced plots on game fields sown 2008**.** P-values for each evaluation specified.

Game fields sown 2008	**Clover**					**Weeds**				
June	Mean	S.E	Max	Min	n	Mean	S.E	Max	Min	n
Biomass exclosures	115	19	310	4	20	484	39	953	256	20
Biomass unfenced	67	16	226	3	20	429	37	771	175	20
p-value biomass	**0,019**					**0,17**				
Height exclosures	49	4	68	32	11					
Height unfenced	36	3	57	20	11					
p-value height	**<0,001**									
August										
Biomass exclosures	185	19	345	52	20	423	27	631	250	20
Biomass unfenced	74	8	175	23	20	551	38	1021	323	20
p-value biomass	**<0,001**					**0,0042**				
Height exclosures	45	1	56	35	20					
Height unfenced	25	1	30	18	20					
p-value height	**<0,001**									
October										
Biomass exclosures	4	1	20	1	20	90	12	215	30	20
Biomass unfenced	2	0	8	1	20	86	13	185	8	20
p-value biomass	**0,023**					**0,54**				
Height exclosures	13	1	17	9	20					
Height unfenced	7	0	10	4	20					
p-value height	**<0,001**									

Table 2b.Mean (± S.E) dry biomass production (g/m²) of clover and weeds and height (cm) of clover in exclosures and unfenced plots on gamefields sown 2009.

Game fields sown 2009	**Clover**					**Weeds**				
October	Mean	S.E	Max	Min	n	Mean	S.E	Max	Min	n
Biomass exclosures	16	2	30	3	14	160	17	243	25	14
Biomass unfenced	1	0	2	1	14	17	3	34	6	14
p-value biomass	**<0,001**					**<0,001**				
Height exclosures	20	1	23	15	14					
Height unfenced	10	1	15	5	14					
p-value height	**<0,001**									

In gamefields sown 2009 there was significant differences in dry biomass, both clover and weeds, within the exclosures and biomass from the unfenced plots (Table 2b). In addition, the height of clover was significantly higher within the exclosures (Table 2b).

The dry biomass production of both clover and weeds during the whole vegetation period (April-November) differed significantly between gamefields sown 2008 and 2009 (Table 3).

Table 3. Total mean dry biomass production (g/m²) of clover and weeds during the whole vegetation period.

Year of gamefield establishment	**2008**		**2009**	
Plots	Exclosures	Unfenced	Exclosures	Unfenced
Mean total dryweight of clover	304	144	16	1
-Minimum weight	*100*	*48*	*30*	*2*
-Maximum weight	*656*	*331*	*3*	*1*
Mean total dryweight of weeds	996	1066	160	17
-Minimum weight	*654*	*643*	*243*	*34*
-Maximum weight	*1643*	*1787*	*25*	*6*
Mean total dryweight of clover and weeds	**1300**	**1210**	**176**	**18**
-Minimum weight	*819*	*707*	*28*	*7*
-Maximum weight	*1713*	*2038*	*268*	*35*

Deciduous tree species occurrence and browsing distribution

The proportion of deciduous trees and bushes with bites, leaf strips or both ranged from 0.52 (linden) to 0.99 (blackthorn) depending on species (Fig 5). Trees and bushes with both bites and leaf strips ranged from 0.24 (maple) to 0.83 (willows). Furthermore, trees with only leaf strips ranged from 0.04 (willows and blackthorn) to 0.27 (maple), whereas trees with only bites ranged from 0 (aspen, linden and ash) to 0.13 (blackthorn) (Fig. 5) The overall trend is that willows, aspen, rowan and blackthorn are the most browsed species while intermediate browsing occurred on alder buckthorn, hazel, ash and penduncculate oak. Silver birch, downy birch, linden and maple, were the species with lowest total browsing pressure (i.e. proportion of trees with bites, leaf strips or both; Fig. 5).

