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Restoration of semi-natural grasslands, a success for phytophagous beetles (Curculionidae)

Magdalena Steiner

Master´s thesis • 30 hec • Second cycle, A2E
EnvEuro Master Programme Soil, Water and Biodiversity
Uppsala 2013
Independent project/Degree project / SLU, Department of Ecology 2013:15

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Credits:	30 hec
Level:	Second cycle, A2E
Course title:	Independent Project in Environmental Science - Master's thesis
Course code:	EX0431
Programme/education:	EnvEuro Master Programme Soil, Water and Biodiversity

Place of publication: Uppsala
Year of publication: 2013
Cover picture: Magdalena Steiner (Site:Läby), James Losey (Protapion fulvipes)
Title of series: Independent project/Degree project / SLU, Department of Ecology
Part no: 2013:15
Online publication: http://stud.epsilon.slu.se

Keywords: weevils (Curculionidae), semi-natural grasslands, restoration success, phytophagous beetle composition, biodiversity, specialist, generalist, feeding preferences, Sweden

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Contents

1 Abstract

Semi-natural grasslands have rich plant and animal communities of high conservation value. The continuity and maintenance of these habitats depend on traditional agricultural methods, which nowadays give low economic output. Therefore biodiversity restoration measures in abandoned semi-natural grasslands have been implemented, which pay farmers for reestablishing and maintaining a semi-natural grassland biodiversity. Between 2000 and 2006 around 3500 ha of semi-natural grasslands were restored in Sweden. The main aim is to conserve the biodiversity, which is well known for its dependence on old agricultural lands. This study aimed to evaluate if these measures may also work successfully for the conservation of diversity of weevils, a phytophagous beetle family. This is a neglected taxon, when it comes to biodiversity assessments of restored grasslands in Europe, although many of them are grassland associated and red listed. Numerous weevils are dietary specialized or closely associated with certain plant genera or even single species, which are often habitat specialized as well. Our study was done by comparing the weevil species diversity and composition of abandoned, old restored, recently restored and continuously managed sites. In total 24 sites were included in the survey. The beetles were collected by sweep-netting. We found no differences in species richness between studied management categories. However the species composition of abandoned sites was significantly different compared to the restored and continuously managed sites. Moreover, the abandoned sites were dominated by polyphagous species whereas the restored and continuously managed sites contained more monophagous species. Our conclusion is that there is a restoration success targeting the phytophagous weevil community of semi-natural grasslands and this justifies the expenses connected with restoration measures.

Keywords: weevils (Curculionidae), semi-natural grasslands, restoration success, phytophagous beetle composition, biodiversity, specialist, generalist, feeding preferences, Sweden

2 Introduction

As many extensively managed, semi-natural grasslands in Europe are facing abandonment or agricultural intensification, which leads to biodiversity loss as a consequence (Silva et al. 2008), restoration and maintenance measures are implemented on regional, national and European Union level. These measures are connected with high expenditures in form of compensatory payments (European Commission 2012). Therefore it is necessary to evaluate if they are successful and the money well spent. This study investigates whether there is a restoration success of phytophagous beetle compositions (Curculionidae) in semi-natural grasslands in Sweden.

2.1 Semi-natural grasslands

Grasslands are habitat types with dominated vegetation by graminoids (Silva et al. 2008). Worldwide grasslands are estimated to constitute 40.5 % to the worlds land cover. Most of the grasslands in Europe are modified by human influence such as agriculture and are therefore categorized as semi-natural grasslands (Silva et al. 2008). Semi-natural grasslands consist of unsown, grassland adapted plant communities but their maintenance depends on human management measures. Such management measures are usually not targeting improvement of productivity but are therefore based on extensive farming methods and include grazing or hay cutting regimes (Silva et al. 2008). Semi-natural grasslands are pastures, characterized by not being substantially modified by intensive agricultural activities but rather managed by mild management methods. Mild management is characterized by low input management and this includes e.g. fertilization if applied with manure from organic farming, drainage, if undertaken, as shallow surface drainage and pesticides and herbicides are not used on a regular base (King 2010). The grazing species of domestic animals are usually traditional breeds. Compared to improved grasslands semi-natural grasslands usually do have a lower primary production (Isselstein et al. 2005).

Semi-natural grasslands are very valuable habitats concerning conservation of biodiversity. Since they usually provide a high plant diversity and structural diversity, the invertebrate diversity is consequently high as well (Schaffers et al. 2008).

2.2 Biodiversity and ecosystem functions in semi-natural grasslands

Besides moral and ethical reasons to conserve the planet and its biodiversity, species richness plays an essential role in sustaining multiple ecosystem processes and functions (Zavaleta et al. 2010). These functions are inevitable for the self-sustainability of ecosystems and therefore important for the survival of all inhabiting organisms (Zavaleta et al. 2010). Ecosystem functions such as pollination, nutrient cycling or primary production are carried out by living organisms (e.g. bees, mycorrhiza, grass species, etc.) which are part of the ecosystem. The most common pattern of interaction between species richness and ecosystem function is hypothesized to be an asymptotic relation. That means the more species are in an ecosystem the more resources are used and physico-chemical processes are conducted. This hypothesis is valid until a certain level of species richness is reached (Aber & Melillo 2001). Since one ecosystem function (e.g. decomposition) is carried out by several different organisms in slightly different ways there is certain redundancy in fulfilling these functions. Consequently this interaction is following an asymptotic curve. However it was shown by several studies that the species richness of ecosystems determines its resilience and ability to cope with disturbances (Aber & Melillo 2001; Zavaleta et al. 2010). Therefore to support the self-sustainability of ecosystems it is necessary to preserve them with all their abiotic and biotic components.

