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Evaluating six crop mixes used for game fields in southwest Sweden

- biomass production, fallow deer preference and species diversity

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Abstract

Game fields are one way to divert animals away from sensitive areas, create shelter and forage, and also to increase the biological diversity. In this study I investigated how the plant composition in six different crop mixes used for game fields affected the biomass production, biomass consumption and biological diversity at the Koberg estate in southwestern Sweden. Six experimental fields were used and each field contained six plots, approximately 1500 m^2 each, that was sown with a different crop mix. The crop mixes ranged from a pure grass mix (A), 70 % grass and 30 % leguminous plants (B), 53 % grass, 21 % leguminous plants and 26 % other herbs (C), 100 % leguminous plants (D) to the most complex mixes constituting of 91 % leguminous plants and 9 % other herbs (E) and 87 % leguminous plants and 13 % other herbs (F). The fields were cut weekly during the summer in 2010, to estimate weekly biomass production. Also a seasonal biomass production was measured inside stationary exclosures, before and after harvest. Exclosures and GPS marked fallow deer (*Dama dama*) were used to estimate biomass consumption and preference. To estimate species diversity I used pitfall traps, beating nets and transects to collect arthropods. The seasonal biomass production without grazing showed that crop mix B, C, D, F produced better than A and E during summer 2010. There was no significant difference between the different crop mixes in weekly biomass production, however a significant difference was found between experimental fields. No significant differences were found in weekly biomass consumption, but crop mix A, D and F had been consumed the most. Two independent measures of the relative use of the six crop mixes showed a similar pattern (GPS locations and relative biomass loss) as crop mix A, E and F was used or grazed more than expected and crop mix B and C was avoided. Simpson´s and Shannon´s diversity index both indicated that crop mix D was the most diverse for carabids (*Carabidae*) and mirids (*Hemiptera: Miridae*), while crop mix E was the most diverse for spiders (*Araneae*). Sequential counting index showed that crop mix D was the most diverse for true flies *(Diptera*). However, I found no significant difference between the different crop mixes regarding abundances of bumblebees (*Apidae*) and butterflies (*Lepidoptera*).

Sammanfattning

Viltåkrar är ett försök att styra bort viltet från känsliga marker eftersom de orsakar stora ekonomiska förluster genom sitt bete på både åkrar och skog. Samtidigt som man bland annat skapar mer foder; vilket möjliggör en större viltstam i området, kan viltåkrar öka den biologiska mångfalden genom att skapa skydd och föda åt andra djur så som insekter, spindlar och fåglar. Jordbruket har förändrats och intensifierats i Sverige och i resten av Europa de senaste decennierna och det småskaliga landskapet med ängs- och betesmarker har minskat och ofta planterats med monokulturer av gran. Detta har bidragit till att fåglar, växter och insekter knutna till dessa miljöer minskat, även stora populationer av vilt anses ibland bidra till minskad biologisk diversitet.

I detta arbete undersökte jag sex olika vallblandningar för viltåkrar. Blandningarna bestod av allt från en ren gräsblandning (A), 70 % gräs och 30 % baljväxter (B), 53 % gräs, 21 % baljväxter och 26 % örter (C), 100 % baljväxter (D) till de mer komplexa blandningarna bestående av 91 % baljväxter och 9 % örter (E) och 87 % baljväxter och 13 % örter (F). Försöken är genomförda på sex försöksfält på Kobergs egendom i Västergötland. På varje försöksfält fanns sex försöksytor, ca 1500 m^2 vardera, som sått med varsin vallblandning. De såddes våren 2009 tillsammans med havre som fungerade som skyddsgröda och undersöktes under sommaren 2010. Veckovis klipptes varje försöksyta, både i och utanför burar, för att uppskatta produktion av biomassa. Även GPS-märkta dovhjortar (*Dama dama*) har använts för att uppskatta deras utnyttjande av de olika försöksgrödorna. Den botaniska sammansättningen och säsongsproduktionen före och efter skörd har undersökts med hjälp av data från Hushållningssällskapet. För att jämföra biologisk diversitet mellan de olika vallblandningarna inventerades vid två tillfällen insekter och spindlar med hjälp av fallfällor, slaghåv och linje-transekter.

Ingen signifikant skillnad hittades i biomassaproduktion mellan de olika vallblandningarna när den mättes varje vecka, däremot fanns en signifikant skillnad i produktion mellan de olika försöksfälten. Dock hittades en signifikant produktionsskillnad (utan bete) i den totala säsongsproduktionen under sommaren 2010 före skörd, där vallblandningarna B, C, D och F producerade bättre än A och E. Jag fann heller ingen statistiskt signifikant skillnad i betestrycket mellan de olika blandningarna, men i genomsnitt så hade A, D och F betats mest. Intressant nog visade två oberoende mått på utnyttjande (GPS-positioner och betestryck) ett liknande mönster. Vallblandningarna A, E och F utnyttjades mer än förväntat och B och C var underutnyttjade, med båda mätmetoderna. Utnyttjandet av vallblandning D skiljde sig dock mellan de båda mätmetoderna och var underutnyttjad enligt GPS-positionerna men överutnyttjad enligt uppmätt betestryck. Det var dock väldigt små skillnader och båda utfallen kan mycket väl bero på att det verkliga utnyttjandet låg nära det förväntade, d.v.s. D-blandningen varken över- eller underutnyttjades. Simpson´s och Shannon´s diversitetsindex indikerade att vallblandning D var den mest varierande för jordlöpare (*Carabidae*), ängsskinnbaggar (*Miridae*) och tvåvingar (*Diptera*). E var den mest varierande för spindlar (*Araneae*). Jag hittade ingen signifikant skillnad mellan de olika vallblandningarna i antalet humlor och fjärilar, men minst besök fick A och B som är de som innehåller minst antal eller inga blommor.

Vallblandningarna B, C, D och F producerade mest biomassa totalt. A, D och F var de som betades mest. Relativt sett var vallblandning A, E och F överutnyttjade och B och C underutnyttjade. Vallblandning D och E var de med högst artdiversitet. Förutom att det är viktigt att välja en vallblandning som passar klimat och jordmån så är ett konkret skötselråd att välja vallblandningar bestående av olika arter som blommar eller bildar frön för att på så sätt gynna fåglar och insekter och höja den biologiska mångfalden. Man bör dock undvika vallblandningar som innehåller rajgräs.

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Introduction

Increasing ungulate densities often lead to conflicts concerning damage on forests and crops caused by browsing and grazing (Gill 1992; Hörnberg 2001). But a way to redistribute animals within the landscape and to divert them away from crop or commercially important forest stands sensitive to browsing is the use of high-quality supplementary forage (Gundersen *et al.* 2004). Likewise game fields might be one way to provide ungulates with high-quality forage and thereby divert animals away from sensitive areas and at the same time improve habitats for biodiversity. At the same time they might also increase the carrying capacity for game populations (Bergqvist et al. 2009). However, when sowing a game field one has to consider the local climate and the soil quality, when choosing crop (Bergqvist et al. 2009; Johansson 2001). It is also suggested to sow different crops in patches next to each other, to create more vertical structure (Jensen 2001). A more complex plant community creates more structures important for feeding, overwintering, resting and sexual display (Brown 1991). Furthermore, the choice of crop type also depends on the aim of the game field i.e. to create shelter or forage and the wildlife species in focus. For ungulates, white clover (*Trifolium repens*), red clover (*Trifolium pratense*) and black medick (*Medicago lupulina*) gives good feeding opportunities and also a good habitat for insects (Jensen 2001). Clovers and black medick is also good since they both fixate nitrogen and in that way fertilize the ground. Game fields has usually a marginal value for moose (*Alces alces*) but is more important for fallow deer (*Dama dama*), red deer (*Cervus elaphus*) and roe deer (*Capreolus capreolus*). Game fields can be sown on unused fallow land and still subsidy money can be collected from EU (Bergqvist et al. 2009). Other cultivated sources of food for high density game populations in southern Sweden is willow (*Salix spp*.) plantations grown as a biofuel crop (Bergström & Guillet 2002).

Another aspect when sowing a game field is the amount of biomass produced, whether its only used to divert animals or if it is to be harvested for winter forage as well. The plant species that you choose is an important part of this, since plants react differently to grazing depending on there ability to compensate for the loss of tissue (Milchunas & Lauenroth 1993). A commonly used crop is white clover because of its resistance against grazing and high nutrient value (Johansson 2001). By choosing a perennial crop you reduce the workload and the effects on the environment (Bergqvist et al. 2009). To increase biodiversity it’s suggested to mix different crops and avoid monocultures, this creates shelter and food for different species (Bergqvist et al. 2009). Crops that flower such as clover (*Trifolium spp.*) and chickory (*Cichorium intybus*) attract insects which serve as a food source for other insects and birds. This environment also increases the population of predator insects. Sunflowers (*Heliantus annuus*) and white mustard (*Sinapis alba*) forms seeds and attract insects, creating a good food source for birds. These plants at the same time create shelter and food for other herbivores such as hares (*Lepus spp*.).