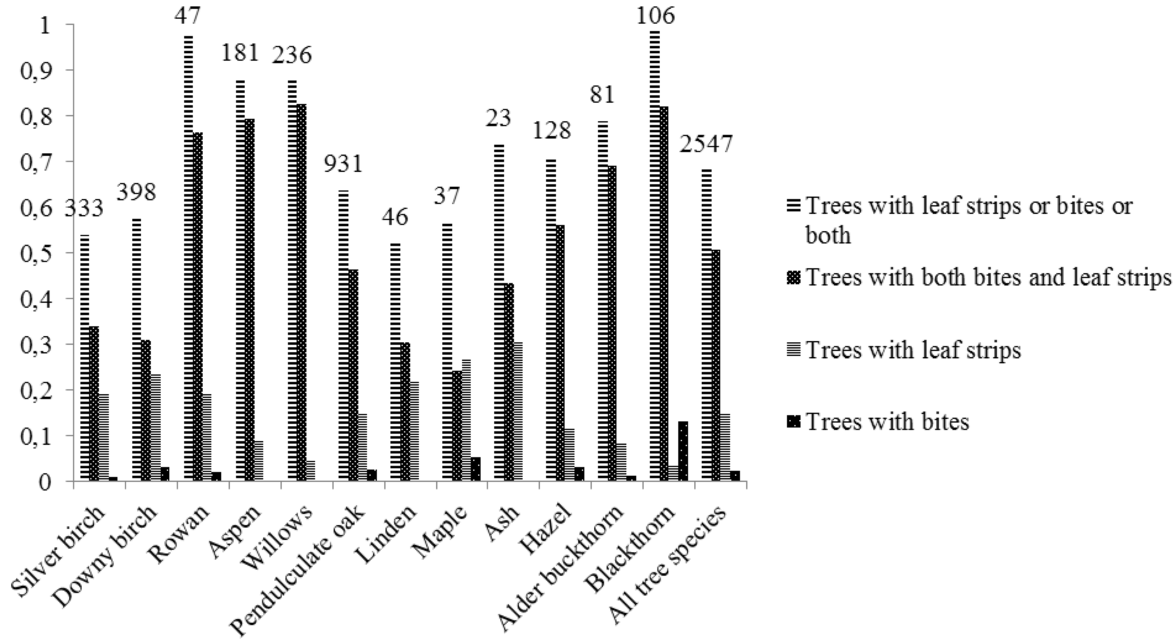

Figure 5. Proportion (mean) of browsing (i.e. proportion of trees with bites, leaf strips or both) on the different tree species. The total number of surveyed trees (sample size) is given for each species above the columns.

