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Produktion av fodermärgkål och klövviltets utnyttjande av viltåker och omgivande skog

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Forage production and summer use by ungulates on game fields and surrounding areas

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Keywords: browsing, damage, game fields, forage availability, ungulates

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Swedish summary

Klövdjur kan genom betning påverka vegetationsstrukturer, biologisk mångfald, växtsammansättning och ekosystemprocesser. Detta leder i sin tur till att människans nyttjande av olika naturresurser påverkas. Bete på ekonomiskt värdefulla trädslag av framförallt älg leder till nedsatt virkeskvalitet och reducerade ekonomiska vinster i skogsnäringen. Samtidigt vill jägarkåren behålla höga viltstammar för jakt. Klövviltets rörelsemönster är starkt korrelerat med förekomst och kvalitet av foder. Tidigare studier har visat att man kan påverka klövviltets rörelse- och betesmönster genom att förse klövviltet med högkvalitativt foder liksom att betestrycket på skogen är beroende av mängden tillgängligt foder. Därmed skulle betestrycket kunna minskas på landskapsnivå genom att skapa mer tillgängligt foder. Därigenom skulle man kunna mildra konflikten mellan olika intressegrupper.

Ett sätt att skapa högkvalitativt foder är att odla för viltet attraktiva grödor på viltåkrar. Viltåkrar är vanligt förekommande i södra Sverige och ett högt utnyttjande av klövvilt har påvisats. Trots detta är kunskapen om foderproduktionen och utnyttjandet av viltåkrar mycket begränsad.

Syftet med den här studien har varit att utvärdera den potentiella produktionen av fodermärgkål (*Brassica oleracea var. medullosa*), hur mycket som utnyttjas, vilka viltarter som utnyttjar grödan samt hur betestrycket på omkringliggande skog påverkas av viltåkrar.

Studien genomfördes från maj till november 2008 på Sveaskogs kronojaktsområde i Misterhult, Sverige (57˚ 27´ N, 16˚ 32´ E). Fem klövviltsarter förekommer i studieområdet; älg, rådjur, kronhjort, dovhjort och vildsvin. I området finns även skogs- och fälthare. I studien ingick nio viltåkrar med fodermärgkål. På dessa placerades totalt 30 hägn (1,6x1,6m) för att skapa ytor som var opåverkade av bete. En kontrollyta placerades 5 meter från varje hägn för att kunna jämföra produktion av biomassa och hur mycket som betats. All ovanjordisk biomassa klipptes och vägdes och medelhöjd mättes. Halva hägnet klipptes i september och andra halvan i november för att kunna jämföra produktionen under sensommar och senhöst. Totalt genomfördes också cirka 20 observationstimmar i gryning och skymning vid viltåkrarna för att studera vilka klövviltsarter som utnyttjade viltåkrarna. För att undersöka betningseffekter på intilliggande skog under sommarperioden lades 500 m långa transekter ut i de fyra väderstrecken. Detta gjordes på åtta viltåkrar med fodermärgkål och fem viltåkrar med klöver. Provytor (20 m²) lades ut på olika avstånd (0, 50, 100, 200, 300, 400 och 500 m) från viltåkrarna. Transekternas första punkt placerades i den mest nordliga, västliga, ostliga och sydliga brynzonen (d.v.s. 0 m). Totala antalet träd, samt antalet träd med bett respektive lövrepning inventerades. Trädarterna som inventerades var vårtbjörk, glasbjörk, asp, rönn, ek, sälg och brakved.

Biomassaproduktionen av fodermärgkål på viltåkrarna var hög. Medelvärdet var 1900 kg/ha (torrvikt) i september, vilket ökade med 74 % till 3320 kg/ha till november. Detta visar på stor potential i foderproduktion jämfört med vegetationstyper som t.ex. salixplanteringar (upp till 1200 kg/ha) och tallungskogar (cirka 500 kg/ha). Utnyttjandet av fodermärgkålen var högt, med tydligt signifikanta skillnader ($p<0.05$) i mängd biomassa och höjd mellan hägn och kontrollytor både i september och i november. Totalt 52 observationer av vilt gjordes på viltåkrarna, vilket är för få för att dra några säkra slutsatser, men rådjur var den art som mest frekvent sågs på viltåkrarna följt av hare.

Studien på betesintensiteten på intilliggande skog visade en generell trend av högre betestryck i kantzonen mellan viltåker och skog jämfört med större avstånd in i skogen. Dessa resultat kunde inte stödjas statistiskt för alla trädarter, vilket troligen beror på stor variation i landskapet samt att provstorleken är något knapp. Den höga produktionen av fodermärgkål på viltåkrarna, det höga utnyttjandet och det höga betestrycket i kantzonerna indikerar att viltåkrarna kan fungera som förvaltningsåtgärd för att koncentrera klövviltets födosök till viltåkrarna och brynzonen runt åkrarna och därmed kanske minska betestryck och betesskador på landskapsnivå.

Abstract

Ungulates are causing conflicts between stakeholders due to browsing damage on forests and agricultural crops. At the same time there is a big demand of keeping high ungulate densities for sports hunting and recreational purposes. Movement patterns of ungulates are strongly correlated with forage availability. Therefore, measures affecting forage quantity and distribution might be a tool to reduce the economical losses in forestry without decreasing the ungulate densities and thereby decrease the conflict between different interest groups.

This study investigated the potential biomass production and utilisation of marrow-stem kale (*Brassica oleracea var. medullosa*), at game fields in Misterhult, Sweden, as well as browsing effects on adjacent forests. The study included nine game fields and a total of 30 large herbivore exclosures. The biomass was cut and weight within the exclosures and paired controls in September and November. Transects of 500 m were distributed at four different directions from the fields with sample plots at seven different distances 0 (edge zone), 50, 100, 200, 300, 400 and 500 m from the game fields. In these plots browsing pressure was surveyed to investigate the browsing intensity in surrounding forests.

A great biomass production was found, with mean dry biomass of marrow-stem kale of 1900 kg/0.01 km² in September significantly ($p<0.05$) increasing with 74 % to 3320 kg/0.01 km² in November. The utilisation was intensive, with highly significant differences between exclosure and control plots at the marrow-stem kale fields in both September and November. The observations of large herbivore species utilising the fields were too few to make any firm conclusions, but roe deer was the species most frequently utilising the marrow-stem kale fields.