Semi-natural grasslands (Hopkins 2009) contribute, besides primary production, more importantly to a wide range of other ecosystem services. Considering the MEA (Millennium Ecosystem Assessment 2005) ecosystem service classification one can identify 4 different types of ecosystem services performed in grasslands. Provisioning services such as habitat provision for species or food production in terms of fodder as well as indirectly by diary or meat (Hopkins 2009). Grasslands act also as a reference for genetic material such as seeds for sowing measures in restoration actions. There are furthermore numerous supporting services performed. Amongst these are denitrification, mineralization, carbon fixation through photosynthesis, decomposition, soil formation, filtering and storage of water and nutrient cycling (Díaz et al. 2006). Regulatory ecosystem functions are contributing to the stability of the natural environment by regulating air quality through mitigating greenhouse gasses such as CO_2 via sequestration, and CH_4. But semi-natural grasslands also contribute to stability by mitigating soil erosion and water run-off through water retention (Hopkins 2009). Furthermore undisturbed ecosystems are increasing the stability by building a higher resistance against invasive species (Zavaleta et al. 2010). The last class cultural services are non-material and include services which are connected to human health and wellbeing such as recreational opportunities or aesthetic experiences (Hopkins 2009).

Invertebrates contribute crucially to all of these functions and processes in ecosystems (Urbanska et al. 1997). Pollination is one of the most important functions performed by grassland insects since humans depend directly on crop pollination. Grassland invertebrates inhabit a main function in pollinating plant species and therefore secure the plants persistence and the crop production (Öckinger & Smith 2007). Other examples for carrying out ecosystem functions are Collembola and their contribution to decomposition and nutrient turnover or ants and their important role as diaspore dispersers (myrmecochory) (Urbanska et al. 1997).

The sustainable functioning of ecosystems includes numerous interaction processes. These processes can be issues of trophic interactions such as predation or herbivory, herbivore-induced plant responses but also non-trophic interactions are shaping the ecosystem such as insect ecosystem engineers and mutualistic interactions (Ohgushi 2008). Insect herbivore-induced plant responses are good examples demonstrating the complex indirect-interaction webs in ecosystems. For instance feeding processes can change the nutritional quality or secondary plant compounds and this in turn may alter the feeding herbivory community. Or herbivore-induced secondary growth may provide new resources for substrate specialized species (Ohgushi 2008).

2.3 Threats to grasslands

Extensively managed semi-natural grasslands are approximately 50% less productive in terms of primary production compared to improved grasslands (Hopkins 2009). This is in general economically unfavorable and the main reason for decreasing grassland areas and deterioration of existing semi-natural grasslands habitats. An increasing demand for agricultural goods and the economically unfavorable extensive management practices led to intensification or abandonment of grasslands. Afforestation, changes in livestock density, lowering of water tables and nitrogen deposition are further threats to grassland habitats (Silva et al. 2008; Isselstein et al. 2005).

Abandonment of pastures leads to a change of plant species composition (Peco et al. 2005) and in later successional stages to an increasing cover with shrubs and trees in those grasslands (Öckinger et al. 2006). This deteriorates the grassland habitat and may result in further alteration of species compositions or species loss. Therefore restoration actions such as removal of woody plants and management actions like the reintroduction of grazing schemes are implemented for maintaining these areas (Öckinger et al. 2006).

2.4 Agri-environmental schemes and sustainable landuse

The **Europe 2020** priorities aim for a green and sustainable development including the halt of biodiversity loss. To achieve this goal several incentives, like the **Flora-Fauna-Habitat (FFH)**, the **Water Framework Directive (WFD)** or the **Biodiversity Action Plans (BAP)**, were launched to provide strategies for halting biodiversity loss. Concerning the agronomic sector agri-environmental schemes were compulsory introduced for EU member states in 1992 as part of the national rural development plans (European Commission 2012). They are a key element to include environmental concerns in the **Common Agricultural Practice (CAP)**. Agri-environmental measures were launched for two main objectives: to reduce environmental risks, like fertilizer or pesticide applications, and to preserve nature and cultivated landscapes (European Commission 2005). The main concept of the schemes is to provide compensatory payments for farmers, who commit themselves, on a voluntary basis to environmental friendly or biodiversity favoring farming methods. Examples for these commitments are environmentally favorable extensification of farming, management of low-intensity pasture systems, preservation of landscape features such as hedges or ditches and conservation of high-value habitats and their inhabiting biodiversity (European Commission 2012). The agri-environmental payments are co-financed by the European Union, with 85% - 60%, and the member states (European Commission 2005). According to the European Commission 22% of the expenses of rural development, which is approximately 20 billion EUR, were spent on agri-environmental measures within 2007-2013. In 2009, 451,519 ha of semi-natural habitats were subsidized by agri-environmental schemes in Sweden (European Economic Interest Group 2012). The average compensatory payments were about 400 €/ha for grazing and 1000 €/ha for mowing in the year of 2012 (European Economic Interest Group 2012). The member states of the European Union are not equally involved in agri-environmental schemes (Figure 1). Finland, Sweden, Luxemburg and Austria have large proportions of more than 75% of the total utilized agricultural area involved in agri-environmental schemes in contrast to Belgium, Netherlands, Spain and Greece where the areas are less than 10% (European Environmental Agency 2006).