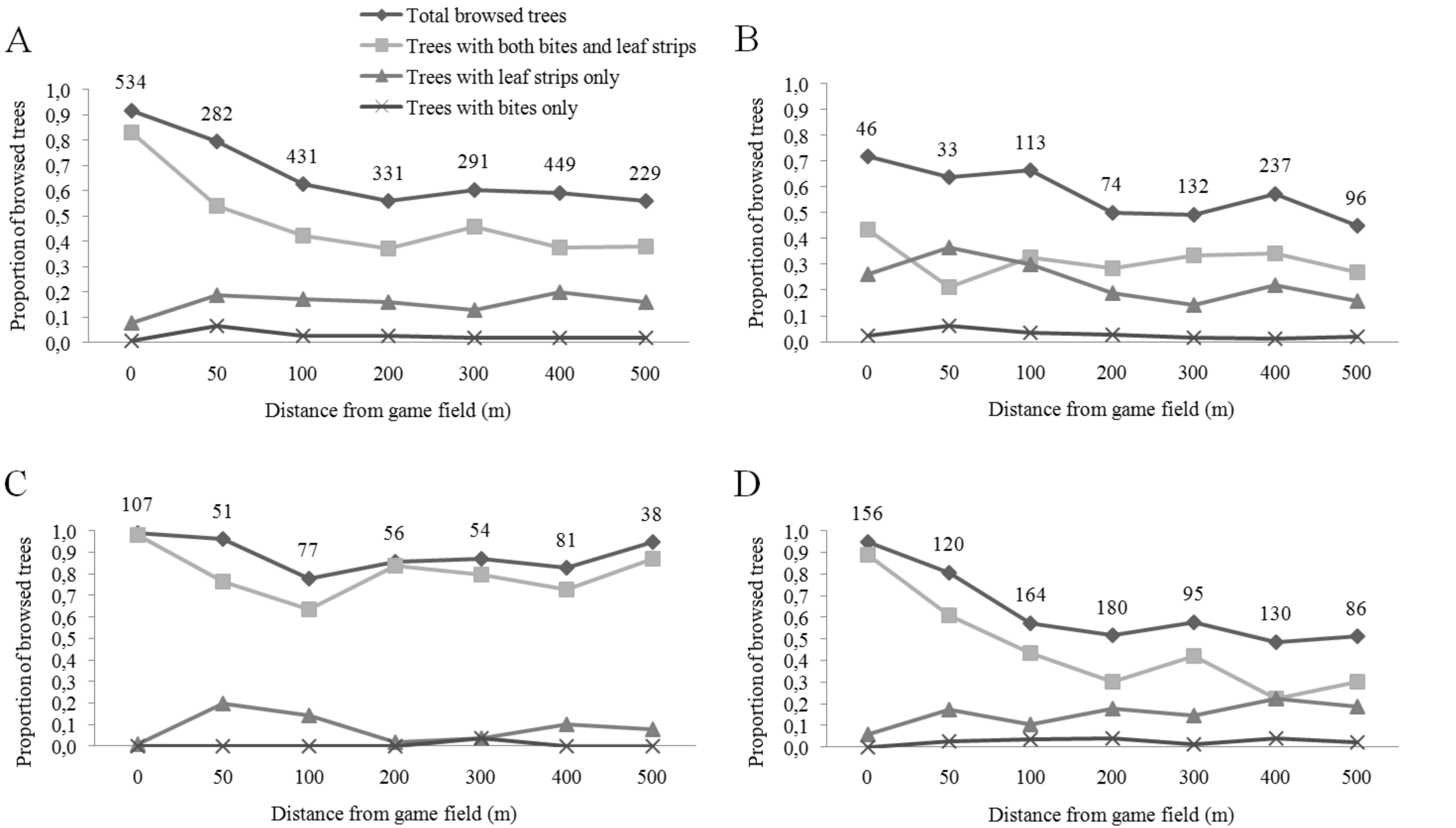

Figure 6. Average proportion of browsing on trees and bushes in relation to distance from game fields**. A)** all surveyed tree species, see method, **B)** silver birch and downy birch, **C)** rowan, aspen and willows, **D)** penduncalate oak. The number of trees surveyed from each tree group are given at each distance.

The general browsing trend show higher browsing intensity in the edge zone (0 m) compared to all other distances from the game fields for all groups of trees (Fig. 6). The occurrence of deciduous trees varied with the distance to the gamefield; all groups except group B (silver birch and downy birch) were more frequent closer to the gamefields (Fig 6).

ANOVA´s showed significant differences in proportion of browsed trees between the distances for group A (F= 11.01, p<0.0001, df=6) and D (F=4,99, p<0,0001, df=6) but not for the other groups of tree species, where no such differences could be found.

Rooting by wild boar

The assessment of the proportion of rooting by wild boar (*Sus scrofa*) ranged from 0 – 45% between the survey plots. However, the average proportion of rooting in the survey plots revealed no significant differences among the different distances from the gamefields (Fig.7).