A general trend with higher browsing intensity in the edge zone (0 m) compared to zones further away from the fields was found. However, this pattern could not be significantly proven in all cases, probably due to the large variation in the landscape in a combination with too few plots.

The biomass production on the game fields and the increased browsing intensity in the edge zone also indicate that game fields may have the potential to redistribute ungulates and decrease browsing intensity at a landscape scale as also found in other studies of supplemental forage.

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Introduction

The large herbivore – forest system

Foraging patterns of ungulates are affected in a complex and dynamic way by a variety of factors (Hett *et al.* 1978; Belovsky 1984; Senft *et al.* 1987; Hörnberg 2001; De Jager & Pastor 2008; Storms *et al.* 2008.) However, one of the main factors affecting foraging pattern is forage availability. Hence movement pattern and distribution of ungulates is strongly correlated with food plant distribution (Fryxell 1991; Gundersen *et al.* 2004). Further, foraging patterns by ungulates can alter ecosystem processes and vegetation structures due to selectivity of habitats, plant species or parts of plants but also by affecting the soil due to trampling and dung (Reimoser & Gossow 1996; Edenius *et al*. 2002). As a consequence, the ungulates also affect the human use of natural resources, such as forests, arable land and wildlife (Gill 1992).

Conflicts between stakeholders

Growing ungulate populations worldwide have lead to conflicts concerning damage caused by browsing and grazing on forests and crops, but also because of effects on biodiversity (Gill 1992; Hörnberg 2001). Browsing by ungulates may cause extensive losses in revenue for the forestry. This is mainly due to decreased quality of the wood following browsing on twigs, leaf stripping and bark peeling on deciduous and coniferous tree species. Further, leaf stripping during the plant growth season may result in a decrease of photosynthetic activity causing reduction in tree vitality and reduction in height and stem diameter growth (Aldous 1952; Bergström & Danell 1995; Miquelle 1983). In contrast to the interests of the forestry, there are great interests in keeping high densities of ungulate species for sports hunting and tourism purposes, also with great socio-economical advantages (Mattson 1990; Gordon *et al.* 2004). The conflicts between different stakeholders may increase when the forestry sector wants to decrease the ungulate densities with the aim to decrease browsing damage and hunters at the same time want to keep high densities for hunting purposes.

Since the distribution of large herbivores is strongly affected by forage availability, the supply, distribution and nutrient content of forage are key factors when managing ungulate populations to integrate social, economical and ecological interests (Gordon *et al*. 2004). Increased supplies of forage lead to a decrease in browsing intensity on productive forest at a given density of ungulates (Cooper *et al.* 2006; Månsson 2007). Further, high-quality forage can be used to redistribute animals within the landscape and therefore reinforce the effect of increased forage by steering animals away from forest stands sensitive to browsing (Gundersen *et al.* 2004). Supplying forage to ungulates might therefore be a management tool to redistribute browsing pressure and thereby decrease browsing intensity on crops and productive forests and still keep densities for good hunting yields.

Alternatives to decrease damage caused by ungulates

A number of management practices, such as hunting, repellents, habitat management and supplemental feeding have been proposed to decrease the risk of damage on forests or agricultural crops. Supplemental feeding has been proved as a management tool to redistribute ungulates and decrease browsing intensity in valuable forest areas without decreasing the density of animals (moose: Gundersen *et al*. 2004, white-tailed deer: Cooper *et al*. 2006). In these studies the animals redistributed and concentrated their activity pattern around feeding stations. Further, the redistribution of moose lead to less browsing pressure on sensitive young Scots pine (*Pinus sylvestris*) stands in the area (Gundersen *et al*. 2004). However, an increased browsing effect on the vegetation close to the feeding stations (<200

m) was evident. Supplemental feeding may in addition to redistribution of ungulates also maintain or increase over winter survival rates, body weight and reproduction success (Cook *et al.* 2004; Putman & Staines 2004), decrease competition (Kramer 2006) and decrease the number of car or train collisions with ungulates (Andreassen *et al*. 2005). Other measures to provide more available forage has also been tested such as growing willow *(Salix spp.)* plantations (Bergström & Guillet 2002), leaving residues from thinning and final felling in pine forest stands (Heikkilä & Härkönen 2000; Skoglund 2006) and managing saplings of deciduous trees along road sides.

Game fields are frequently occurring in the southern parts of Sweden. The aims with the game fields are to create forage to increase the fitness of the ungulates, providing shelter and to redistribute ungulates in the landscape. A variety of crops are used such as marrow-stem kale (*Brassica oleracea* var. *medullosa*), rapeseed (*Brassica napus*) and clover (*Trifolium spp.)* (Jensen 2001). A high utilisation has been observed but a quantitative and objective knowledge of forage production, utilisation by ungulates and effects on adjacent forests are lacking.

Aim
The general aim of this study was to quantify the biomass production and utilisation of forage on game fields with marrow-stem kale as supplemental forage crop. Further, it was tested whether summer browsing on adjacent forest is affected by the presence of game fields.

More specifically addressed questions were:

1. What is the available biomass of marrow-stem kale and weeds on the marrow-stem kale fields in late summer and late autumn?
2. How large part of this biomass is utilised as forage by ungulate species in late summer and late autumn?
3. Which ungulate species are utilising the marrow-stem kale fields and to what extent?
4. Is there any increase in summer browsing on deciduous tree species in adjacent forests due to concentrations of ungulates on the game fields?

Methods

Study area
The study was carried out May till November 2008 in Misterhult (Fig. 1), located in the hemi-boreal zone of south-eastern Sweden (57˚ 27´ N, 16˚ 32´ E). The area is 43 km² and owned by Sveaskog. Forest management and sports hunting stand for the big revenues from the area (Jimmy Petterson, Sveaskog, pers. comm.)

The landscape is small-grained with deciduous forests mixed with coniferous forest stands. The dominating tree species are Scots pine, Norway spruce (*Picea abies*), silver birch (*Betula pendula*), downy birch (*Betula pubescens)* and penduculate oak (*Quercus robur).* Also rowan (*Sorbus aucuparia),* aspen (*Populus tremula),* willows and alder buckthorn (*Frangula alnus)* are frequently occurring. The study area consists of 81 % forest land, 10 % mountain, 4 % mire, 2 % pasture and the rest is arable land, water and other land cover types. The mean patch size for terrestrial habitats (e.g. forest stands, pastures, mire) is 2.1 hectare (Sören Pedersen, pers. comm.). The period of vegetative growth (mean temperature

> 5˚ C) starts in the middle of April and continues until the end of October (Wastenson *et al*. 1990).