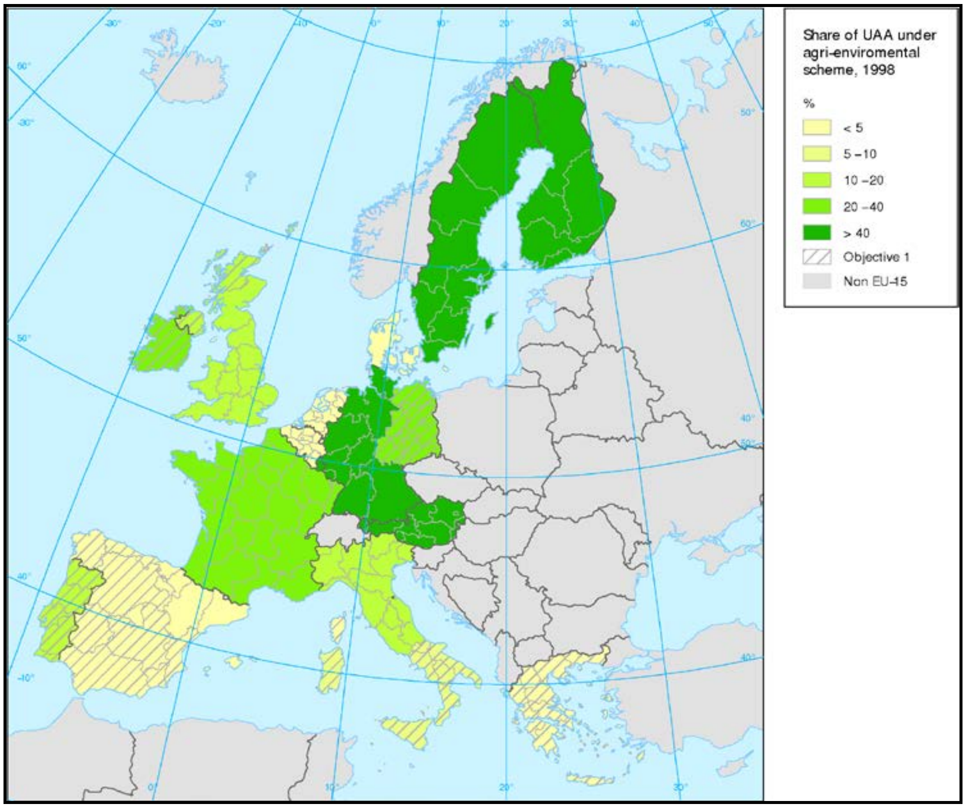

Figure 1 Relative percentage of utilized agricultural area (UAA) under agri-environmental schemes (EU-15).

© EEA 2001, on the basis of data of the European Commission, DG Agriculture.

2.5 Restoration and management of grasslands

Restoration actions of semi-natural grasslands aim for reestablishing grassland habitats with typical, grassland adapted plant and animal species compositions and with the performance of associated ecosystem functions. In most cases it is not possible to restore the same type of ecosystem. The result of such management actions is often rather a system which is imitating a continuously managed system and its functions but differs in community composition (Jordan et al. 1990).

As grassland habitats in Europe are mainly existing because of human activity, the species communities are also referred to as plagioclimax communities, which means that without human intervention the plant communities would change into a further succession state and finally change into a woodland climax community (Mortimer et al. 1998).

To hold succession in restored grasslands in the desired biodiversity rich state it is necessary to implement maintenance schemes. There are several management options applied to maintain grassland habitats. One common approach is the frequent removal of above ground biomass. Such methods can be different grazing schemes differing in intensity, grazing species and mowing schemes varying in time of the year and frequency (Wahlman & Milberg 2002). Burning is one comparatively cheap method to remove biomass but studies which evaluated this method did not confirm the same positive effects on biodiversity of plants as extensive grazing or hay cutting regimes (Wahlman & Milberg 2002).

Today (Condé et al. 2003) approximately 200 000 ha of semi-natural grassland are left in Sweden. This area represents ca. 10% of the grassland area in the beginning of the twentieth century (Bernes 1994).

Grassland restoration projects have been increasingly implemented within the last decade in European countries induced by LIFE, WWF, local conservation programs (e.g. Swedish EPA or LONA) and directed by agri-environmental incentive schemes. According to Andersson (2009) 3500 ha of semi-natural grasslands in Sweden were restored between 2000 and 2006.

2.6 Restoration success

In 2004 the Society for Ecological Restoration International Science & Policy Working Group (SER) published the "SER International Primer on Ecological Restoration". This document provides a guideline for assessing restoration success. According to the Primer a successfully restored system should fulfill the following attributes: (1) a similar species assemblage and community structure as the reference site; (2) a species consistency with focus on indigenous species; (3) presence of all functional groups or the potential for their colonization; (4) physical environment has the capacity to sustain reproducing populations; (5) system functions normally; (6) the restored system is integrated in a larger matrix or landscape; (7) potential threats have been eliminated or reduced; (8) system is resilient to natural disturbances; (9) the ecosystem is self-sustainable to the same degree as the reference system (SER 2004).