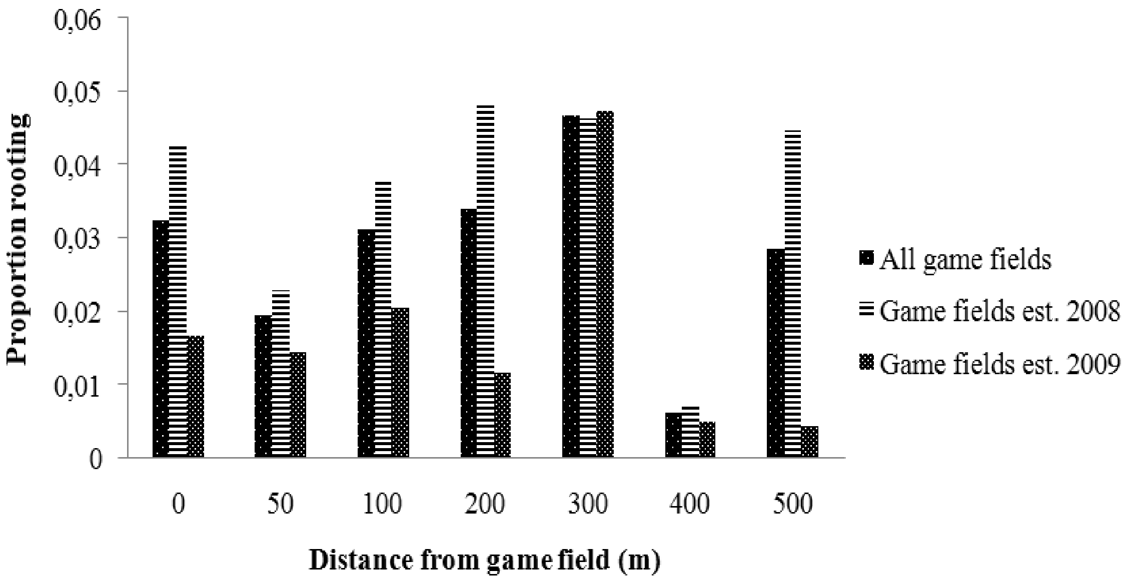

Figure 7. Proportion of rooting by wild boar *(Sus scrofa)* at each given distance from the gamefields.

Observations

The gamefields were observed during dusk and dawn for 31 days. This resulted in 60 hours of observation time where in total 291 animals were sighted. Roe deer was the most sighted species on the gamefields, followed by hare. Wild boar represented in 20% of the sighted animals, but only during 22 occasions, which means that they were sighted in larger numbers, i.e. family groups, more often than any of the other sighted animals (Fig. 8).

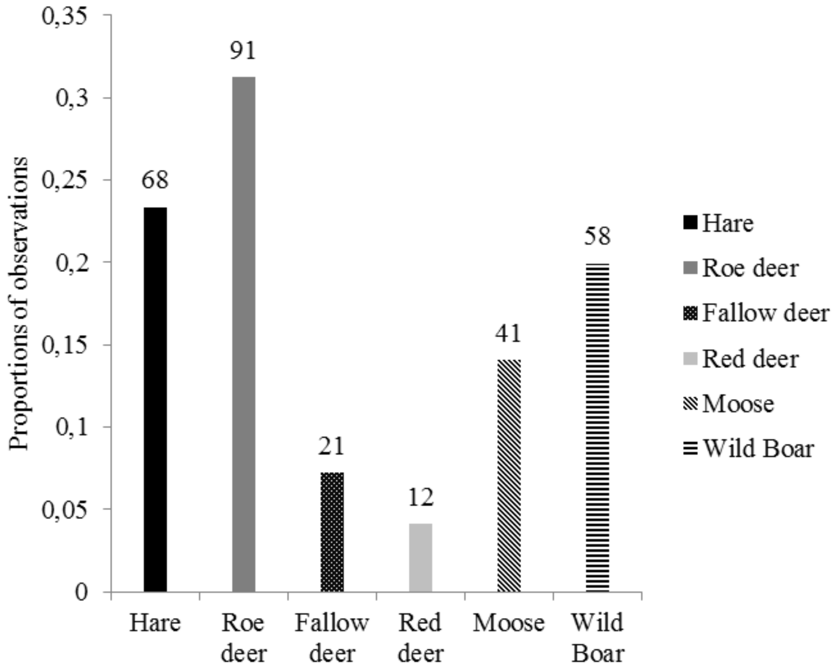

Figure 8. Proportion of total number of animal sightings of the different species utilizing the game fields during the observation occasions. Number of observed animals above each column.