Five ungulate species occur in the area, moose (*Alces alces*), roe deer (*Capreolus capreolus*), red deer (*Cervus elaphus*), fallow deer (*Dama dama*) and wild boar (*Sus scrofa*). European hare (*Lepus europaeus*) and mountain hare (*Lepus timidus*) are two other herbivores also occurring in the area. An aerial survey was conducted over a larger area than the actual study area (from Blankaholm in north to Fårbo in south) in February 2007 and the estimated moose density was 9.1±1.3 moose/10 km² (mean±S.E) (Svensk Naturförvaltning AB 2007). Pellet group counts in April 2008 within the study area estimated the densities of deer species to 17.8±1.3 moose/10 km², 4.4±1.0 red deer/10 km² and 141.3±22.7 roe deer/fallow deer/10 km² (the pellet groups were not separated for the two species since they are hard to separate in field; (Månsson unpubl.). Faecal counts conducted by Svensk Naturförvaltning AB in 2007 assessed the densities of wild boars to 3.4-6.7 animals/10 km².

Biomass of marrow-stem kale fields

The study included nine marrow-stem kale fields in a size range of 2000-22000 m², scattered over the study area (Fig. 1). A total of 30 exclosures, each 1.6x1.6 m, were randomly distributed on the marrow-stem kale fields to exclude browsing by ungulate species. The number of exclosures at each game field was dependent of the size of the game field and ranged from 1-7 per game field.

The game fields were fertilized with manure with a quantity of 3 tonnes/0.01 km² before, or in case of very wet soil conditions, right after ploughing. When the marrow-stem kale had grown to a height of about 10 centimetres a second fertilization was conducted with N-P-K fertilizer in proportions of 21-10-3 and an amount of 200 kg/0.01 km². Game field A4, A6 and A9 (Fig. 1), were excluded at the second fertilization due to substantial growth of weeds. The amount of seeds spread was 3 kg/0.01 km². The distance between the sowing rows was 30 centimetres, with few exceptions where the distance was up to 2 metres due to failed sowing. The most abundant weeds on the marrow-stem kale fields were common couch *(Elytriga repens),* clover (*Trifolium spp*.), creeping thistle *(Cirsium arvense),* fat-hen *(Chenopodium album),* shepherd's purse *(Capsella bursa-pastoris)* and pale persicaria *(Persicaria laphatifolia).*

The biomass available within exclosures and controls was estimated in both September and November. In September, the aim was to evaluate forage availability and utilisation during the summer period, i.e. factors affecting summer browsing on adjacent forest areas. In November, the aim was to evaluate the potential available biomass when the winter starts, i.e. when the quality of other forage resources decrease and the risk for browsing damages on valuable coniferous forest increases (Cederlund *et al*. 1980). The first estimation of biomass production was conducted during the first two weeks of September 2008. To be able to study utilisation of the crop a sample plot (control) was pair-wise linked to each exclosure. The control plot was placed five metres northwards from the northwesternmost corner of the exclosure in September. In both the exclosure and control plot all above ground biomass was cut and separated into weeds and marrow-stem kale on an area of 0.8x1.6 m (i.e. half of the exclosure size). The total fresh biomass was weighed on scales to nearest gram. Furthermore, average height of the marrow-stem kale was estimated. The same procedure was carried out at the other half of the exclosure in November 2008. To avoid placing the control area in the same spot as in September, the control plot was set out five metres southwards from the most south easternmost corner of the exclosure. Two exclosures were crashed between September and November resulting in a sample size of 28 exclosures.

Dry matter estimations
In order to calculate the dry matter ratio (dry weight/ fresh weight), representative samples of 150 grams, or if less, as much as was available, from marrow-stem kale and weeds separately were collected from exclosures and control plots, respectively. The samples were dried to constant weight before weighing.

Browsing on adjacent forests
Browsing pressure on deciduous tree species in relation to distance from game fields were studied around eight of the nine marrow stem kale and on five other game fields with clover (Fig. 1). One game field was excluded as it was surrounded by fields and a lake. The browsing survey was conducted at the end of September 2008, i.e. the end of the summer season but before frost and leaf fall. Sample plots of 20 m^2, were systematically distributed along transects at a distance of 0, 50, 100, 200, 300, 400, 500 m from the field by using handheld GPS. The transects were distributed from the most northern, southern, eastern and western edge of the game field (Fig. 1). Transects or parts of transects were excluded if lakes, wetlands or other game fields were coming across. The starting point (0 m) of the transects was at the edge-zone between game field and forest. The edge between the field and the forest was defined as the first tree or shrub next to the game field. The sample plot was placed so that the border of the plot closest to the game field included all twigs of the tree closest to the field. At each distance, two sample plots were surveyed. 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 analyses to avoid pseudo-replication.

Sample plots on the transect without occurrence of trees were moved 5 metres to the right and the second sample plot beside the transect was sometimes moved to the right of the transect (still 20 m) to avoid plots with no occurrence of trees.

In each sample plot, the total number of trees, the number of trees with bites, the number of trees with stripped leaves, the number of trees with both stripped leaves and bites were counted for seven tree species. Only trees with leaves within the height interval of 0.5-2.5 m were included. The tree species surveyed were silver birch, downy birch, rowan, aspen, penduculate oak, willows and alder buckthorn.

Figure 1. Schematic figure over the study area, marrow-stem kale fields A1-A9, clover fields (▲) and transect set up.

The tree species were grouped concerning preference by the ungulates in the analyses to increase the sample size for each group. In general rowan, aspen and willows are highly preferred species by moose, roe deer and red deer followed by oak and the two birch species (Bergström & Hjeljord 1987; Baskin & Danell 2003). Therefore, rowan, aspen and willow were clustered into one group, the less preferred downy birch and silver birch to a second while the abundant penduculate oak formed the third group. Analyses were also conducted on all surveyed tree species all together. Since the browsing pressure is a proportion (proportion of browsed and stripped trees) the variable was arcsine transformed ($x'=\arcsin(\sqrt{(x)})$) to avoid problems with non-normality (Krebs 1999).

Observations of utilising species

Observations of wildlife were carried out at the game fields to evaluate what species that actually are utilising the marrow-stem kale fields. Observations were conducted during dawn or dusk by observing the nine game fields. Some spotlighting by car during the dark hours was conducted on game field close to roads.