In reality it is in most cases not possible to measure all the SER attributes (Ruiz-Jaen & Aide 2005) due to a lack of time and financial resources. Most studies, about evaluation methods for restoration success, measured attributes that can be categorized as diversity, vegetation structure or ecological processes and these were seen to be the most important ones for long-term persistence of ecosystems (Ruiz-Jaen & Aide 2005). For future restoration success evaluation it was suggested that at least two variables within each category should be included. Furthermore Ruiz-Jaen & Aide (2005) suggest to include at least two reference sites to cope with variation concerning spatial and temporal dynamics of an ecosystem.

So far studies about the effects of abandonment, restoration success and management methods have been carried out for few organism groups such as vascular plants and butterflies (Öckinger et al. 2006), a few beetle families such as carabids, weevils and Chrysomelidae (Woodcock et al. 2010).

In a study by Öckinger et al. (2006) it was investigated how plants and butterflies specialized on grassland ecosystems are affected by abandonment, restoration and management. It was shown that plants and butterflies were negatively affected by abandonment in terms of lower species richness as a consequence of increasing establishment of woody plants and shrubs. Furthermore they found out that the species richness of both groups was positively correlated with increasing vegetation height and that the species composition differed depending on grazing species. Sheep affected species richness more negatively than cattle and horses. They further suggest to prioritize sites of a younger succession stage for restoration actions for more efficiency than restoring sites with an older succession stage (Öckinger et al. 2006).

Wahlman & Milberg (2002) found out that the different management schemes such as continued grazing, mowing every year, mowing every third year, annual spring burning and removal of woody plants resulted in grasslands with very different vegetation types. Among these the annually mown sites and grazed sites had the highest species diversity.

Another study, by Lindborg & Eriksson (2004) aimed to investigate the effects of restoration on 10 plants, which are used as indicator species in grazed grasslands. They found out that an abundance of shrubs and trees to a certain amount as well as time since restoration have a positive effect on species richness and density. They also suggest *Campanula rotundifolia* as an indicator for improved habitat quality since it occurred with increasing abundance with time since restoration. Due to the fact that short-living species were rarely found they hypothesize that for these species it may be necessary to recolonize from surrounding habitats and therefore the landscape context may be important for successful reintroduction.

There were also some studies carried out investigating the invertebrate diversity in restored grasslands. Batáry et al. (2007) investigated the effects of grazing intensity and landscape complexity on three beetle families (Carabidae, Chrysomelidae and Curculionidae) in extensively and intensively grazed cattle pastures in the Hungarian Great Plain. They found out that the species richness of Chrysomelidae was higher in extensively grazed sites than in intensively grazed sites. Increasing grassland coverage in within a 500 m radius had a negative effect on generalist species. Furthermore the species composition of beetle assemblages was affected by landscape composition since in species level analyses landscape effects were shown. Thus they suggested that the biodiversity conservation in these habitats requires a landscape perspective as well as a management perspective.

Another study (Harvey et al. 2008) concerning the effects of different vegetation succession scenarios on beetle fauna showed that carnivorous Carabids preferred sites with an open vegetation structure and that phytophagous species favor sites with higher plant diversity. The study was conducted over 3 years and it showed also that the year of sampling had a great effect on the species composition and abundance of their relative trophic guilds, where carnivorous species were more abundant and diverse in the first year and herbivorous species had a peak in the third year. The highest overall species richness was observed in the second year and is described as an omnivore species composition. These changes in abundance of the different trophic guilds were mainly explained by plant species richness and habitat heterogeneity. Therefore it was suggested for future research to consider the importance of structural variation of the plant diversity as this affects populations of insect predators (Harvey et al. 2008).

Vessby et al. (2002) investigated if the number of species of the six different taxa plants, birds, butterflies, bumblebees, ground beetles, and dung beetles covary in semi-natural landscapes. The results showed that neither grassland plant species richness nor any other surveyed taxon showed reliable correlations and therefore none of these groups can be used as a biodiversity indicator for the other included groups. They suggest that grassland management action should be targeted towards a wide spectrum of grassland characteristics to provide for a wide spectrum of taxon demands.

Hemerik and Brussaard (2002) investigated the effects of succession on the soil macro-invertebrates and found out that the Carabid fauna of semi-natural grasslands was strongly affected by short-term varying abiotic factors and that polyphagous, predatory Carabids appeared to be largely independent from vegetation succession. The diversity of adult weevils in contrast showed that they are clearly affected by long-term successional stage such as the nutrient status of the grasslands. This can be explained by the fact that weevils are often specialized herbivores and therefore are strongly dependent on the vegetation composition which is in turn strongly affected by the nutrient status.

Woodcock et al., (2010) conducted a study to investigate the role of landscape context and management on the success of restoring phytophagous beetle assemblages in grasslands. They found that the beetle restoration success increased over time and was positively correlated with restoration success of plant species. It was also shown that restoration success was twice as successful in landscapes with high proportion of species rich grasslands as in those with low proportions.