The choice of game crop should be considered not only in a spatial and climatic context but also from the perspective of the target species. Ungulates typically select forage in relation to what is optimal in the given context, meaning that they optimize food intake to maximize fitness (Bergman et al. 2001). This has been called the “optimal foraging theory” (Stephen & Krebs 1986) and states that the decision to consume a food item is determined by its value relative to other available food items and the costs associated with handling and searching time. As the availability of more profitable forage declines, the search time needed per prey item increases to a point where it becomes profitable to include less rewarding food items in the diet. Herbivores diet may be regulated by many different factors such as nutrient and toxin intake, digestion and ingestion rates, limits of daily foraging time (Stephen & Krebs 1986). Due to the low concentrations of nutrients and digestible energy in some plants, herbivores need to ingest large amounts (Bergvall et al. 2007; Alm et al. 2002). But many plants are a potential food source since herbivores use microorganisms to help them digest the cellulose (Alm et al. 2002). The frequency of occurrence and the quality of available food sources influence the food choice (Alm et al. 2002; Parsons et al. 1994) and also large herbivores change their diet according to availability and quality during different seasons (Hofmann 1989). Fallow deer prefer tender herbs and grasses during the summer, while eating bark, buds and brush wood in the winter. Many herbs and grasses are suitable for fallow deer because of their wide diet. By browsing on the shrubs and plants in the ground vegetation layer, deer indirect increase the amount of grasses, ferns and mosses (Gill 1992). So an overabundance of deer can have a negative effect on biodiversity (Côté et al. 2004) but the main cause of biodiversity loss is a result of the human altered landscape. During the last decades a rapid and large structural change has appeared in Europe in the agricultural landscape due to an intensification and modernization of agriculture (Krebs et al. 1999; Chamberlain et al. 2000; Donald et al. 2001; Weibull et al. 2003). The historical landscape was composed of a small scale mix of meadows, pastures and arable land, today it is more homogenous and dominated by large areas of arable land (Ihse 1995). Since the end of the 19th Century the total amount of meadows and pastures has declined from 1.5 million to 0.5 million hectares (The Swedish Board of Agriculture 2010). The meadows and pastures have either been cultivated, become overgrown or planted with mainly Norwegian spruce (*Picea abies*; Eriksson et al. 2002). This change in habitat structure has led to that many groups such as birds (Donald et al. 2001), invertebrates and plants have disappeared and become rare in today's farmland (Krebs et al. 1999). The benefits of biological diversity can be to enhance ecosystem-functions such as primary productivity and nutrient retention, or ecosystem services such as pollination and biological control (see Weibull et al. 2003 for a review). Since biodiversity has a broader meaning including both genetic-, species- and ecosystem diversity, often only one part like species diversity is used when estimating biodiversity in an area. To estimate species diversity in the agricultural landscape, different groups are typically used such as carabids (*Carabidae*), rove beetles (*Staphylinidae*) and spiders (*Araneae*) which are all species-rich groups. They have different specializations thus reacting differently to changes in the landscape (Weibull et al. 2003).

In this study I investigated biomass production, consumption, preference and species diversity in six different types of crop mixes used on game fields for fallow deer. This knowledge is important for management decisions, whether it is to improve carrying capacity or to divert the wildlife away from other vulnerable areas such as crops and forest stands and at the same time increase biodiversity. Fallow deer were introduced in Sweden in the 1570´s and were first kept at big estates (Carlström 2005). In 1997 they could be found in the wild in 12 of the southern provinces (Chapman & Chapman 1997) and now approximately 20 000 are harvested during the regular hunting season annually (The Swedish Association for Hunting and Wildlife Management 2011). The fallow deer are social and form herds, with sizes differing during the seasons, but they are typically not described as territorial except during the rut and when giving birth (Chapman & Chapman 1997). Fallow deer are found in many different habitats such as deciduous and mixed woodlands and open fields, and can adapt to different climates due to their wide food choices and since their preferences change during the year (Chapman & Chapman 1997). The fallow deer is a generalist, but grass constitutes the largest part of the diet throughout the year, combined with herbs during the summer (Chapman & Chapman 1997). In winter they also eat broad leaved trees, bramble (*Rosaceae: Rubus*), holly (*Aquifoliaceae*), conifer (*Pinaceae*) and fruits (Chapman & Chapman 1997). In cafeteria tests fallow deer has been found to adapt to changes in food type distributions and they also tended to use more common food to a higher extent (Alm et al. 2002). The fallow deer feed during the whole day but the intensity of feeding increases around dusk and dawn (Chapman & Chapman 1997). As a result of their wide food choice the fallow deer selects food with higher amounts of nutrients and lower amounts of toxins, showing an intermediate degree of selectivity (Alm et al. 2002).

Objectives

The aim of this study was to evaluate six different crop mixes used for game fields with different plant compositions regarding the quantity of grass, leguminous plants and herbs. By investigating:

- Does the biomass production vary between the six different crop mixes?
- How does the plant composition change in the different crop mixes?
- Does the fallow deer show a preference for any of the crop mixes?
- Does the species diversity differ in the different crop mixes?

Materials and methods

Study area

This study was conducted at the Koberg estate (58.12 N, 12.39 E) located in south-west Sweden, during June and July 2010. The study area is 54.35 km^2 and divided in two parts by a fenced road; north and south, this study took place in the southern area. The study area consists of 79 % forest of which 44 % is conifer forest (Winsa 2008), 16 % arable land and pastures, 2 % mires and marshes and the last 3 % is made up of lakes, ponds, and properties (Winsa 2008; SMD a satellite generated digitized map, Svensk Marktäckedata). The mean annual temperature is 6˚C and the annual precipitation is 800 mm/year. The length of the vegetation period is approximately 200 days and there is on average 75 days of snow during the period November 25 to April 5 (SMHI long term mean, 1961-1990). Most of the arable land and pastures are cropped for the wildlife to improve their habitat and forage availability. In the Koberg estate free ranging fallow deer has been present since the 1920´s when a few individuals were released from an enclosure (Count Niclas Silfverschiöld unpubl. data). In 2006 the fallow deer population was estimated to 327 animals/10 km^2 (Rydholm 2007). Except from the large population of fallow deer on Koberg other ungulates that can be found are wild boar (*Sus scrofa*), roe deer, moose and occasional red deer. A high density of fallow deer and wild boar are maintained for hunting by supplementary feeding during the winter and cropped pastures serving as game fields.

During this study five areas were used for six experimental fields; 1) ”Nedre Snuggebo N” 2)”Nedre Snuggebo S”, 3) “Risåker”, 4) “Grönemaden”, 5) “Tuppekärr” and 6) “Hultet” (Fig. 1). On each experimental field there were six plots (> 1250 m^2) cultivated with one out of six different crop mixes called A (100 % grass), B (70 % grass, 30 % leguminous plants), C (53 % grass, 21 % leguminous plants, 26 % other herbs), D (100 % leguminous plants), E (91 % leguminous plants, 9 % other herbs) and F (87 % leguminous plants, 13% other herbs; for a complete list of plant species in each crop mix see Appendix 1). This makes a total of 36 plots, with six replicates for every crop. The fields have earlier been treated with lime. The fall prior to sowing they were sprayed with the herbicide “Roundup” and then later ploughed. In spring 2009 the fields were harrowed and sown together with oats (*Avena sativa*), to protect the target crop mixes during the first season for a secure establishment. No oat was present during the summer 2010. Two variables (weekly biomass production and consumption) were used to test for differences between crop mixes and experimental fields using a Repeated Measures ANOVA (R. M. ANOVA; StatView, SAS Institute Inc. 5.0.1).

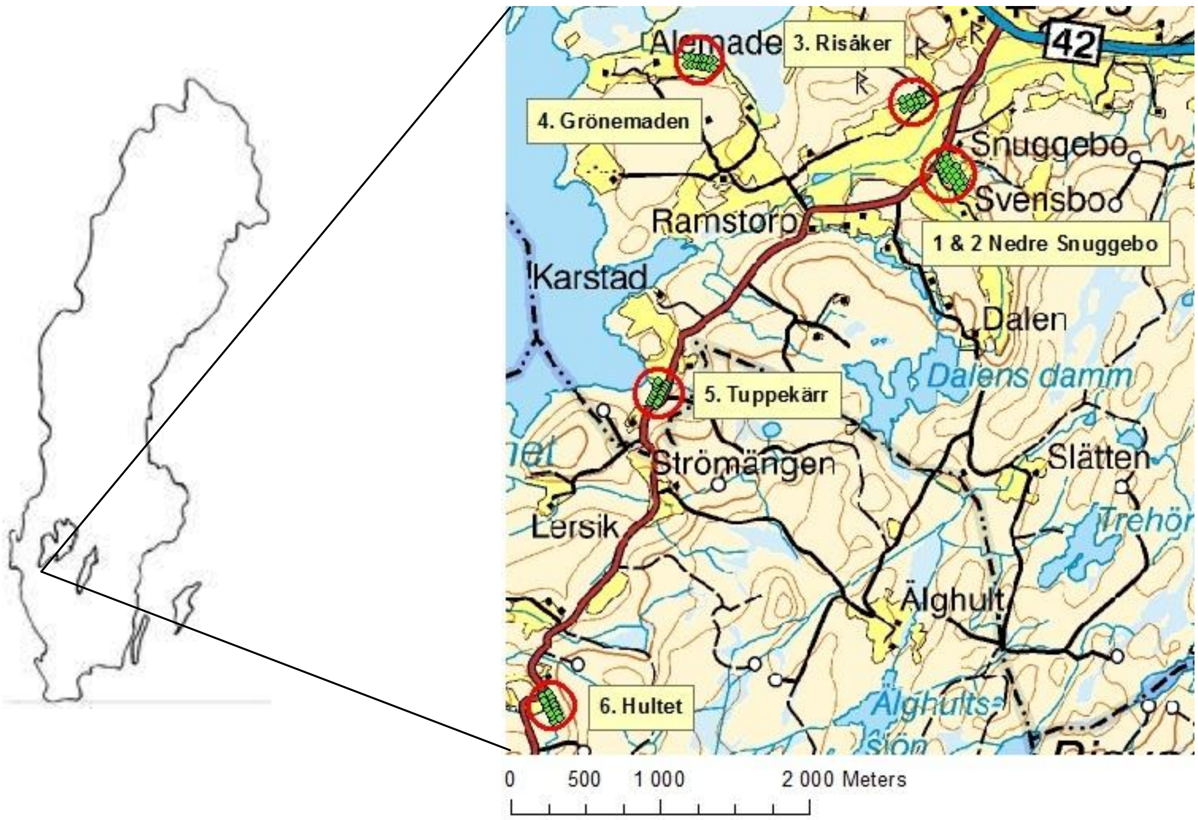


Figure 1. The Koberg estate location in Sweden, with close up showing part of the south study area where game fields were situated. Red circles mark the locations of the game fields. **© Lantmäteriet Gävle 2010. Medgivande I 2010/0055**