Statistical analyses

To statistically test whether there was any difference between, available biomass and average height of the marrow-stem kale between the exclosures and the control areas paired t-tests were used. To test the difference in biomass availability of marrow-stem kale and weeds between September and November a paired t-test was conducted. In this analysis two exclosures were excluded as they were crashed in November. Browsing intensity patterns with increasing distance from game fields were tested with one-way ANOVA´s and Tukey´s post hoc analyses. The dependent variable was the transformed browsing pressure with distance to the game field as factor. All analyses were done in SPSS.

Results

Biomass estimations on marrow-stem kale fields

The mean fresh biomass of marrow-stem kale in the exclosures was 1239±204 (S.E 95 %) g/m² in September and 1941±301 g/m² in November. The corresponding biomass in the control (grazed) plots was 260±96 g/m² and 83±33 g/m², respectively. The dry matter quota was on average 13 % and 17 % for marrow-stem kale and 19 % and 17 % for weeds in September and November, respectively (dry weights in Fig. 2-3, table 2-3).

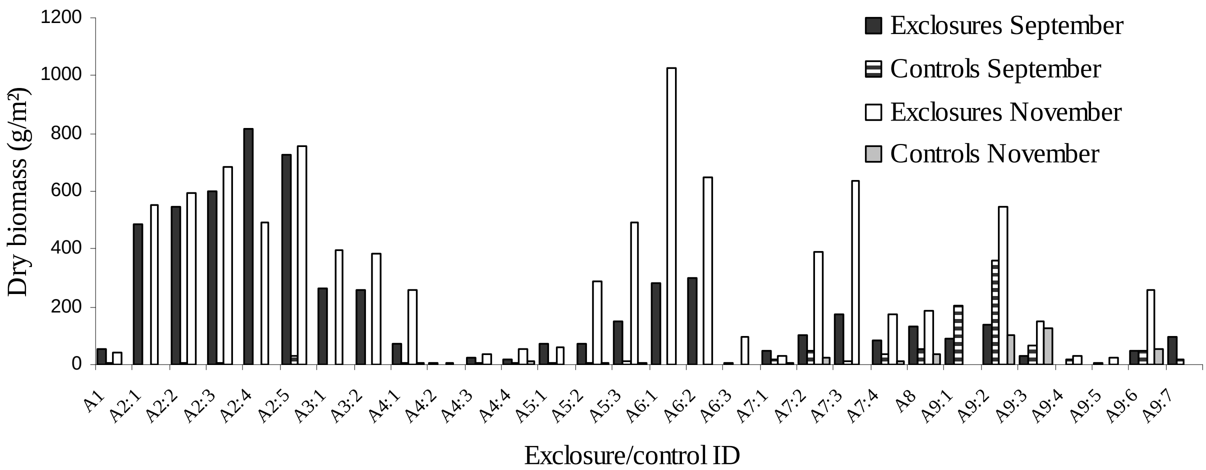

Figure 2. Dry biomass (g/m²) of marrow-stem kale in exclosure and control plots in September and November. The x-axis represents the exclosure and control identity number at game fields A1-A9 (Fig1).

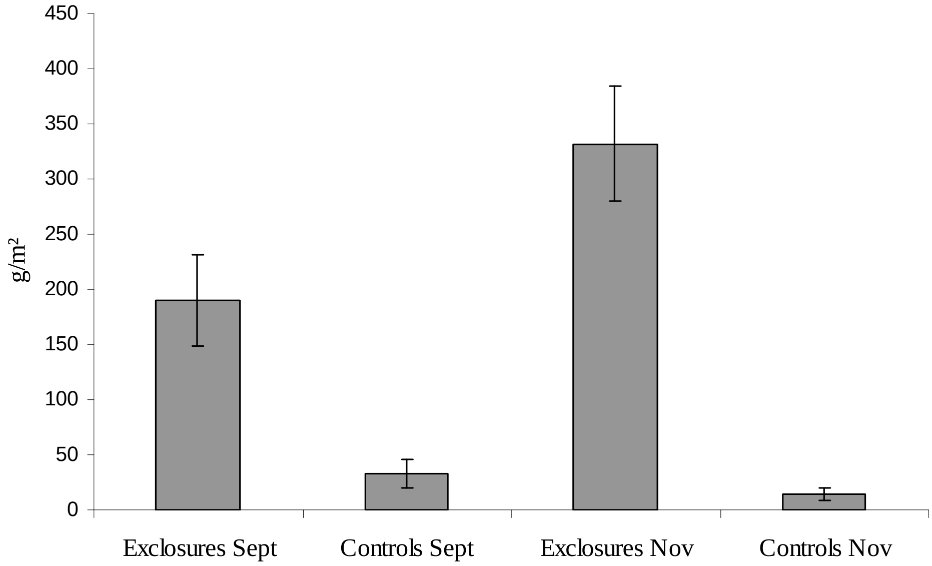

Figure 3. Mean (±S.E) dry biomass production of marrow-stem kale (g/m²) in September (n=30) and November (n=28).

The available biomass of marrow-stem kale differed significantly between the exclosures and the control plots in both September (paired t-test; t=3.5, p=0.001, df=29) and November (t=6.0, p<0.0001, df=27). The height of marrow-stem kale also showed a significant difference between the exclosure and the control plots (Sept: t=8.4, p<0.0001, df=29; Nov: t=9.1, p>0.0001, df=27). However, no significant difference (p>0.05) in available biomass of weeds between the exclosures and the control plots was found (Fig. 2-3, table 2-3).

The biomass of the marrow-stem kale in the exclosures was significantly higher in November compared to September (paired t-test; t=3.6, p=0.01, df=27). However, there was no significant difference in height between the two periods (t=0.84, p=0.41, df=27). The mean biomass in the exclosures increased with 74 % from September to November. The height of the marrow-stem kale in the controls was significantly lower (t=6.0, p<0.0001, df=27) in November compared to September. However, there was no significant difference in biomass (t=1.3, p=0.19, df=27). The weed biomass was significantly lower in both exclosures (t=4.1, p<0.0001, df=27) and controls (t=5.7, p<0.0001, df=27) in November compared to September (Fig. 2-3, table 2-3).

Table 2. Mean (± S.E 95 %) of dry biomass production (g/m²) in September of respectively, marrow-stem kale and weeds and height (cm) of marrow-stem kale in exclosures and control plots.