2.7 Why studying weevils

With approximately 60 000 species weevils are the most species rich family of the animal kingdom (Rheinheimer & Hassler 2012). According to Freude, Harde and Lohse (1981) there are ca. 1400 species in Europe. According to the Swedish red list 2010, in Sweden there are about 618 species of the superfamily Curculionoidea including bark beetles (approx. 80 species) (Gärdenfors 2010). About 137 species are red listed, respectively to the categories 17 are categorized as Data Deficient, 6 Regionally Extinct, 2 Critically Endangered, 6 Endangered, 26 Vulnerable and 80 species as Near Threatened (Gärdenfors 2010).

Weevils are almost exclusively feeding on plants, with a few exceptions within the genera *Anthribus, Ludovix, Tentegia* and Trachyphloeus, which are feeding on insect eggs or are coprophagous (Rheinheimer & Hassler 2012). Many species are specialized in terms of their host and feeding plants. Some of them are specialized on one genus or subfamily of plants whereas others are highly specialized and monophagous on one plant species. Since many species have high requirements in terms of habitat quality, Rheinheimer & Hassler (2012) suggest to use those species as indicators for assessing habitat quality. Due to their high abundance in almost every habitat they play an important role in the food chain as prey for other organisms as well as consumers in the guild of phytophagous insects. Therefore weevils can have a major influence on ecosystems. This was observed in several oak forests where specialized species occurred in high numbers and caused a complete loss of an acorn generation (Rheinheimer & Hassler 2012). For these reasons they play also an important role as pest species in forestry and agriculture. Their specialized feeding behavior additionally led to their application in the field of biological control against neophytes (Rheinheimer & Hassler 2012).

2.8 Aim and objectives of the study

There are a few studies describing the effects of grassland management on phytophagous beetles (Woodcock et al. 2005; 2010) and other insects (Kruess & Tscharntke 2002; Öckinger et al. 2006) in semi-natural grasslands. Weevils are so far a less studied group, when it comes to biodiversity assessments of restoration success in Europe, even though many of them are grassland associated and red listed.

Numerous weevils are dietary specialized or closely associated with certain plant genera or even single species which are often habitat specialized as well (Rheinheimer & Hassler 2012). Restored semi-natural grasslands have a high and valuable and in most cases specialized plant community (Cousins & Eriksson 2001). Therefore it is interesting to investigate if the weevil fauna is also as diverse and valuable.

This study aimed to investigate if there was a restoration success in restored semi-natural grasslands concerning the weevils. This is done by comparing the weevil diversity and composition of four different management categories of abandoned pastures, old restored pastures, recently restored pastures and continuously managed sites. Additionally was tested if other landscape characteristics or site features have influence on the species diversity and composition. Restoration success was defined as reassembling the weevil community of continuously managed sites. Therefore continuously grazed sites were used as reference group.

The scientific questions to be addressed in this experiment were:

(1) Do the number of species and number of individuals differ between plots of different management categories?

(2) Do other landscape and site characteristics influence the number of species or number of individuals?

(3) Does the species composition differ between plots of different management categories?

(4) Do the species compositions differ in terms of their feeding preferences classified as monophagous, oligophagous and polyphagous?

Hypothesis

H1: Management categories differ significantly in number and composition of species. Where a higher number of species is hypothesized in restored and continuously managed sites than in abandoned sites.

H0: Management categories do not differ significantly concerning number and composition of species.

3 Materials and Methods

This study is done within an ongoing research project ‘Habitat restoration in fragmented landscapes: Effects on biodiversity and ecosystem functions’ by Erik Öckinger and Marie Winsa, who also chose the sites to be included in the study. For the selection of the study sites, information was gained from a geographical data base provided by the Swedish Board of Agriculture, County Boards and municipalities. To identify the continuously grazed and abandoned sites they used a Swedish geographical data base of semi-natural pastures (www.jordbruksverket.se/tuva). In combination with information from the County Boards, the Uppland foundation and the municipalities in the region, restored pastures, where the landowners had received economical compensation to restore the pastures after abandonment, could be identified and selected. The sites were located in the counties of Uppsala, Stockholm and Västmanland.

3.1 The sites

Sweden belongs to the boreal biogeographic region in Europe together with Finland, parts of Norway, Russia and the Baltics (Condé et al. 2003). The habitats of the boreal region are estimated to consist of 58% forest, 17% agriculture and gardens, 6% rivers and lakes, 2% heath/shrub land, 2% wetlands, <1% coastal habitats and 14% grasslands (Condé et al. 2003). All the study sites were in the provinces of Uppsala and Västmanland. The sites (Figure 2) were situated in the boreo-nemoral vegetation zone (Rydin et al. 1999). The forests of this region are dominated by spruce *(Picea sp.)* and pine *(Pinus sp.)* but also have widely spread stands of deciduous trees with pedunculate oak *(Quercus robur)*, silver birch *(Betula pendula)*, aspen *(Populus sp.)* and on richer soils also small-leafed linden (*Tilia chordata)*, Norway maple *(Acer platanoides)*, hazel *(Chorylus avellana)*, elm and ash *(Fraxinus sp.)* can be found frequently (Rydin et al. 1999). Many of these forest areas were formerly used for grazing purposes and are therefore characterized by semi-cultural elements by being open and not overgrown by shrubs. The herbaceous vegetation layer is rich in species diversity and common species are *Pteridium aquilinum* and *Calamagrostis arundinacea* (Rydin et al. 1999).