Estimating weekly biomass production and consumption

To estimate weekly biomass production and consumption on the different crop mixes A – F, I used a mesh cage (L: 0.53 m * W: 0.44 m * H: 0.18 m) which was randomly placed on the experimental field, one on each crop type. The random selection was done by throwing a marked stick from the corner of the field, shifting corner clockwise for each throw. If the random patch were damaged i.e. areas with bare soil, the closest undamaged patch was selected. I cut the grass under the cage using a pair of garden scissors and stored it in paper bags in a freezer until it could be dried. A new location was randomly selected, with the same requirement to be undamaged, and then the cage where secured to the ground, to prevent the animals to move it and avoid grazing on the particular patch. The following week, I started by removing the cage, cutting the grass underneath (ungrazed sample). Then randomly selecting a grazed location, cutting the grass there (grazed sample), before randomly selecting a new location where the cage was again fixed to prevent grazing. This procedure was repeated regularly for seven times approximately once a week, during the period June 1 - July 20, 2010. After that the grass cutting had to stop because the haymaking started. When the field work was completed I dried the frozen grass. The whole paper bag where put inside a desiccator set to 70 ˚C for ≥72 hrs. Afterwards the dried samples were weighed to the nearest 1g. The sample weight was finally recalculated in to g/m^2.

Weekly biomass production was calculated as the difference between ungrazed biomass week two and grazed biomass week one. This was done to estimate how much the crop grew during one week, when not grazed. Consumed biomass was calculated as the difference in biomass between ungrazed and grazed plots from the same week. To estimate the fallow deer preference I assumed that the more biomass that was consumed the higher the preference. Unfortunately, the experimental field 3 (Risåker) had to be removed from both analyses since this field was totally overgrown with a thistle (*Cirsium* spp.) "infestation" and the available forage biomass could not be compared to the other fields.

To estimate which crop mix (A – F) that were preferred by the fallow deer I used locations from GPS-marked fallow deer that had a home range overlapping any of the experimental game fields. I used ArcGIS 9.3 (Environmental Systems Research Institute, Redlands, California) to match the GPS-locations from the animals with the exact locations of the plots. The application spatial join were used to join the fallow deer GPS-locations with the different game fields. Only high precision locations during the period June 1 to July 27, 2010 that had the status: 3D and validated were used; this resulted in 98 locations from 8 different adult individuals (3M, 5F). The data where then processed in Microsoft Excel (2010). I used the number of visits to each crop mix as an estimation of preference and tested for differences using a χ^2 test. To establish if the preference for a crop mix were related to the amount of forage available, I used an ANOVA and two different quotas, the crop mixes were also compared in pairs using Fisher´s PLSD. I compared the relative number of GPS-locations with the relative biomass available for each crop mix, using the grazed weight as an index on how much biomass that was available. To calculate the grazed weight I used data from six cutting occasions between June 8 to July 20 to create a mean for each field and crop mix. The other way I used was to compare the relative biomass consumption with the relative available biomass. The available biomass was calculated as above, using the six cutting occasions to calculate a mean for each field and crop mix. The consumption was then calculated as a mean from the six cutting occasions for each field and crop mix, using the weekly weight difference between the grazed and un-grazed plots. To be able to use all values I added on 300 g on every weight, so that negative values could be used. I used the natural logarithm (ln) to transform the quotas for each field and crop mix, to accomplish comparable indices of relative use. A quota > 0 means that the crop mix was overused and a quota < 0 that it was underused.

Additionally, the Swedish Rural Economy and Agricultural Society measured the plant composition and seasonal biomass production on the experimental fields and plots during five different occasions; April and November 2009 and April, July and November 2010. When the crop was measured during spring 2009 and 2010, almost nothing were available, therefore the production was set to zero at these occasions. A 1 m^2 exclosure were used to prevent grazing and placed at the same location from April 2009 until April 2010 and April 2010 until November 2010. The plant composition was measured both inside and outside the exclosure by cutting 2* 0.5 m^2 of the crop (at the ground level) and calculating the percentage of biomass for each plant species. The biomass that was cut inside the exclosures was also used to calculate the seasonal biomass production in fresh weight without grazing. When the exclosures were cut on July 27, the rest of the fields were harvested for hay. These cuttings in the exclosures gave an estimate of the seasonal biomass production without grazing for the periods April 1 - November 11, 2009, April 1 - July 27, 2010 and July 28 - November 8, 2010, to investigate differences I used an ANOVA. The crop mixes was also compared in pairs, using Fisher´s PLSD test. I also tested for differences using an ANOVA when the different mixes were categorized in to two groups; Grass (A, B, C) and Leguminous (D, E, F) based on their plant composition. In contrast to the weekly biomass production where field 3 was excluded (see above), it was included in the analyses of seasonal biomass production, since the Swedish Rural Economy and Agricultural Society sorted out thistles as weeds pre weighing.

Estimating species diversity

Arthropods were used as indicators of possible differences in species diversity, between the six crop mixes. Three different methods were used to collect the arthropods; pitfall traps, beating nets and transects. Different sampling techniques were used to ensure that several potential niches were searched.

Pitfall traps

One pitfall trap was placed randomly in the middle of each plot to avoid border effects, resulting in 36 traps in total, six traps for each crop mix. A round plastic jar with the measurements D: 0.12 m * H: 0.18 m: was used as trap, dug down so that the edge was levelled with the surrounding ground. The jar was filled with a small amount of water to prevent the organisms from eating each other. The trappings were conducted between June 6 - 12 and July 16 – 21, 2010 and all the organisms were stored in labelled jars containing 70 % alcohol, until they could be identified at the lab. Due to problem with wild boar excavating the traps a mean of 3.71 (max 4, min 2) trap nights per period per trap was accomplished, to correct for this all results reports captures per trap night.

Transects

In each plot, one line transect was used to estimate arthropod diversity, they went from north to south or west to east, always passing through the centre of the field. I always choose the direction that resulted in the longest transect, which resulted in a total transect-distance of: 50 m in field 4, 5, 6; 40 m in field 3 and 2 and 45 m in field 1; summing up to 275 meter for each crop. Transects were used for three different surveys; 1) beating net, 2) butterfly counts and 3) bumblebee counts.
1) To collect arthropods I used a beating net making 30 strokes while walking one transect. Also these samples were stored in 70% alcohol until they could be identified in the fall. This was done at two occasions during the summer, June 14 - 16 and July 18, 2010.
2) When I counted the butterflies (*Lepidoptera*) I walked the transect once, and butterflies within a distance of 5 m was counted. It had to be sunny, no wind (< 8-13.8 m/s) and no clouds. This was done two times during the summer, June 5 - 6 and July 20, 2010.
3) Bumblebees (*Apidae*) were counted while walking the transect on the way back after finishing counting butterflies, now looking in a 2 m radius. This was done on one occasion during the summer, July 20.

Determination of arthropods and species diversity indices

The arthropods were sorted and identified to either order or family (Appendix 3). The organisms were then combined for both pitfall traps and the beating net and determined to species level for three groups; spiders, carabids and mirids (*Hemiptera: Miridae*). Two different indices were used to estimate species diversity in the different crop mixes; Simpson´s (1 - D) and Shannon´s (H'; as described in Krebs 1999). Differences in butterfly and bumblebee abundance in the different crop mixes were tested with Kruskal-Wallis test. True flies (*Diptera*) were not determined to species level instead sequential counting index (SCI) was used as an index of diversity (Wratten and Fry 1980). To calculate the SCI; the flies were randomized for each crop and then randomly lined up in a petri dish. The total number of changes in species between adjacent flies was recorded to calculate the ratio between the number of changes and the number of individuals.

Results

Biomass production

Seasonal biomass production

There was close to a significant difference in seasonal biomass production between the different crop mixes (without grazing) both during fall 2009 (ANOVA; $F_{5, 30} = 2.26$; $P = 0.074$) and summer 2010 (ANOVA; $F_{5, 30} = 2.22$; $P = 0.079$; Table 1). But not during the fall 2010 (ANOVA; $F_{5, 30} = 1.10$; $P = 0.384$; Table 1). Generally crop mix B produced most biomass and F the least during fall 2009, but during summer and fall 2010, F produced the best (Table 1). During the fall 2009 mix B and C produced significantly better than F (Fisher´s; $P_{B > F} = 0.006$; $P_{C > F} = 0.017$). There were indications that also B produced better than A (Fisher´s; $P_{B > A} = 0.059$). In summer 2010, F produced significantly better than A and E, and also B produced significantly better than E (Fisher´s; $P_{F > A} = 0.037$; $P_{F > E} = 0.013$; $P_{B > E} = 0.031$). A trend could be seen where both C and D produced better than E, and B produced better than A (Fisher´s; $P_{C > E} = 0.076$; $P_{D > E} = 0.060$; $P_{B > A} = 0.078$). In the fall of 2010 F produced significantly better than A (Fisher´s; $P_{F> A} = 0.044$). There was close to a significant difference in seasonal biomass production between the two crop groups ("Grass" and "Leguminous") in fall 2009 where "Grass" produced more than "Leguminous" (ANOVA; $F_{1, 34} = 3.83$; $P = 0.059$). In summer and fall 2010 there were no significant difference in production between the two groups (ANOVA; summer 2010: $F_{1, 34} <0.01$; $P = 0.988$; fall 2010: $F_{1, 34} = 2.59$; $P = 0.117$).