Discussion

Gamefield production

The biomass of clover and supportive weeds within the exclosures was found to be significantly higher than in the unfenced control plots. That relation complies with both fresh and dry weight of clover, weeds and clover and weeds all together. This indicates that the gamefields that were subjected to a high utilization by herbivores. Since there were significant differences in clover biomass found in all of the June, August and October studies we can conclude that the utilization of the gamefields stretches over most of the vegetation period. The significant differences found in the height of clover also indicate that the clover is extensively grazed throughout the vegetation period. The differences apply to gamefields sown both 2008 and 2009. Furthermore, as the production on gamefields sown 2008 peaked during August, the production on gamefields sown 2009 had just about initialized due to much precipitation and bad planting conditions. Trimmings on the gamefields sown 2008 might have had negative effects on the potential biomass production due to soil compaction. On the other hand, the trimmings contribute to earlier and extensive flowering of clover as well as repression of weed growth (Evans *et al* 1998).

Additional differences were found between exclosures and control plots during the field work that were not recorded or measured quantitatively during this study, such as differences in foliage and clover stems, weed composition and edge-zone effects in the exclosures. It appeared that the vegetation, and clover in particular, inside the exclosures seemed to grow larger foliage and thicker stems when not subjected to browsing pressure. As the unbrowsed clover quickly became dominant inside the exclosure, several of the natural and/or planted weedspecies seemed to be suppressed. Since all the gamefields in the study differed from each other in terms of both biotic and abiotic conditions, there were various differences in biomass production between the gamefields.

The biomass production of clover and weeds can be compared to previous year's studies on marrow stem kale (Nilsson 2009) and rapeseed (Lidberg 2011). Both marrow stem kale and rapeseed are annuals but have shown great potential in mean biomass production: marrow-stem kale 1900 kg dry weight per hectare (Nilsson 2009) and rapeseed 4020 kg dry weight per hectare (Lidberg 2011). Mean biomass production on one-year old clover gamefields was 3040 kg dry weight per hectare and varied from 1000 kg to 6560 kg per hectare. The fields sown 2009 however showed poor production of clover, between 30 kg to 300 kg per hectare, with a mean production of 160 kg per hectare.

However, the current gamefield crop also contained a big proportion of weeds and herbs and since wildlife utilized both clover and weeds to some extent, all of the biomass should be taken into account. For the fields sown 2008, the mean total dry biomass production was 13000 kg per hectare. Gamefields sown 2009 produced 1760 kg dryweight clover and weeds per hectare in total. In addition, the perennial clover-mixture provides forage to some extent throughout winter and spring although this requires plowing to make the crops available during snowy winters.

Clover as a gamefield crop has big potential. Together with the supportive grasses, weeds and herbs in a gamefield-mix, as used in these trials, the advantages of clover can be even greater. Soils that are sensitive to drying or have deficient structure can benefit from taproots that are provided from red clover (*Trifolium pretense*) especially (Hall 2008). Gamefields sown with clover or other crops rich with herbs and flowers also provide other benefits for both wildlife and the ecosystem because of the legumes nitrogen binding abilities (McVay *et al* 1989; Hall 2008). Since clover pastures are trimmed during the vegetative period, harvest yields can provide supplementary forage during winter. Other benefits such as shelter for smaller game can be taken into account whereas the supportive grasses and weeds make the clover substantially higher, mean height in June was measured to exceed 48 cm in gamefields sown 2008.

Browsing pressure on adjacent forest
The study showed variations in magnitude of browsing damages to the different deciduous trees. The study also revealed differences of occurrence of the tree species in relation to distance to the gamefields. Similar to previous studies by Nilsson (2009) and Lidberg (2011) this study has shown that there are distinct edge-zone effects.

The grouping was motivated by large herbivore preferences (Månsson *et al* 2007; Nilsson 2009; Lidberg 2011). Rowan, aspen and willows followed by oak and the two birch species (Van Hess *et al* 1996) are found to be preferred by moose, roe deer and red deer. Therefore, the less preferred downy birch and silver birch formed group B, rowan, aspen and willows formed group C and pendunculate oak formed group D. Group A contain all surveyed species together.

Rowan, aspen and willows (group C, Fig. 6) were subjected to a high browsing pressure, no matter where in the landscape they were located. This is in accordance with previous knowledge about the preference of ungulates for those species (Bergström & Hjeljord 1987; Baskin & Danell 2003; Edenius *et al* 2004; Månsson *et al*. 2007). Also the magnitude of the browsing damages comprised both leaf strips and bites regardless of distance to the gamefields. The occurrence of rowan, aspen and willows are generally more common in the field margins than farther into the woods.