There are several types of grasslands in Sweden differing in wide ranges of light conditions, pH, soil depth, moisture, nutrient availability and geographical region. Our study sites were representatives of dry and mesic grasslands. Dry, grazed grasslands in the boreal zone typically inhabit *Festuca* dominated plant communities with species such as *Deschampsia flexuosa, Festuca ovina, Agrostis capillaris Danthonia decumbens* and *Nardus stricta* (Rydin et al. 1999). Mesic, extensively managed grasslands in central Sweden are mainly characterized by *Agrostis capillaris-Alchemilla spp. Rhytidiadelphus squarrosus* communities together *Achillea millefolium* and *Trifolium repens* (Rydin et al. 1999).

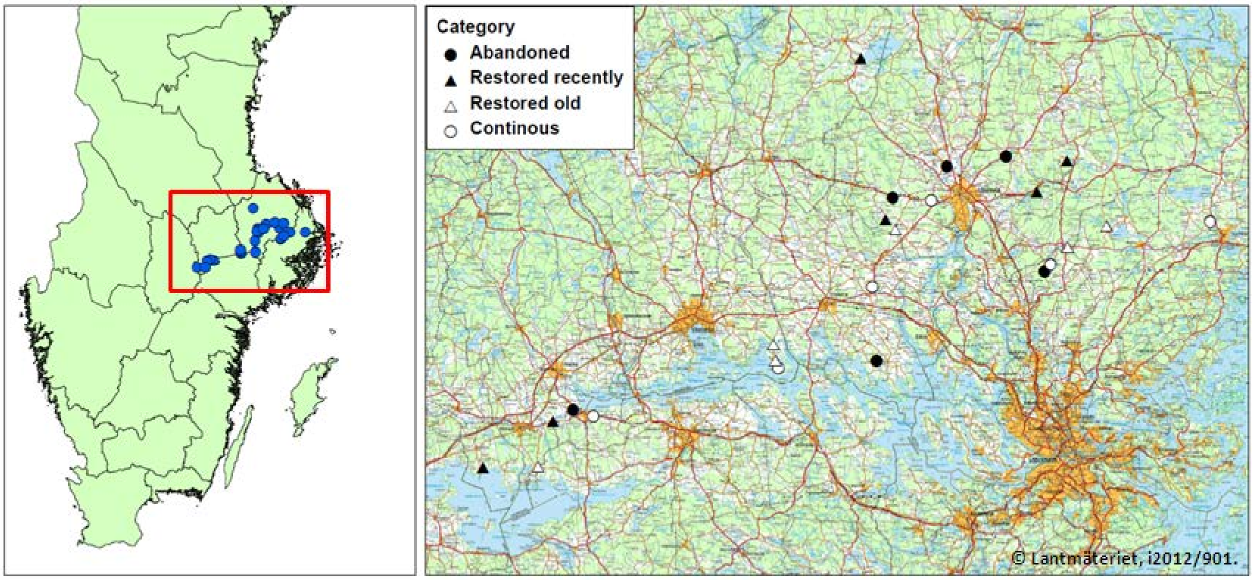

Figure 2 The locations of the study sites in the provinces of Uppland and Västmanland, Sweden.

The sites of this study ranged from the smallest with 0.787 ha to the largest with 7.601 ha. The age since restoration of the recently restored sites ranged from 3 to 7 years and in the old restored sites between 10 and 17 years. In total 24 sites (see Appendix 1) were surveyed including 6 repetitions of each category.

The study sites were categorized in four management categories:

- Continuously grazed pastures (reference)
- Old restored (10-17 years ago)
- Recently restored (3-7 years ago)
- Abandoned not restored (overgrown)

The variation of the vegetation structure was fairly high within and between the management categories (Figure 3). This can be explained most probably by different management schemes of the sites, differing in introduction of domestic grazing species, number of grazing individuals or frequency of grazing. The abundance of woody plants was often high in abandoned sites whereas in restored and continuously managed sites, woody plants were only scattered. In abandoned sites the time of abandonment, ranging from 22 to 51 years, was thought to be an important factor influencing the vegetation structure, since with abandonment a succession process started and more woody plants were colonizing the site (Öckinger et al. 2006). Therefore some of the old abandoned sites were similar to a forest habitat whereas the more recently abandoned sites were open and more sun exposed.

Figure 3 Pictures of study sites representing three management categories, on the upper left side a continuously managed site 'Läby', recently restored 'Ahelzons Hage' (right) and abandoned 'Sjöängen Engsö' (below).

3.2 Sampling

The weevils were collected by sweep netting (Figure 5) during the 10th to the 19th of June 2013 with sunny, warm weather conditions. A prior recognition of the terrain was performed to obtain an overview of the heterogeneity of the vegetation structure of each site. Four experimental plots (A, B, C, D) at each site (Figure 4) were chosen so that they were representing the on-site, plant species rich, homogenous herbal vegetation layer, large enough to not sweep-net the same spot twice. The sweep-netting of the herbal vegetation layer in each plot was random and standardized by a time of five minutes, and thus not by area. Mesic spots were chosen for sweep-netting and structural features such as hills, depressions, very moist or dry spots were avoided.