Table 1. Mean seasonal biomass production of six different crop mixes inside stationary 1m^2 large exclosures to protect the crop against grazing. Measured by The Swedish Rural Economy and Agricultural Society at Koberg, Sweden, at three occasions. The measurements are given in fresh weight (g/m^2) and are the mean of all the different fields. Harvest took place on July 27, 2010.

	First year establishment; November 2009		Before harvest; July 2010		After harvest; November 2010	
Crop	Mean	SE	Mean	SE	Mean	SE
A	763	207	964	89	471	153
B	1352	169	1303	106	819	120
C	1228	170	1223	131	595	101
D	876	233	1245	168	780	217
E	935	291	881	109	792	244
F	470	175	1369	163	985	157

Weekly biomass production during summer 2010

The mean weekly biomass production in the different crop mixes did not significantly differ (R. M. ANOVA; $F_{5, 24} = 0.23$; $P = 0.947$; Fig. 2). But the mean weekly production varied significantly between the different experimental fields (R. M. ANOVA; $F_{4, 25} = 3.27$; $P = 0.028$).

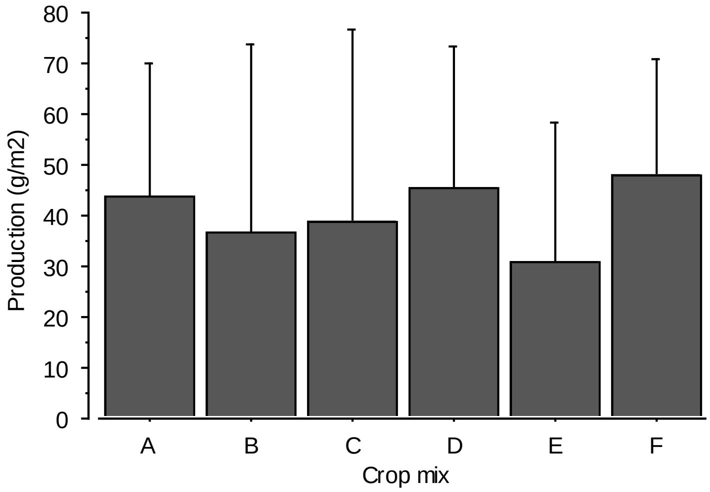
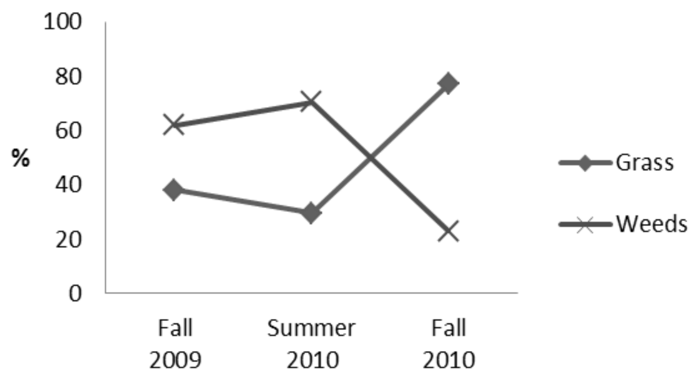


Figure 2. Mean weekly biomass production (g/m^2, dw) in six different crop mixes during June 1 to July 20, 2010, measured on seven occasions and based on five repetitions (fields), at Koberg, Sweden. Error bars indicate 95% C.I.

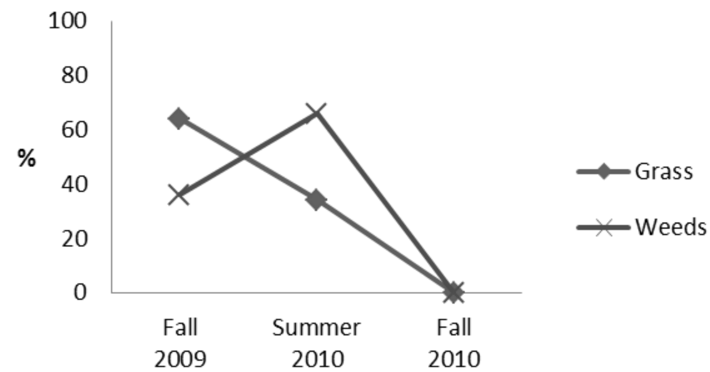
Plant composition

After the sowing in spring 2009 the plant composition changed, during both seasons and years (Fig. 3; Appendix 2). Crop mix A consisting of timothy (*Phleum pratense*) and narrow leaved meadow-grass (*Poa pratensis*), had been outcompeted by weeds when not grazed (Fig. 3 A). Except in the fall 2010 after the harvest, then the grass mix outcompeted the weeds (Fig. 3 A). When crop mix A was grazed, there was less weeds then grass the first year 2009, but in summer 2010 the grass was outcompeted by the weeds (Fig. 3 A). In fall 2010 no crop was left on the field, everything had been grazed (Fig. 3 A). Crop mix B and C both contain rye grass (*Lolium spp*.), even if different species (Appendix 1) and they follow the same pattern (Fig. 3 B; C). The rye grass outcompeted all the other plants and were the only plant remaining in the fall 2010, when everything else had been grazed (Fig. 3 B; C). During summer 2010 when the crop was not grazed the white clover grew better than both the rye grass and weeds (Fig. 3 B). The herbs in crop mix C was outcompeted by weeds, leguminous plants and rye grass in summer 2010 when not grazed (Fig. 3 C). But when grazed the weeds were less abundant and both the rye grass and herbs grew better, while leguminous remained the same (Fig. 3 C). The white clover in crop mix D was outcompeted by weeds in fall 2009 whether it was grazed or un-grazed (Fig. 3 D). But in summer 2010 white clover grew better then weeds, but was then outcompeted by the weeds in fall 2010 after harvest when not grazed (Fig. 3 D). When grazed, both white clover and weeds disappeared in fall 2010 (Fig. 3 D). Crop mix E contained no grass only leguminous plants and herbs, they were when not grazed outcompeted by weeds at all occasions (Fig. 3 E). But like in all other crop mixes the leguminous grew better than the herbs in summer 2010 whether grazed or not (Fig. 3 E). When grazed the leguminous plants outcompeted both weeds and herbs in summer 2010, but after harvest and grazing nothing was left in fall 2010 (Fig. 3 E). Also the leguminous plants and herbs in crop mix F was outcompeted by weeds at all occasions when not grazed (Fig. 3 F). When grazed the leguminous plants outgrew both the weeds and herbs in summer 2010, but nothing was left in fall 2010 because of heavy grazing (Fig. 3 F).

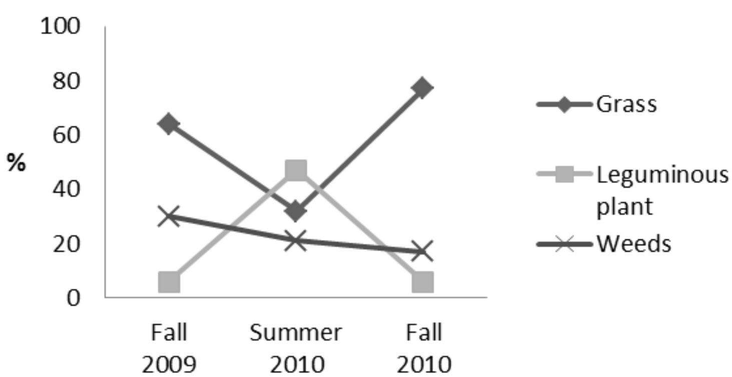
A: Ungrazed)



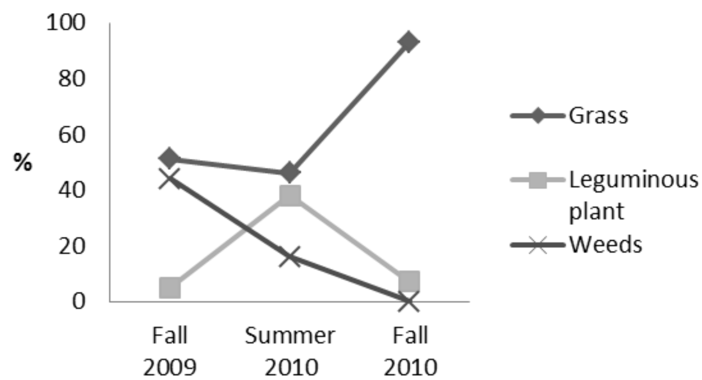
A: Grazed)