	September									
	Marrow-stem kale					**Weeds**				
	Mean	S.E	Max	Min	n	Mean	S.E	Max	Min	n
Biomass exclosures (g/m²)	190	41	818	1	30	171	31	711	0	30
Biomass controls (g/m²)	33	13	361	0	30	168	24	451	19	30
Height exclosures (cm)	59	4	105	15	30	-	-	-	-	-
Height controls (cm)	21	3	70	0	30	-	-	-	-	-

Table 3. Mean (± S.E 95 %) of dry biomass production (g/m²) in November of respectively, marrow-stem kale and weeds and height (cm) of marrow-stem kale in exclosures and control plots.

	November									
	Marrow-stem kale					**Weeds**				
	Mean	S.E	Max	Min	n	Mean	S.E	Max	Min	n
Biomass exclosures (g/ m²)	332	52	1025	8	28	28	7	147	0	28
Biomass controls (g/ m²)	14	6	129	0	28	18	3	69	0	28
Height exclosures (cm)	62	5	100	25	28	-	-	-	-	-
Height controls (cm)	11	3	70	0	28	-	-	-	-	-

Browsing on adjacent forests

The proportion of trees and bushes with bites or leaf strips ranged from 0.061 to 0.77 depending on species (Fig. 4) The overall trend is that willows and alder buckthorn are the most browsed species, intermediate browsing occurred on penduculate oak, aspen and rowan. Silver birch and downy birch were the species with lowest total browsing pressure (i.e. proportion of trees with bites or leaf strips). However, the leaf stripping pressure was the second highest on silver birch after willows (Fig. 4).

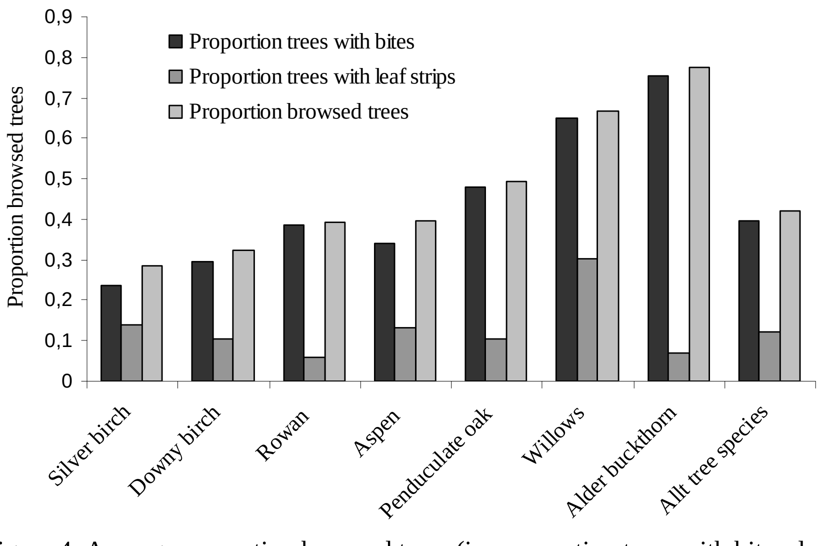

Figure 4. Average proportion browsed trees (i.e. proportion trees with bites, leaf strips or both) of the different tree species.

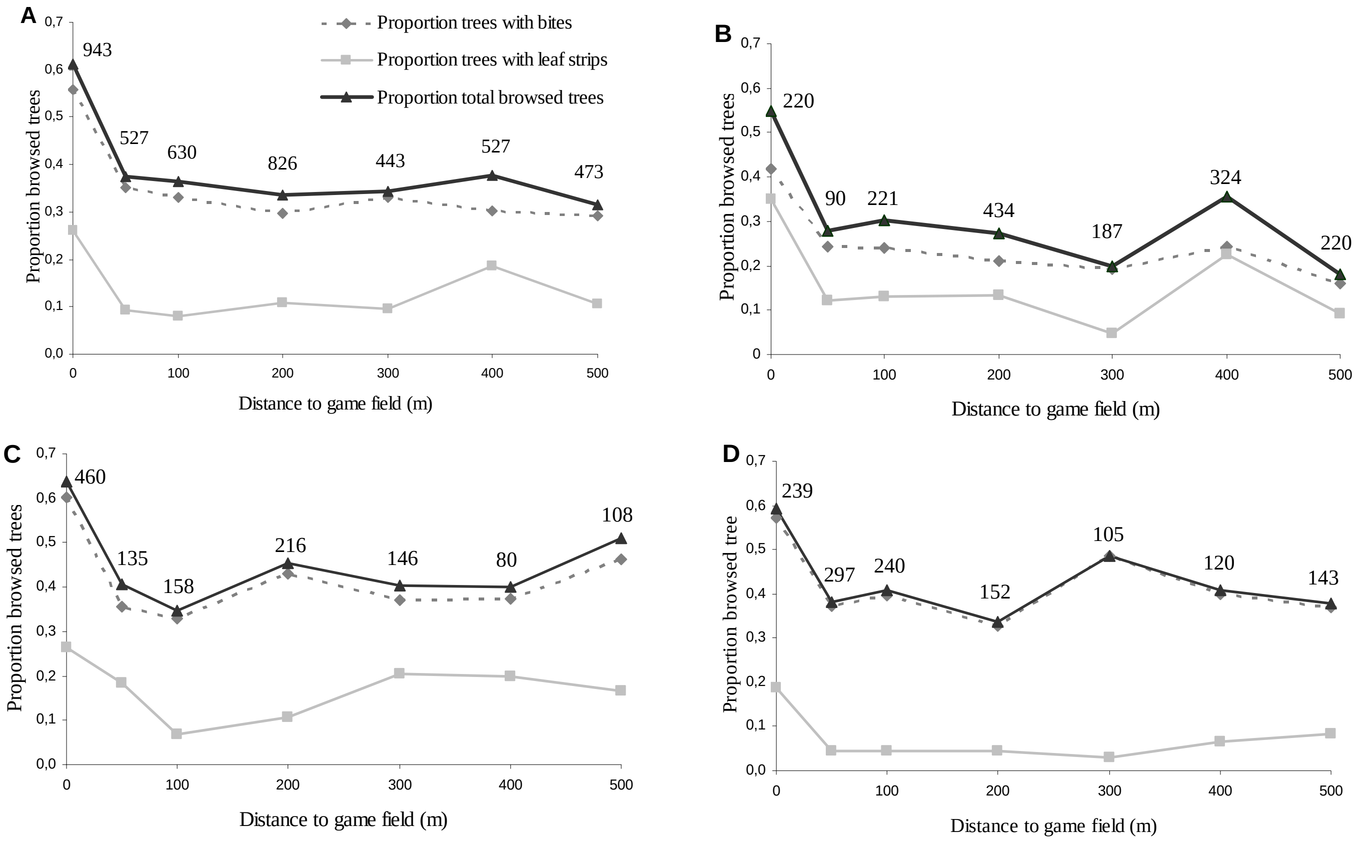

Figure 5. Average browsing intensity (untransformed) on trees and bushes in relation to distance from game fields**.** Number of surveyed trees are given at each distance**. A)** All surveyed tree species, see method, **B)** silver birch and downy birch, **C)** rowan, aspen and willows, **D)** penduculate oak.