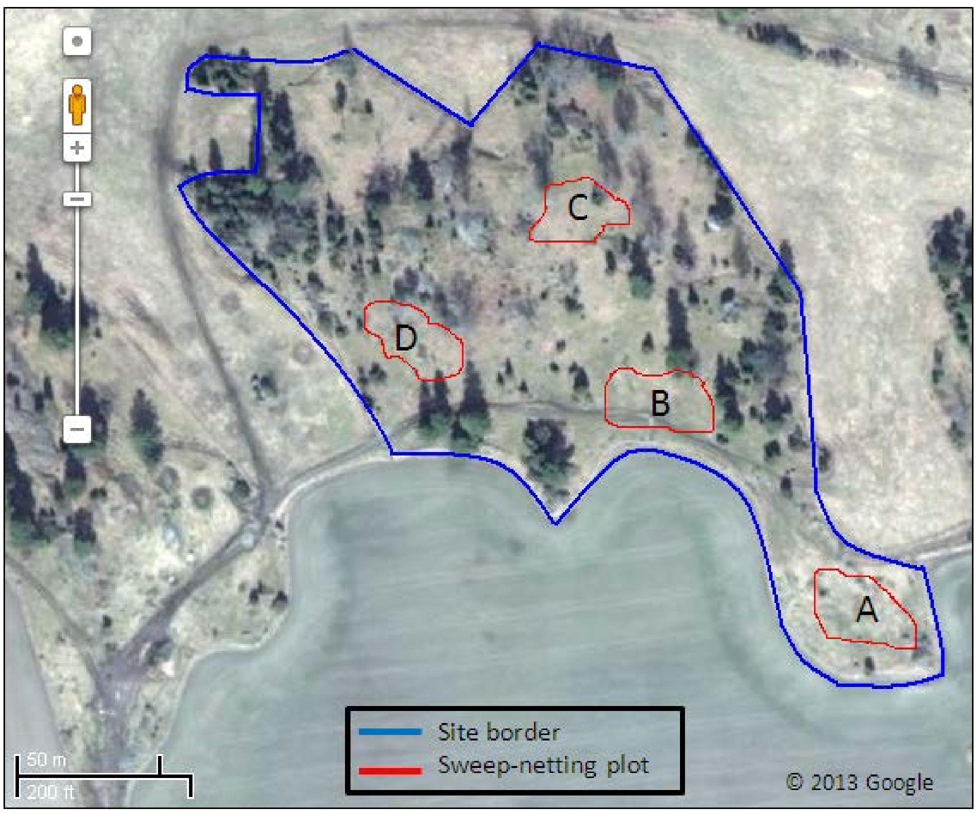

Figure 4 Outline of the sweep-netting in the field. Here shown for the continuously managed site 'Graneberg Litslena'. The blue line represents the border of the semi-natural grassland site and the red line marks the four plots (A, B, C & D) with the approximate area of sweep-netting.

Horváth et al. (2002) found out that weevils are sensitive to edge effects, meaning a higher species diversity in the edge of the sites. To obtain representative results it was decided to avoid sampling in those zones by considering a buffer zone of 10 meters.

Figure 5 The weevils were collected by sweep-netting the herbal vegetation layer.

3.3 The environmental variables

The environmental variables (Table 1) were total area of the site [Area], proportion cover of semi-natural grassland within a circular area of a radius of 5km [Prop_5] and 1km [Prop1], count of plant species recorded in a plant diversity inventory on the sites [Count_pl], time of abandonment in years since abandonment or years of abandonment before restoration [tAbandon], Vegetation height [Veg_h] measured four times at each site and the nominal variable management category [Category] which consists of four classes namely continuously managed, restored old (from 10 to 17 years), restored young (from 3 to 7 years), abandoned and abundance of *Campanula rotundifolia* [Camp_abu]. The abundance of *Campanula rotundifolia* was included because it is suggested (Lindborg & Eriksson 2004) to be an indicator species for good habitat quality of semi-natural grasslands. A Pearson correlation of Campanula abundance and the age of the restored sites was conducted in a pre-analysis. Although the moderate positive correlation (Pearson correlation = 0.522) was not significant it had a low p-value (p=0.081).

Total area of each study site and the proportion of semi-natural grassland in a circular area with a radius of 5km and 1km surrounding each study site were calculated with GIS and this data was obtained from inventories of each meadow, by Marie Winsa and Erik Öckinger, as well as the management category.

The data for the variables count of plant species and *Campanula* abundance were also obtained from the vascular plant inventory in 2011, by Marie Winsa and Erik Öckinger. The plants were recorded in 1m²-plots with 10 plots per site.

The time of abandonment was obtained by estimation with areal photos by Johanna Wärnsberg (2013).

The vegetation height was measured simultaneously with the sweep netting in each experimental plot, as one measurement of the dominating plant species in the herbal layer. In the analyses the mean value of the four measurements was calculated and used.

The response variables are number of weevil species per site and number of total individuals pooled for each site.

Table 1 Description of environmental variable and covariables.