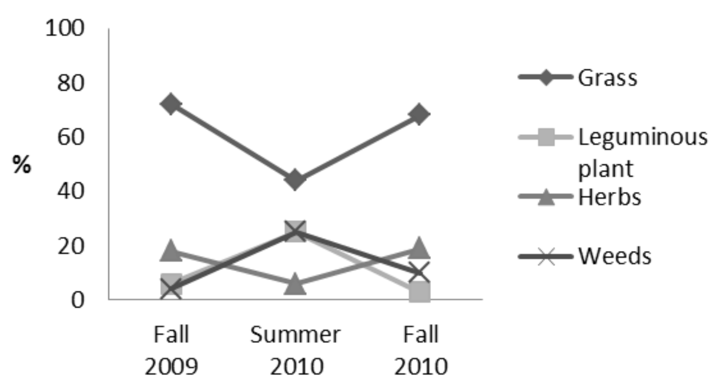
B: Ungrazed)



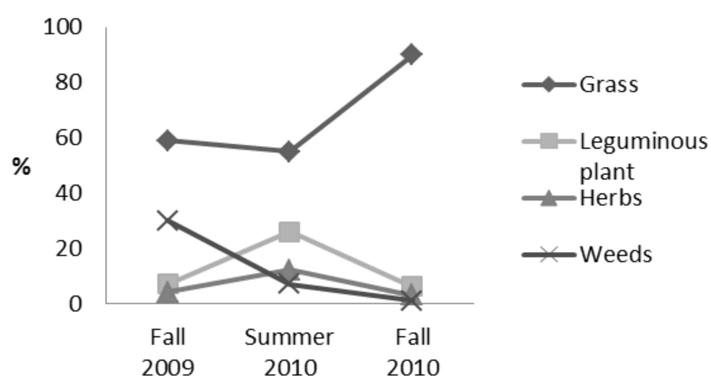
B: Grazed)



C: Ungrazed)



C: Grazed)



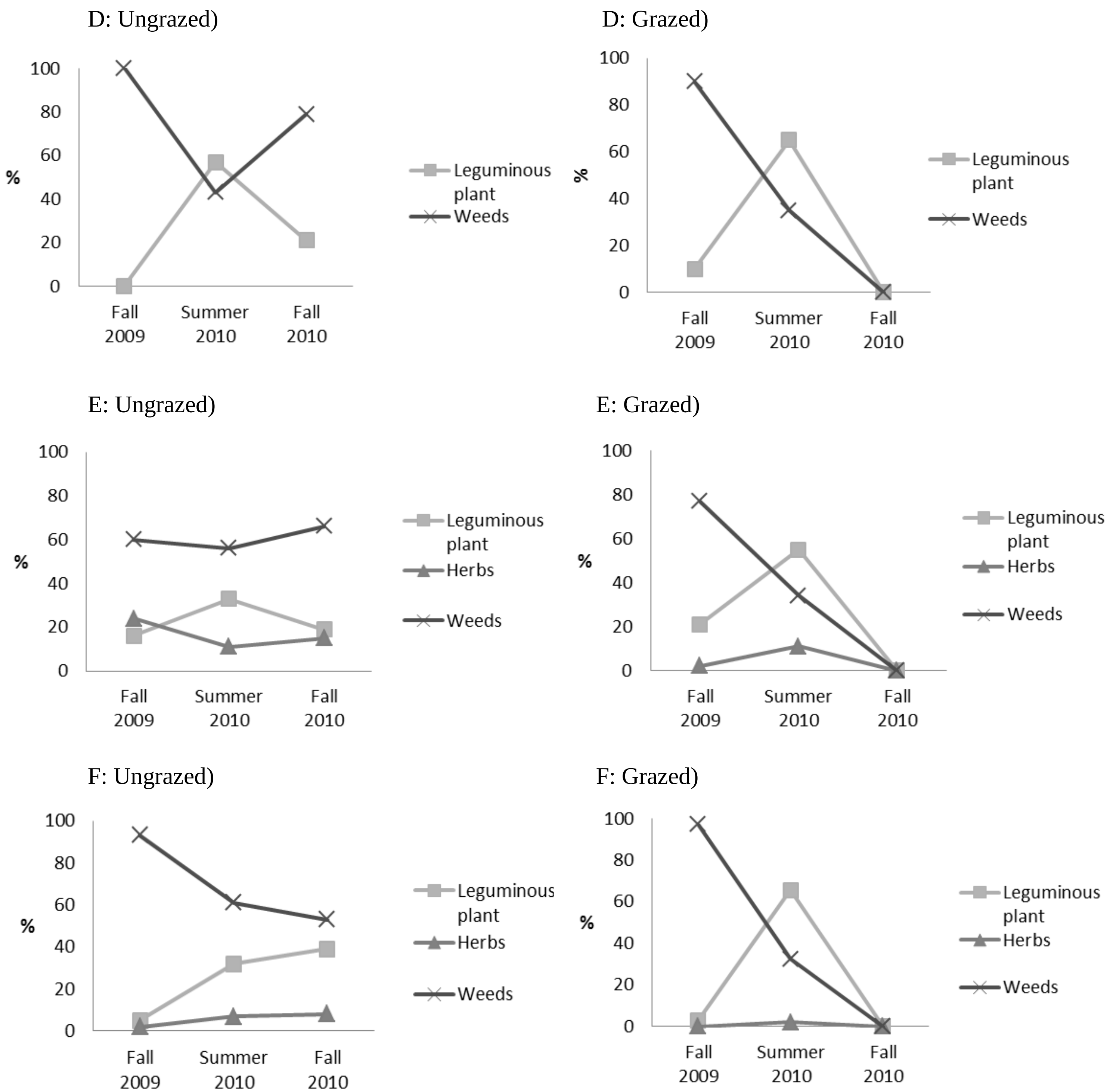


Figure 3. The plant composition (%) measured by The Swedish Rural Economy and Agricultural Society on three occasions; fall 2009, summer 2010 and fall 2010 on both ungrazed and grazed plots at Koberg, Sweden. The experimental fields were sown in April 2009 and harvested in July 2010. Development of grass, leguminous plants, other herbs and weeds was compared between six different crop mixes A - F.

Biomass consumption

The mean weekly biomass consumption did not significantly vary between the different crop mixes (R. M. ANOVA; $F_{5, 24} = 0.70$; $P = 0.630$; Fig. 4) or between the different experimental fields (R. M. ANOVA; $F_{4, 25} = 1.71$; $P = 0.180$).

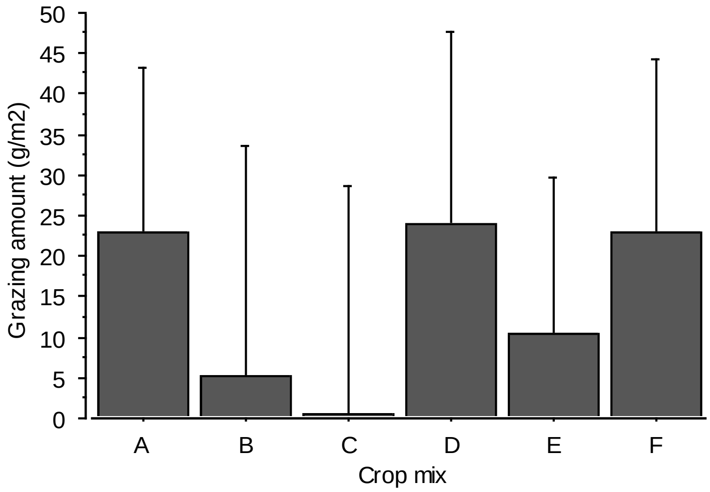


Figure 4. Mean difference in biomass consumption (g/m², dw) between grazed and ungrazed plots during, June 8 to July 20. This is a combination of five fields and six cutting occasions. Error bars indicate 95% C.I.

Relative utilization of biomass

In general crop mix A was significantly more used than B and C (Fisher´s; $P_{A > B} = 0.026$; $P_{A > C} = 0.021$) and crop mix F was almost significantly more used than B and C (Fisher´s; $P_{F > B} = 0.061$; $P_{F > C} = 0.051$). But there were no significant interaction between the relative number of GPS-locations and relative removed biomass by grazing (ANOVA; $F_{5, 36} = 0.64$; $P = 0.670$). But the two indices of relative use (based on GPS-locations and biomass consumption) had almost the same pattern, with A, E and F > 0 (used more than expected) and B and C < 0 (used less than expected; Fig. 5). Only the utilization pattern of crop mix D diverged between the two indices (> 0 when using biomass consumption and < 0 when using GPS-locations; Fig. 5). There was no significant difference in number of visits from GPS-marked fallow deer on the different crop mixes during the summer period June 1 to July 27, 2010 (χ^2 test = 6.93; P = 0.226; DF =5).

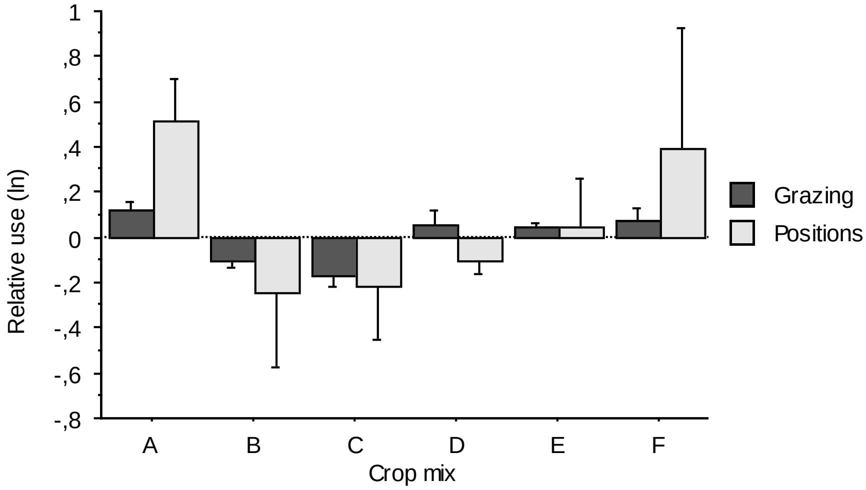


Figure 5. The relative use (GPS-positions) and biomass consumption (grazing) of fallow deer in relation to availability in six different crop mixes during summer at Koberg, Sweden in 2010. A mean made from all cutting occasions for each field and crop mix. The zero indicates the expected use. Error bars indicate standard error.