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. 5).

ANOVA´s showed significant differences in proportion of browsed trees between the distances ($F= 2.5-4.6$, $p<0.024$, $df=149-247$) for all cases except C). In group C the trend was not significant ($F=1.9$, $p=0.082$, $df=172$; Fig. 5) Further, Tukey´s posthoc analysis indicated that the differences in browsing pressure between the distances was only significant between the edge zone and other distances i.e. no effect was found on further distance than the edge zone (Table 4).

Table 4. Significant differences ($p<0.05$) found in Tukey´s posthoc analyses, of proportion browsed trees between the distances (m) are marked with tree group A-D. A) All surveyed tree species, B) silver birch and downy birch, C) rowan, aspen and willows, D) penduculate oak. Non significant differences are marked with x. No significant differences between the distances were found in group C.

Distance (m)	0	50	100	200	300	400	500
0	x						
50	B	x					
100	A	x	x				
200	ABD	x	x	x			
300	AB	x	x	x	x		
400	ABD	x	x	x	x	x	
500	AB	x	x	x	x	x	x

Observations
A total of 20 observation hours have been spent at the marrow-stem kale fields. Altogether 52 observations were done and roe deer was the most common species, followed by hare and moose (Fig. 6). One observation equals to one animal, but individuals can not be distinguished between times of observations.

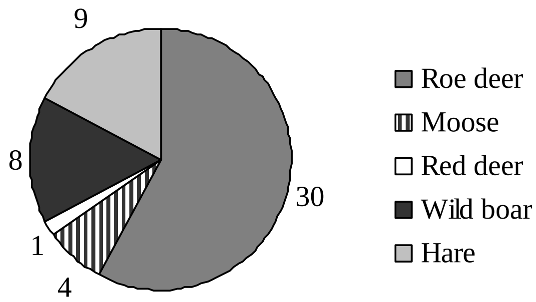

Figure 6. Proportion of total number of observations of the different species utilising the marrow-stem kale fields. The number of observations of each species is given. Fallow deer occur within the study area but was never observed at marrow-stem kale fields.

Discussion

The high biomass production and the intensive utilization by ungulates of the game fields showed that the marrow-stem kale can be considered as good alternative forage for ungulates. It therefore has the potential to alter movement patterns of ungulates and to decrease the overall browsing pressure on trees and bushes in the landscape. A higher browsing pressure was found in the edge zones around the game fields compared to further distances. This indicates a potential of supplemental forage as a management action to redistribute ungulates in the landscape.

Biomass production and utilisation
The mean dry biomass available was 1900 kg/0.01 km² in September and increased with 74 % to 3320 kg/0.01 km² in November when the period of plant growth ended (i.e. mean temperature < 5°C). The marrow-stem kale was slightly grazed in two of the exclosures (ID A2:3-5, A3:1-2) in November which may result in an underestimation of mean biomass production. The dry spring period and the increased distance between the sowing rows due to failed sowing at the game fields may also contribute to an underestimation of the potential biomass production of marrow-stem kale. These biomass values can be compared to food biomass for large herbivores in willow plantations, which showed a biomass of summer forage of 128-1222 kg/0.01 km² depending on plantation age (Bergström & Guillet 2002). Winter forage of annual shoots on Scots pine in young forests is in the order of 500 kg/0.01 km² (reported in Bergström & Guillet 2002). The height of the marrow-stem kale did not significantly differ between September and November, but the biomass showed a highly significant increase between the periods. This means that the marrow-stem kale were getting thicker and produced more leaf biomass but did not grew in height between the two survey periods.

The utilisation of the marrow-stem kale was extensive already at the end of the summer. The early utilisation suppresses the marrow-stem kale and this benefits the weed production, which in turn suppresses the marrow-stem kale even more (cf. Edwards *et al.* 2004). As a consequence, the weeds decrease the potential forage production. The design of this study therefore makes it impossible to estimate the total biomass that actually has been produced and consumed at the control plots. However, there were highly significant differences in both height and biomass between the exclosures and the control plots in both September and November. These differences became even greater in November as the mean marrow-stem kale biomass increased with 74 % in the exclosures while it decreased with 58 % in the control plots. Furthermore, the marrow-stem kale decreased significantly in height between September and November. The biomass also decreased in the controls but the decrease was not significant. However, this might be a result of the fact that the marrow-stem kale was getting thicker but not higher between the periods and that grazing still occurred. The biomass and height of marrow-stem kale in the control plots were already low in September and may indicate that intensive browsing occurred early in the season. No regrowth of the browsed marrow-stem kale was observed.

Forage potential of marrow-stem kale

A moose needs approximately 5-10 kg dry forage per day during winter and up to 20 kg dry biomass per day during the summer period (Scwartz & Renecker 1997; De Jager & Pastor 2008). This means that the marrow-stem kale fields has the potential as a forage resource equivalent to about 450 moose days per hectare (0.01 km^2) during the winter, with the assumptions that all the forage is being consumed and that the marrow-stem kale is ungrazed until the winter period starts or about 100 moose days per hectare during the summer period. The summer estimation is based on mean dry biomass in September and the winter estimation is based on mean dry biomass in November. Depending on body size and nutritional needs, the marrow-stem kale has the potential to feed even more individuals of the other occurring ungulate species.

Weeds

The biomass of weeds was of the same size as marrow-stem kale biomass in September but had decreased significantly to November, probably as a result of the ending vegetation period in November (table 2-3). The decline of weed biomass may have eased the competition with the marrow-stem kale and been an influencing factor causing the great biomass increase between the two periods.