Pendunculate oak (group D, Fig. 6) is very attractive to ungulates. Oaks residing in the edge zones are subjected to a high browsing pressure. Almost all of the surveyed oaks in close vicinity to the gamefields were browsed, and also they were browsed heavily. The occurrence of oak decreased slightly with increasing distance to the game field. Increasing canopy cover with increasing distance to the game field may be an explanation for the declining occurrence However, unlike the previous studies this study points at a slightly decreasing browsing pressure further away from the gamefields.

Silver birch and downy birch (Group B, Fig. 6) show relatively small differences of occurrence at the different distances. Evaluating the magnitude of damages to the trees reveals a lower browsing pressure and a smaller magnitude of the browsing damages.

Most game chose to reside in the edge-zone before they graze the gamefield (Ball *et al* 2000; Gundersen *et al* 2004). Both the gamefield and the border zone may attract wildlife to forage. The trend for all tree species together showed a clear edge zone effect both regarding the tree species found and the browsing pressure. Since the clover gamefields creates an attractive forage, it can be applicated as an effective management tool to redistribute large herbivores from sensitive plantations. Consequently, gamefields with clover might decrease browsing damages seen in a landscape perspective (Gill 1992a; Gundersen *et al*. 2004; Cooper 2006; Nilsson 2009; Lidberg 2011)

Wildlife observations

Similar to the observations by Nilsson (2009) and Lidberg (2011), the most frequent visitor to the gamefields were roe deer, followed by hare. Hare was included in the study since it utilizes the gamefields to a great extent. The relatively low height of clover, compared to previous studies on marrow-stem kale and rapeseed, also made it possible to spot hare during the observations. The third most frequent visitor was wildboar, though the number of occasions spotted was low, the number of individuals was high. This is probably due to the fact that wildboars often move and search for forage in family-groups, often a sow with several piglets. The gamefields were also utilized by moose, fallow deer and red deer. Perhaps the larger herbivores would have been observed more frequently if the study had been stretched over the darker hours, i.e 1 hour before and after dusk and dawn.

Management implications

In order to maximize the benefits of the efforts establishing and maintaining a gamefield, it is crucial that the landowner or other stakeholders cooperate. Establishing a gamefield in an area that already holds substantial amounts of forage, a varied forest-landscape with year-around available forage and rich soils might not be the best suitable solution economically. Addressing the proper questions whether there is a problem or not, high or low ungulate densities, traffic incidents, damages to agri- and silvicultural plantations are basic for an elaborate management plan. Furthermore, clarifying the existing and lacking resources in a wider perspective, the landscape perspective can be of great benefit reaching the goal of the ungulate management. If the goal is to reduce browsing pressure to sensitive Pine plantations, then it might not be a such a good idea establishing a gamefield in close vicinity. A more proper placement would be to place the gamefields within forests with canopy cover, thus producing forage in an otherwise forage-scarce environment. In addition, gamefields placed with natural habitat and/or migration routes taken into consideration in combination with other management tools, such as utilizing the residues after thinning, supplemental feeding during winter, providing fresh water and shelter might have an even greater impact (Ball *et al* 2000; Heikkilä & Härkönen 2000; Gundersen *et al* 2004; Kramer et al 2006; Månsson *et al* 2008; Roberge *et al* 2009).

Further studies

This study is the last of three field assessments of biomass production on gamefields and browsing on adjacent forests. In all of the studies there was found high utilization of the biomass and clear edgezone-effects to the surrounding forests. Questions regarding whether the higher browsing intensity in the edge-zones was due to the gamefields or subjected to the fact that there was an edge between forest and field (Cadenasso & Pickett 2000; Thurfjell *et al* 2009) has arisen. To be able to study this relationship closer and to properly assess the effect of gamefields, other edgezones should be evaluated. For example edges towards roads, other fields, powergrid clearings could be evaluated.

Since the transect setup that have been used in these studies are conducted in a small-grained and varied landscape, as it usually occurs in southern Sweden, it would have been interesting to use shorter transects with more sample plots, thus avoiding the problems of having to exclude transects.

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