Species diversity

Crop mix D was found the most diverse for all the different groups and diversity indices except for spiders, where crop mix E was the most diverse (Table 2). Crop mix B was the least diverse regarding spiders, C the least diverse for carabids and mirids and crop mix A the least diverse for true flies (Table 2).

Table 2. Arthropods collected during the summer 2010 at Koberg using pitfall traps, beating nets and transects. Simpson´s- and Shannon´s index used as a measure for species diversity for three different families. And a sequential counting index (SCI) used for the true flies (*Diptera*). * Symbolizes the highest rank.

		Crop mix					
Group	Index	A	B	C	D	E	F
Spiders	Simpson´s	0,96	0,95	0,95	0,96	0,96*	0,95
	Shannon	4,82	4,48	4,67	4,78	4,93*	4,59
Carabids	Simpson´s	0,83	0,75	0,51	0,86*	0,68	0,85
	Shannon	2,85	2,58	1,79	3,17*	2,42	3,06
Mirids	Simpson´s	0,62	0,58	0,47	0,64*	0,58	0,58
	Shannon	1,54	1,56	1,30	1,59*	1,45	1,45
True flies	SCI	0,82	0,86	0,89	0,95*	0,84	0,86

No significant difference was found between the different crop mixes regarding the abundance of bumblebees (Kruskal-Wallis test, P = 0.988 H = 0.60; DF = 5) or butterflies (Kruskal-Wallis test, P = 0.790; H = 2.41; DF = 5). But a trend was seen when ranking the number of visits to each crop mix; bumblebees (C D E F A B) and butterflies (C F E D A B). Where C was consistently the most visited while A and B always was the least visited.

Discussion

I found no significant differences between the different crop mixes in weekly biomass production. However a significant difference was found between experimental fields, showing how important factors such as soil quality, water content etc. are and how much they can differ within areas. But the seasonal biomass production without grazing showed that crop mix B, C, D, F produced better than A and E during summer 2010. No significant differences could be found in the weekly biomass consumption, but crop mix A, D and F had been consumed the most. When I used two independent measures of the relative use of the six crop mixes (GPS- locations and relative biomass loss) it showed a similar pattern as crop mix A, E and F was grazed more than expected and crop mix B and C was avoided. Species diversity indices indicate that crop mix D was the most diverse for carabids, mirids and true flies, while crop mix E was the most diverse for spiders. Though, I found no significant difference between the different crop mixes regarding abundance of bumblebees and butterflies. I will in the following text continue to discuss each of these results more in detail.

Biomass production

The average biomass production on the game fields in my study was estimated to 400 kg (dry weight; dw) / ha per week, which would add up to 2400 kg / ha before the harvest (27 July). An organic field grown with ley produce on average 6000 kg (dw) / ha during one vegetation season, whereof 3370 kg / ha until the first harvest (Arnesson 2001). Compared the production is about 1000 kg / ha less for the game fields in my study than for commercial grown organic fields, but compared to the forage available in the forest it is higher. On average a young pine (*Pinus sylvestris*) produce 100 – 400 g (dw) / tree and birch (*Betula spp*.) 50 – 150 g / tree, which makes about 200 – 500 kg / ha for pine and less than 100 kg / ha for birch (Bergström et al. 2005). But important to remember is that they are food sources for different seasons, with pine and birch being important during winter (Bergström & Hjeljord 1987). When comparing grazed and ungrazed plots for different crop mixes, differences could arise from the fact that plant species react different on grazing, thus producing more or less biomass. Creating a bigger difference between grazed and ungrazed plots for some crop mixes, not because they were grazed more or less but because they produce more or less biomass then the neighboring plot. I have tried to correct for this by measuring the production and consumption once a week. Milchunas and Lauenroth (1993) found that in grasslands the differences between grazed and ungrazed plots were explained to 47 % by consumption and site productivity (above ground net primary production). In all the crop mixes that did not contain grass (D, E, F) the weeds outgrew everything after the harvest, when not grazed. While the crop mixes that contained grass (A, B, C), either rye grass or timothy, outcompeted the weeds when not grazed after harvest. When grazing occurred nothing was left in any of the crop mixes except for the rye grass in crop mix B and C, in the fall after the harvest. It therefore seems like the ryegrass is avoided by the fallow deer and other herbivores in the area. Weeds are usually defined as all plant species that were not part of the original seed mix and considered as negatively affecting biomass production of the target plants. However, in a game field with the primary aim to produce forage and to maximize biodiversity, weeds do not necessarily have to be something bad, as it apparently still is forage for the animals.

The results of crop production from the first year of game field establishment is not comparable to the estimates from 2010 because they include the whole vegetation season April – November without harvest and the crop also had to compete with oats. In fall 2010 the cutting was done late in November and the grass was either frozen or dead, which caused a big difference in amount of water in the plants compared to July 2010 (Swedish Rural Economy and Agricultural Society, pers. comm.). The seasonal production measurements are unfortunately presented in fresh weight, while the weekly biomass production measurements for summer 2010 are presented as dry weight. The amount of water present in different species could be one explanation why I get a significant result between the different crop mixes when measured as seasonal production summer 2010 but not when I measured the weekly production in dry weight during the summer. Another reason could be that the sample size is smaller for the weekly production since field 3 was removed because of thistles. Due to the harvest in July 2010 we mimicked the natural state, because game fields are usually harvested for winter forage. The regrowth of crops depends on where the growth zone is located during harvest, therefore the low growing white clover with its many growth zones usually produce better after harvest than many other plants (Nilsdotter-Linde 2001). Crop mix F had the highest production and is also the only crop mix where leguminous plants increased instead of decreased. Crop mix A is the only mix that did not contain leguminous plants and it may explain why it had the lowest production in fall 2010. All crop mixes had a very low regrowth of white clover, which can depend on what herbivore species that were grazing and the total grazing pressure in the area. Generally it is described that grazing increase the number of growth zones as long as the plant is not over grazed (Stadig 1994). At the Koberg estate there is a very high density of fallow deer and wild boar, it is therefore likely that the clover could have been over grazed. At the same time, clover regrowth was low also without grazing, as was the case inside the exclosures. There was also a big difference in weekly biomass production between experimental fields, indicating effects of low sample sizes and that more repetitions (fields) would have been preferable to generate a more clear result.

Crops often consist of a mix of species and leguminous plants are often combined with grasses, this because the grass regulates the amount of leguminous plants (Nilsdotter-Linde 2001). Rye grass has in trials with white and red clover been found to be an intermediate grass, while Cock's-foot (*Dactylis glomerata*) is the top regulator and Meadow Fescue (*Festuca pratensis*) the weakest regulator grass (Nilsdotter-Linde 2001). But in crop mix B and C rye grass outcompeted both leguminous plants and weeds both before and after harvest, whether it was grazed or not. This could be because the fallow deer seem to avoid grazing on rye grass. Grass can be divided into two groups; depending on if they develop spikes or use plant propagation to reproduce. Plant propagation results in a quicker regrowth after harvest and rye grass, narrowleaved meadow-grass and timothy typically belong to this group (Nilsdotter-Linde 2001). The grass starts to grow earlier in the spring and keeps growing longer in to the fall than the leguminous plants, but the leguminous plants has their maximum production in the mid of the summer (Nilsdotter-Linde 2001). At Koberg estate in spring 2010 all crop mixes with grass had started to grow, while all crop mixes that contained clover had to some extent been routed up by wild boar (Swedish Rural Economy and Agricultural Society pers. comm.). However, even if wild boar are known to like the nutritious rots of clover (F. Widemo, pers. comm.), when I started my field work, in June 2010, I did not see any differences in damage between the crop mixes. Even so, if wild boars are present in the area, caution should be taken when sowing, if big seeds like beans, corn or peas are used, the fields are often raided by wild boar and nothing is left to grow (Bergqvist et al. 2009).

Biomass consumption and utilization

I found no significant difference in biomass consumption between the different crop mixes. But crop mix A, D and F had the highest amount of removed biomass, so it seems like these crop mixes would be more preferred in comparison to especially B and C. The negative values that I got when I measured the consumption are puzzling. However, fallow deer tend to graze on some patches and leave others ungrazed even if they have the same plant composition (Johansson 2001), thus possibly creating large interplot variance. Also wild boar routings and the micro-climate can have contributed to the variance. The confounding negative grazing values could therefore be caused by having too few iterated measures from the same plot.

Food choice is usually described to be affected by the frequency of occurrence of different food types (Parsons et al. 1994) and sheep has been found to consume less clover than grass when the abundance of clover is low, although they normally prefer clover over grass (Parsons et al. 1994). Even though crop mix E is the “standard”, at the Koberg estate, used on more or less all fields surrounding the experimental fields, it surprisingly seem to be no preference for this crop mix. This could have been expected since fallow deer has been found to use more common food to a higher extent (Alm et al. 2002). Fallow deer normally shows a higher preference for lower tannin content (Alm et al 2002), although they seemed to avoid the rye grass even when this was the only available forage on the fields. This could perhaps be explained by the fact that herbivores switch to higher quality forage, as even tannin-rich leaves is preferred when the grass becomes less nutritious (Hofmann 1989). This is also supported by the observation by Murden & Risenhoover (1993) showing that herbivores seem to become more selective when feeding on natural forage if they have high quality alternatives as supplemental forage.