The ungulate-forest system and browsing on adjacent forests

Marrow-stem kale creates an attractive forage resource for ungulates. Therefore, it has the potential to be used as a management tool to redistribute ungulates from sensitive forest stands, decreasing the browsing pressure at a landscape scale and in the long run decrease economical losses in forestry (Gill 1992; Gundersen *et al.* 2004; Cooper *et al.* 2006). As ungulate distribution and movement is proved to be strongly correlated with forage abundance and quality, a higher local density of ungulates can be expected close to the game fields. An increased local density can affect plant diversity, plant abundance and increase browsing damage on economically important tree species (Hörnberg 2001; Anouk Simard *et al.* 2008). This study showed a general trend of higher browsing pressure in the edge zone between the game field and forest. A similar pattern has been shown in studies with feeding stations or supplied forage for ungulates (Ball *et al.* 2000; Gundersen *et al.* 2004). Gundersen et *al.* (2004) found an increased browsing pressure up to 200 metres from the supplied food. Thereby this study differed from the study by Gundersen *et al*. (2004) as this study only showed an increase in browsing intensity in the edge zone between forest and game field and not on further distances. The differences in extent of affected distance from the supplied forage may be a result of differences in density of ungulates, occurring predation risk, season and forage characteristics in adjacent habitats (Belovsky 1984; Gross *et al*. 1993; Ball *et al*. 2000; Gundersen *et al*. 2004) However, the exact mechanism behind the increased browsing pressure in the edge zone can not be separated in this study, i.e. both the game field and the actual edge can attract the ungulates (Alverson et al. 1988; Takatsuki 1992; Cadenass & Pickett 2000; Gundersen *et al.* 2004).

Apart from the higher browsing pressure in the edge zone, this study failed to show a change in browsing pressure with increasing distance from the game fields. Still, it may well be that game fields generally decrease the browsing pressure in the landscape.

As the density of ungulates increases, the browsing intensity increases (Hörnberg 2001). Furthermore, forage availability also affects the browsing pressure. When forage availability per herbivore increases it will result in an ease of browsing pressure. However, an increased supply of forage increases the carrying capacity in the landscape, which in turn may boost growth in ungulate populations (Edwards *et al*. 2004). Hunting must therefore be adapted to a possible increase in population growth to reach balanced goals.

In general the browsing pressure was higher in the edge zone compared to all other distances from the game fields, but the trend of greater browsing intensity in the edge zone was not significant in all cases. The lack of significant statistical support can always be a result of the sample size and not least so in browsing studies in small-grained landscape with a patch-work of stands with varying forage quality and great variations in browsing intensity (Edenius *et al.* 2002) Further, the proportion of browsed trees might be too a rough estimate of browsing intensity to detect differences. Proportion of browsed twigs might be a more precise, but also a considerably more labour-intensive measurement.

Browsing at different deciduous trees

Alder buckthorn and willows were the most intensively browsed species followed by aspen, rowan and penduculate oak and finally downy and silver birch (Fig. 4). This pattern coincides with the food preference by ungulates as presented in the literature (Bergström & Hjeljord 1987; Baskin & Danell 2003). Willows and silver birch were the species with largest proportion leaf strips (Fig. 4.). Differences in twig morphology are thought to be an explanation to why some tree species have higher frequency of leaf stripping than others (Bergström & Guillet 2002).

Observations of ungulates

The number of observed animals is too low to make any firm conclusions about what species and to what extent ungulates utilize the supplied marrow-stem kale. The data indicate that roe deer are the species that most eagerly feed on the fields. The majority of the game fields were already intensively browsed when the observations started in September and the available forage biomass was low which probably made the game fields less attractive as a food resource at the time of the observations.

Management implications

Marrow-stem kale is a highly attractive food resource for large herbivores. The marrow-stem kale was grazed already during the growth season, which may cause growth suppression and lower the availability of food biomass during the winter season. If the densities of ungulates are high in the management district, the game fields may preferably be fenced until the crop has established well. This may help to protect the supplemental forage from heavy grazing in early season. If the crop is left ungrazed during the growth season, the potential forage resource (as a mean of several fields) of marrow-stem kale can be at least 3000 kg dry biomass/ha when the winter arrives. However, some plots indicated that biomass values of 8-10 tonnes can be reached, but such values are probably difficult to reach regularly due to weeds, weather etc.

As showed in this study, the biomass production of weeds was similar as the forage production of marrow-stem kale, causing competition and growth suppression of the crop. The data also indicate that the weeds were not utilized to any extent by the large herbivores. To decrease the weed competition and gain the marrow-stem kale growth, mechanical or chemical weed control on the game fields may be an advantageous management option.

Adding forage like marrow-stem kale to a grazing system may release grazing pressure on economically valuable tree species and therefore be a management tool for a combination of different interest groups. As the browsing pressure is most intensive in the edge zone between the game field and the forest, these zones creates a forage resource and should be managed with the aim to increase the forage availability. A suggested management strategy for increasing the forage availability in the edge zones could be to leave preferred tree species as willows, rowan and alder buckthorn or even extra plant saplings to decrease the browsing intensity at further distances from the game field. It should be considered that this strategy may increase the risk of browsing damage if there are any regeneration stands in the close vicinity, as also has been shown by Gundersen *et al*. (2004) and Hines *et al*. (2007). To decrease the risk for car collisions, game fields should be kept at a considerable distance from heavily trafficked roads due to aggregation of ungulates at the game fields (Andreassen *et al*. 2005).

Future directions

This study is one of the first in Sweden where the potential forage production on game fields have been quantified. The co-operation between SLU, Sveaskog and Skogforsk will continue and this study will be conducted following years with other forage crops, gathering more observational data and data on browsing intensity on adjacent forests. This will increase the sample size and the statistical power. Further studies are also needed to give a better understanding of temporal and spatial variation and of cost effectiveness of management practices. To further understand the economical advantages, browsing effects during the winter season on the economically important Scots pine should be studied.

The majority of studies of forage for ungulates focus on abundance. As forage availability is not the only factor affecting foraging decisions but also quality, it might be relevant to study the nitrogen content of the supplied crop as well as utilisation of different crop species. Further studies also need to be done on how to avoid too much browsing of the supplied forage in early season, with the aim to help the crop establish without suppression by intensive grazing by ungulates.