When looking at the utilization of game fields; the GPS locations from marked fallow deer and the estimated biomass consumption, correlates. They tend to use crop mix A, E and F more than expected, which means that they spend time there not because there is more food there but because they seem to prefer these mixes. Fields with crop mix B and C is clearly used less than expected in relation to forage availability. But when only looking at the GPS- locations and the number of visits to each crop mix it shows that A is the most visited followed by B, E, F, D. While crop C is the least visited during the period 1 June to 27 July, 2010. So even if crop mix B has many visits it seems not to be grazed. But since the rye grass is high it could be that they use it for shelter when resting and hiding newborn fawns, and in support of this I often saw signs of bed sites in this crop mix. Crop mix D was the only one that did not correlate; according to the GPS- locations the crop mix is underused but according to the established biomass consumption it was overused. This could be because other herbivores than fallow deer graze these fields. But most likely and when considering the large variation around the mean, it should be considered as no difference between the two measures.

The variation in biomass production and consumption, not only between experimental fields but also between plots, was probably affected by so called environmental variation stemming from small differences in soil type, water availability and more importantly by the placement of the plots, regarding distance to shelter, roads etc. One example was the two Snuggebo experimental fields, where the south field (2) had more visits than the north field (1), field two was closer to the forest while field one was closer to the road. Although the distribution of crop mixes in an experimental field was randomized an interrelation between the plots could be possible.

Depending on which crop mix that was bordering the other, it could get more visits when the fallow deer was actually aiming for the neighboring plot. Also the estimates of species diversity could be affected by the interrelation between plots and I think that the crop mix per se was of lower importance instead it was the vertical structure and amount of flowering plant species that was more meaningful. Since my plots with the different crop mixes were situated close together they could be seen as a mosaic and may have led to increased values of species diversity in total. But I think that even if only one crop mix is used on a field it cannot be regarded as a monoculture since many plants are part of the composition which creates structures and different feeding opportunities and could not be compared with the commercial monocultures where only one crop is used.

Species diversity

In this study I used pitfall traps and line transects to estimate the variation in species richness between crop mixes. Even though I did not cover all taxonomic arthropod groups perfectly with this procedure it is known that species richness of many taxonomic groups is strongly correlated to the total species richness along transects in cultivated areas (Duelli & Obrist 1998). When estimating species diversity I used two different indices to compare the result. Simpson´s index take into account the number of species present and their relative abundance and it is one of the most meaningful and robust diversity measures according to Magurran (2004). Shannon´s index on the other hand, measures both species numbers and the evenness to their abundance and the index increase when unique species occur in the sample. The index usually ranges between 1.5 to 3.5, were a high number indicates high species richness, and my estimates were mostly in this range. The most diverse species group was spiders irrespective of index used i.e. Simpson´s or Shannon's index. It was also in this group that I found the most individuals and different species. Crop mix E was found to be the most diverse for spiders, but the values were similar between all crop mixes which may be explained by that spiders care more about the structural complexity of the vegetation (Balfour & Pypstra 1998) and the amount of food available than the actual plant species per se. They may therefore not even discriminate between the crop mixes when running between different plots. Crop mix D was found to be the most diverse for all other groups such as carabids, mirids and true flies. Flowers are obviously important for these groups, since they create nectar and attract other insect's which means more food for predators like spiders and carabids. The highest number of true flies was also found in crop mix D and the least in crop mix A. This could be explained by the fact that many flies feeds on nectar, which causes them to choose a different field than the pure grass mix A. To mix different crops is also preferred when aiming to maximize biodiversity, since species richness of plants, butterflies and carabids has been found to increase with small-scale landscape heterogeneity (Weibull et al. 2003). Even if no significant result could be found between the different crop mixes regarding the abundance of butterflies and bumblebees, I found a consistent trend were crop mix A and B was the least visited by both these insect groups. Further, these two crop mixes had no or the least amount of flowers, which are of paramount importance to these two species groups. Different butterflies fly during different periods and have different host plants (Ahrné et al. 2011) and they occur in many different habitats, even forest roads, clear cuts and power line areas are important habitat for the butterflies in Sweden (Ahrné et al. 2011). Species richness is therefore considered strongly dependent on plant and habitat composition, however, in this study I was just counting number of individuals as an index of butterfly abundance, i.e. not discriminating species. If one aim is to do a count of number of butterfly species, repeated visits are needed. Since my plots were situated close together it was hard to exactly distinguish which plot the butterflies actually wanted to visit, since they mostly were detected when flying.

Arthropods are usually good candidates for estimating biodiversity because in cultivated areas they make up over 65 % of all organisms (Duelli & Obrist 1998). But there are both pros and cons regarding arthropods; some carabids and spiders are predators and therefore considered as beneficial organisms used for biological control and they are easy collected (Duelli et al. 1999). Insects and their larvae also serve as an important food source for game birds, such as the Pheasant (*Phasianus colchicus*) and the Grey Partridge (*Perdix perdix*). Therefore, an abundant arthropod fauna is beneficial and the use of insecticides is often avoided in game crops. Also, buffer strips free from pesticides may be used in a conventionally managed landscape, in order to facilitate the reproduction of game birds (Widemo 2009). In order to provide biological control of insect pests, special structures called 'beetle banks' can be used. These constitute of strips that are sown with grass without being harrowed, creating perfect habitats for overwintering predator insects and prime nesting habitat for birds. An abundant and diverse fauna of predator insects in the field can be viewed as evidence for a good potential to handle insect pests. This may be of importance to game keepers, who have to show that agricultural practices using less pesticide are economically viable options to conventional methods (F. Widemo, pers. com.). Cons with arthropods are usually described as that they do not correlate well with overall biodiversity even if they indicate good quality for biological control organisms. Further, it is both time consuming and expensive to identify arthropods in contrast to inventories of birds and plants (Duelli et al 1999; Duelli & Obrist 1998). In Switzerland spiders and carabids have been found to not correlate well with local biodiversity and even worse correlation are found when using the Shannon and Simpson index (Duelli & Obrist 1998). Flight traps were found to sample more species than pitfall traps that catch mainly predator arthropods which are more dependent on the type of cultivation instead of site biodiversity (Duelli & Obrist 1998). In the same study arthropods were found to have the highest diversity in semi natural habitats such as meadows and slightly lower values were estimated in grasslands, while uniform (monocultures) annual crop got the lowest value (Duelli et al. 1999). However, the main aim in my study was to evaluate the differences between the different crop mixes, not to make an estimate of the biological diversity in the whole area.

Conclusions and management implications

Crop mix B (70 % grass and 30 % leguminous plants), C (53 % grass, 21 % leguminous plants and 26 % other herbs), D (100 % leguminous plants), and F (87 % leguminous plants and 13 % other herbs), had the highest biomass production throughout the summer. Crop mix A (100 % grass), D, and F were the most grazed and crop mix A, and F were clearly being overused and could most likely be seen as preferred by fallow deer but this might to some extent also be true for mix D and E (91 % leguminous plants and 9 % other herbs). Accordingly, the crop mixes that produced the best and also were preferred for grazing were F and to some extent D. Rye grass seems always to be avoided by the animals and should be avoided in the crop mix. Crop mix D and E had the highest arthropod diversity of the crop mixes. In conclusion it is good to choose a crop mix optimizing as many of these traits as possible i.e. that produce well, is preferred by the game, contain flowering plants (and to let them flower before harvest) thus creating more food for arthropods and birds and thereby increasing diversity. Another way could be to sow different crop mixes to create a heterogeneous landscape and increase species richness, it can be good to mix both leguminous plants and grass. It is also important to choose a crop mix that suit your climate and soil conditions.

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Appendix 1

Plant composition of the six different crop mixes.

Crop mixes

- A: Timothy (Phleum pratense) 80 %, Narrowleaved meadow-grass (Poa pratensis) 20 %
- B: White clover (Trifolium repens) 30 %, hybrid rye grass (Lolium spp.) 70 %
- C: Perennial rye grass (Lolium perenne) 52.6 %, White clover 10.5 %, Common birdsfoot trefoil (Lotus corniculates) 10.5 %, Black medick (Medicago lupulina) 10.5 %, Chickory (Cichorium intybus) 5.3 %, Caraway (Carum carvi) 5.3 %, Ribwort plantin (Plantago lenceolata) 5.3 %.
- D: White clover 100 % (“Klonike”, “Rivendal”, “Nonouk”, “Crusader” and “Riesling”)
- E: White clover 47.9 %, Chickory 16.2 %, Alsike clover (Trifolium hybridum) 9 %, Lucerne (Medicago sativa) 9 %, Red clover (Trifolium pratense) 17.3 %, Crimson clover (Trifolium incarnatum) 9 %.
- F: White clover 50.2 %, Rape (Brassica napus) 22 %, Red clover 17.3 %, Chickory 10 %, “Weed” 0.1 %

In Swedish: Vallblandningar

- A: Timotej 80 %, Ängsgröe 20 %
- B: Vitklöver 30 %, Hybridrajgräs 70 %
- C: Engelskt rajgräs 52.6 %, Vitklöver 10.5%, Kärringtand 10.5 %, Humlelusern 10.5 %, Cikoria 5.3 % Kummin 5.3 %, Svartkämpe 5.3 %
- D: Vitklöver 100 % (“Klonike”, “Rivendal”, “Nonouk”, “Crusader”, ”Riesling”)
- E: Vitklöver 47.9 %, Cikoria 16.2 %, Alsikeklöver 9 %, Blålusern 9 %, Rödklöver 9 %, Blodklöver 9 %
- F: Vitklöver 50.2 %, Raps 22 %, Rödklöver 17.3 %, Cikoria 10 %, Ogräs 0.1 %

Appendix 2

The total biomass production (g/m^2) of the different crops sorted on crop mixes during the three periods April – November 2009, April – July 2010 and July – November 2010.

		First year establishment; November 2009		Before harvest; July 2010		After harvest; November 2010	
		Grazed	Un-grazed	Grazed	Un-grazed	Grazed	Un-grazed
Crop Mix	Crop (Swedish species name)	Mean	Mean	Mean	Mean	Mean	Mean
A	Narrowleaved meadow-grass (Ängsgröe)	95	99	24	15	0	587
A	Timothy (Timotej)	69	191	44	210	0	
A	Weed (Ogräs)	92	473	135	538	0	175
B	Hybrid rye grass (Hybridrajgräs)	214	865	121	433	27	1041
B	White clover (Vitklöver)	21	81	100	635	2	81
B	Weed (Ogräs)	185	406	42	284	0	230
C	Rye grass (Rajgräs)	248	884	143	540	79	835
C	White clover (Vitklöver)	25	12	66	307	5	37
C	Common birdsfoot trefoil (Kärringtand)	0	0	21	49	1	184
C	Ribwort plantin (Svartkämpe)	17	196	1	12	1	37
C	Chickory (Cikoria)	0	25	9	5	1	12
C	Black medick (Humlelusern)	4	61	0	0	0	0
C	Weed (Ogräs)	126	49	18	313	1	123
D	White clover (Vitklöver)	16	184	140	499	0	184
D	Weed (Ogräs)	140	692	75	377	0	692
E	White clover (Vitklöver)	17	56	104	308	0	65
E	Red clover (Rödklöver)	23	84	0	2	0	299
E	Alsike clover (Alsikeklöver)	0	9	4	0	0	0
E	Chickory (Cikoria)	4	224	21	103	0	75
E	Black medick (Humlelusern)	0	0	0	0	0	0
E	Weed (Ogräs)	146	561	66	523	0	617
F	White clover (Vitklöver)	5	14	148	150	0	33
F	Red clover (Rödklöver)	0	0	0	0	0	150
F	Rape (Raps)	0	9	0	0	0	0
F	Chickory (Cikoria)	0	9	5	33	0	38
F	Weed (Ogräs)	148	437	73	287	0	254

Appendix 3

Arthropods found during the summer 2010 at Koberg on all six fields, using the methods pitfall traps, beating net and transects.

			Crop mix					
Order	Family (*suborder)	Species	A	B	C	D	E	F
Total: Araneae			170	157	154	132	217	152
	Araneidae	Araneus sturmi	0	1	2	0	1	0
		Dipoena tristis	0	1	0	0	0	0
		Larinioides cornutus	1	0	0	0	0	0
		JUVENILES	2	0	1	0	1	0
	Dictynidae	Dictyna arundinacea	1	0	0	0	0	0
	Theridiidae	Achaearanea riparia	0	1	1	0	1	0
		Neottiura bimaculata	1	0	0	0	0	0
		Robertus arundineti	0	0	0	0	2	0
		Theridion impressum	1	2	1	4	1	0
		Theridion pictum	0	0	0	1	0	0
		Theridion varians	0	0	1	1	0	0
		Theridion sp.	1	1	0	2	0	0
		JUVENILES	7	7	10	2	9	6
	Linyphiidae	Araeoncus humilis	0	0	0	1	0	0
		Bathyphantes gracilis	0	0	0	0	1	0
		Bathyphantes setiger	0	0	0	0	0	1
		Dismodicus bifrons	1	0	1	1	1	1
		Dismodicus elevatus	2	2	1	0	0	0
		Erigone atra	15	9	5	5	8	15
		Erigone capra	1	0	0	0	1	0
		Erigone dentipalpis	13	15	13	9	27	18
		Erigone longipalpis	0	0	0	0	1	0
		Gongylidiellum murcidum	1	0	0	1	1	0
		Hypomma cornutum	0	0	0	0	0	1
		Lepthyphantes mengei	0	0	0	1	0	0
		Linyphia triangularis	0	0	0	0	4	0
		Meioneta rurestris	0	0	0	3	0	0
		Microlinyphia pusilla	2	5	4	1	0	2
		Oedothorax agrestis	0	0	0	0	0	1
		Oedothorax apicatus	16	18	14	12	30	8
		Oedothorax fuscus	5	7	1	3	7	13
		Oedothorax retusus	5	1	4	4	3	5
		Pelecopsis parallela	0	0	0	0	0	2
		Savignya frontata	1	2	1	0	0	0

Order	Family (*suborder)	Species	Crop mix					
			A	B	C	D	E	F
Araneae		Silometopus elegans	0	0	0	0	1	0
		Silometopus reussi	0	0	0	1	0	0
		Tenuiphantes cristatus	0	0	0	0	0	1
		Tenuiphantes flavipes	0	0	0	0	1	0
		Tenuiphantes sp.		0	0	0	1	0
		Walckenaeria vigilax	2	0	0	0	1	0
		JUVENILES	6	2	3	9	8	4
	Tetragnathidae	Meta sp.	0	0	1	0	0	1
		Pachygnatha clercki	1	2	0	1	3	2
		Pachygnatha degeeri	1	0	1	1	5	1
		Tetragnatha extensa	1	5	4	3	6	1
		JUVENILES	1	3	1	0	2	0
	Lycosidae	Pardosa agrestis	7	2	15	13	24	14
		Pardosa amentata	8	2	2	5	8	1
		Pardosa fulvipes	2	1	2	3	1	1
		Pardosa lugubris	0	0	0	0	1	0
		Pardosa palustris	10	6	6	6	6	6
		Pardosa prativaga	30	50	39	22	31	35
		Pardosa pullata	5	4	5	3	6	2
		Pardosa sp.	1	0	0	0	2	2
		Pirata piraticus	1	2	1	1	1	1
		Trochosa ruricola	0	0	0	1	2	0
		Trochosa terricola	0	0	0	1	0	1
		JUVENILES	8	3	6	4	4	2
	Pisauridae	Dolomedes fimbriatus	1	0	0	0	1	1
	Philodromidae	Thanatus sp.	2	0	0	0	0	1
	Zoridae	Zora sp.	0	0	1	0	0	0
		JUVENILES	0	0	1	0	0	0
	Thomisidae	Diaea dorsata	0	0	0	0	1	0
		Misumena vatia	0	1	0	0	0	0
		Ozyptila sp.	0	0	1	0	0	0
		Xysticus audax	0	0	0	1	0	0
		Xysticus cristatus	0	2	3	3	1	1
		Xysticus ulmi	1	0	1	0	0	0
		Xysticus sp.	3	0	0	3	0	0
		JUVENILES	3	0	1	0	1	1

Order	Family (*suborder)	Species	Crop mix					
			A	B	C	D	E	F
Total: Coleoptera			203	255	204	302	296	295
	Carnivorous beetles		3	2	3	3	4	2
	Herbivorous beetles		138	167	118	207	186	198
	Staphylinidae		13	21	13	22	13	21
	Carabidae		49	65	70	70	93	74
		Acupalpus dorsalis	0	0	0	0	0	1
		Agonum muelleri	3	2	2	6	5	6
		Agonum sexpunctatum	0	0	0	1	0	0
		Amara communis	0	0	0	0	0	1
		Amara famelica	0	1	0	0	1	0
		Amara similata	14	30	43	16	49	16
		Anisodactylus binotatus	0	0	0	0	0	1
		Bembidion aeneum	7	13	4	16	10	12
		Bembidion lampros	9	5	7	6	7	8
		Carabus granulatus	0	1	0	0	0	0
		Clivina fossor	1	1	0	3	2	1
		Harpalus affinis	0	1	0	1	0	0
		Harpalus rufipes	4	2	2	2	3	3
		Loricera pilicornis	6	6	3	6	5	16
		Nebia brevicollis	1	1	1	4	2	0
		Pterostichus cupreus	2	2	6	7	2	6
		Pterostichus niger	1	0	1	2	3	2
		Trechus discus	0	0	0	1	0	0
		Trechus micros	0	0	0	0	0	1
		Trechus quadristriatus	0	0	1	0	0	0
		Trechus secalus	0	0	0	0	1	0
Total: Diptera			114	104	81	111	116	125
	Culicidae		5	8	10	7	11	9
Total: Hymenoptera			38	37	28	41	29	33
	Apidae		13	13	17	21	14	16
	Formicidae		5	5	5	3	2	12
	Symphyta*		2	3	5	4	7	2
	Apocrita*		31	29	18	32	19	19

Order	Family (*suborder)	Species	Crop mix					
			A	B	C	D	E	F
Total: Hemiptera			140	172	146	239	204	259
	Heteroptera*		94	121	94	183	162	182
	Reduviidae		14	19	27	20	6	21
	Pentatomidae		0	0	2	2	2	4
	Saldidae		12	2	4	2	10	1
	Miridae		82	118	114	179	151	177
		Capsus	1	9	4	2	2	2
		Lygus	29	14	13	32	25	29
		Polymerus	13	25	9	70	40	44
		Stenodema	39	70	62	75	84	102
	Homoptera*		32	32	25	36	36	56
Total: Lepidoptera			12	13	18	13	12	15
Total: Collembola			104	133	138	110	182	125