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APPENDIX 1		Distance (m)																				
		0			50			100			200			300			400			500		
		N	Mean	S.E	N	Mean	S.E	N	Mean	S.E	N	Mean	S.E	N	Mean	S.E	N	Mean	S.E	N	Mean	S.E
Silver birch	Total trees	168	4	0,92	46	1,07	0,29	100	2,70	1,04	174	4,70	1,67	72	2,32	0,59	179	5,77	1,66	163	5,26	2,44
	Damaged trees	88	2,10	0,47	17	0,40	0,18	35	0,95	0,47	34	0,92	0,39	12	0,39	0,18	63	2,03	0,94	29	0,94	0,45
	Trees with bites	63	1,50	0,32	16	0,37	0,18	23	0,62	0,34	24	0,65	0,28	11	0,35	0,16	35	1,13	0,58	24	0,77	0,39
	Trees with leaf strips	58	1,38	0,35	7	0,16	0,12	21	0,57	0,33	21	0,57	0,34	6	0,19	0,10	46	1,48	0,70	17	0,55	0,30
Downy birch	Total trees	52	1,24	0,43	44	1,02	0,56	121	3,27	1,16	260	7,03	3,28	115	3,71	1,22	145	4,68	2,40	57	1,84	1,07
	Damaged trees	33	0,79	0,32	8	0,19	0,11	32	0,86	0,30	84	2,27	1,10	25	0,81	0,28	52	1,68	1,26	11	0,35	0,15
	Trees with bites	29	0,69	0,28	6	0,14	0,07	30	0,81	0,29	68	1,84	0,82	25	0,81	0,28	44	1,42	1,07	11	0,35	0,15
	Trees with leaf strips	19	0,45	0,23	4	0,09	0,09	8	0,22	0,10	37	1,00	0,76	3	0,10	0,05	27	0,87	0,81	3	0,10	0,07
Rowan	Total trees	54	1,29	0,43	72	1,67	0,47	55	1,49	0,38	40	1,08	0,34	19	0,61	0,24	15	0,48	0,14	21	0,68	0,37
	Damaged trees	25	0,60	0,17	24	0,56	0,15	13	0,35	0,15	15	0,41	0,16	8	0,26	0,17	4	0,13	0,06	15	0,48	0,36
	Trees with bites	25	0,60	0,17	21	0,49	0,12	13	0,35	0,15	15	0,41	0,16	8	0,26	0,17	4	0,13	0,06	14	0,45	0,36
	Trees with leaf strips	2	0,05	0,05	8	0,19	0,08	0	0,00	0,00	0	0,00	0,00	0	0,00	0,00	1	0,03	0,03	2	0,06	0,04
Aspen	Total trees	203	4,83	1,14	21	0,49	0,25	74	2,00	1,00	81	2,19	1,10	78	2,52	1,18	24	0,77	0,47	58	1,87	0,90
	Damaged trees	114	2,71	0,66	6	0,14	0,06	19	0,51	0,20	29	0,78	0,60	32	1,03	0,70	3	0,10	0,05	17	0,55	0,33
	Trees with bites	104	2,48	0,62	3	0,07	0,04	17	0,46	0,18	27	0,73	0,57	30	0,97	0,70	2	0,06	0,04	14	0,45	0,30
	Trees with leaf strips	46	1,10	0,34	3	0,07	0,04	4	0,11	0,05	11	0,30	0,24	21	0,68	0,59	1	0,03	0,03	5	0,16	0,10
Pendulculate oak	Total trees	239	5,69	0,93	297	6,91	0,96	240	6,49	1,03	152	4,11	0,79	105	3,39	0,77	120	3,87	1,04	143	4,61	0,86
	Damaged trees	142	3,38	0,49	113	2,63	0,37	98	2,65	0,46	51	1,38	0,29	51	1,65	0,49	49	1,58	0,50	54	1,74	0,39
	Trees with bites	137	3,26	0,49	111	2,58	0,36	95	2,57	0,46	50	1,35	0,29	51	1,65	0,49	48	1,55	0,49	53	1,71	0,38
	Trees with leaf strips	45	1,07	0,23	13	0,30	0,10	11	0,30	0,08	7	0,19	0,09	3	0,10	0,05	8	0,26	0,14	12	0,39	0,14
Willows	Total trees	203	4,83	1,13	42	0,98	0,56	29	0,78	0,33	95	2,57	1,29	49	1,58	0,82	41	1,32	0,46	29	0,94	0,38
	Damaged trees	154	3,67	0,89	25	0,58	0,36	23	0,62	0,28	54	1,46	0,72	19	0,61	0,37	25	0,81	0,35	23	0,74	0,34
	Trees with bites	148	3,52	0,84	24	0,56	0,34	22	0,59	0,28	51	1,38	0,67	16	0,52	0,29	24	0,77	0,32	22	0,71	0,34
	Trees with leaf strips	73	1,74	0,45	14	0,33	0,20	7	0,19	0,09	12	0,32	0,17	9	0,29	0,20	14	0,45	0,26	11	0,35	0,23
Alder buckthorn	Total trees	24	0,57	0,18	5	0,12	0,06	11	0,30	0,12	24	0,65	0,29	5	0,16	0,10	3	0,10	0,07	2	0,06	0,06
	Damaged trees	21	0,50	0,17	4	0,09	0,06	9	0,24	0,10	11	0,30	0,18	5	0,16	0,10	3	0,10	0,07	0	0,00	0,00
	Trees with bites	20	0,48	0,15	4	0,09	0,06	9	0,24	0,10	11	0,30	0,18	5	0,16	0,10	2	0,06	0,04	0	0,00	0,00
	Trees with leaf strips	3	0,07	0,04	0	0,00	0,00	0	0,00	0,00	1	0,03	0,03	0	0,00	0,00	1	0,03	0,03	0	0,00	0,00
All tree species	Total trees	943	22,45	2,45	527	12,26	1,28	630	17,03	2,22	826	22,32	4,26	443	14,29	2,26	527	17,00	3,62	473	15,26	3,10
	Damaged trees	577	13,74	1,51	197	4,58	0,56	229	6,19	0,94	278	7,51	1,85	152	4,90	1,02	199	6,42	2,11	149	4,81	1,01
	Trees with bites	526	12,52	1,37	185	4,30	0,52	209	5,65	0,89	246	6,65	1,52	146	4,71	0,98	159	5,13	1,60	138	4,45	0,98
	Trees with leaf strips	246	5,86	0,82	49	1,14	0,31	51	1,38	0,35	89	2,41	1,15	42	1,35	0,64	98	3,16	1,44	50	1,61	0,49