(For detailed information about the range of the variables see Appendix 1)

Environmental variable and covariables	Description	Unit
Category (env. variable)	Consists of four management categories: continuously grazed, restored old, restored recently and abandoned.	-
Area	Calculated area of the meadow using GIS.	m^2
prop_5	Proportion cover of semi-natural grasslands within a circular area of 5km radius surrounding each site.	%
prop_1	Proportion cover of semi-natural grasslands within a circular area of 1 km radius surrounding each site.	%
Count_pl	Number of plant species recorded by the plant diversity survey.	-
Camp_abu	Number of Individuals of *Campanula rotundifolia* at each site recorded by the plant diversity survey in 2011.	-
Veg_h	Mean value of the measured vegetation height from four sample plots at each site. Measured was plant of the dominating species in the herbal layer.	cm
tAbandonment	The time of abandonment of the abandoned sites and time of abandonment before restoration of the restored sites.	Years

The covariables were pretested for collinearity with Pearson correlations. Only one significant (p=0.006) moderate (Coef=0.545) positive correlation was detected, between size of the site [Area] and the number of plant species [Count_pl]

3.4 Species identification

The determination of the weevil species was conducted by the author with support from Håkan Ljungberg for determination of difficult individuals. The beetles were determined to species level except for individuals of the genus *Sitona* since the corresponding species are very variable in their appearance and therefore the determination would have been difficult and time consuming.

The main determination literature used was Rheinheimer & Hassler (2012) and additionally were used Freude, Harde and Lohse (1981) as well as Morris (2002). The nomenclature used in this study follows Rheinheimer & Hassler (2012). The classification of the species into the three feeding groups was based on ecological information of the species according to Rheinheimer & Hassler (2012).

3.5 Statistical analysis

The number of species and number of individuals were pooled for each of the 24 sites. The numbers of individuals were square root transformed in order to obtain a normal distribution of the data. Whether the management categories differ significantly from each other with respect to their total number of weevil species and the total number of individuals was tested by comparing their means in a one-way ANOVA.

Additionally we investigated whether other landscape and site characteristics (see environmental variables Table 1) have significant effects on number of species or number of individuals. All variables were tested individually against the number of species and the number of individuals in one-way ANOVAs. Consequently all variables were tested together in a general linear multiple regression with backward selection. The p-values of the one-way ANOVAs were used to arrange the order of the variables in the general linear model, with the lowest p-value on top (Table 3). In the consequently multiple regressions the variables are reduced stepwise by removing the variable with the highest p-value from the model. This stepwise exclusions were executed until there were only significant ($p<0.05$) variables left. The multiple regressions and the one-way ANOVAs were conducted with the program Minitab 15.

In order to investigate the species composition a DCA (Detrended Correspondence Analysis) was conducted. In our dataset there was one outlier (Site: Forkarby) therefore a detrended correspondence analysis was chosen. In a DCA the gradients of the second and higher ordination axes are rescaled and decompressed. With this method study sites are arranged in a multidimensional diagram according only to their similarity in species composition. Following a CCA (Canonical Correspondence Analysis) was conducted where also environmental variables were included in the analysis. For these ordination analyses a quantitative species matrix was used and all species with single occurrences were excluded from the analysis since they would give an unproportionally high influence on the results. Single occurrences were considered as species which were found at one study site only. Also empty samples, plots where no weevils were captured (Samples no.: 11A, 11B, 16C), were excluded. In total 24 study sites and 62 species were included in the analysis. The effects of the variables on the species composition are visualized in an ordination diagram and the significance of the variables was tested by a Monte Carlo Permutation test (499 permutations). The program Canoco for Windows 4.5 package was used for ordination. To include the nominal variable management category a dummy dataset was created, where the value of the sample was either 1 (if it belongs to the category) or 0.

To address the question whether the management categories inhabit weevil communities with different feeding preferences another CCA was conducted. All the collected species (N=93) were included in this analysis and the dataset used was also a quantitative species matrix. The management categories were the only environmental variables included in the analysis.

Additionally the species were categorized as monophagous, oligophagous and polyphagous according to their feeding preferences (Rheinheimer & Hassler 2012). The species of the genus *Sitona* were not categorized since they were not determined to species level and feeding preferences were not assignable because they include species of all three feeding groups. Subsequently the three feeding groups were compared in respect to the scores of the single species along the first ordination axis derived from the species compositional gradient.

4 Results

4.1 *The beetles*

In the 24 study sites 1920 weevil individuals from 93 species were collected and determined. Approximately 27% of the species collected were represented by one individual only and another 20% of the species had less than 5 individuals. The most common species were *Protapion fulvipes, Protapion gracilipes, Sitona sp., Protapion apricans* and *Perapion curtirostre.* These species occurred at least in 14 of the 24 sites and formed 54% of all individuals caught. One red listed species *Protapion interjectum* was found in site 'Forsbacka Rimbo' which was an old restored site. The identification of *Protapion interjectum* was verified by Håkan Ljungberg (www.artdatabanken.se).

The weevil species, except *Sitona,* were categorized within three groups of dietary preferences, where 16 species were monophagous, 54 species were oligophagous and 22 were polyphagous.

Figure 6 Three frequently captured weevil species *Protapion fulvipes, Hypera sp., Zacladus geranii.*

4.2 *Species richness*

The one-way ANOVAs showed that there were no significant differences in beetle species richness (p=0.561) or number of individuals (p=0.933) between the plots of different management categories (Table 3).

Table 2 Means and medians of the total numbers of weevil species/site and total numbers of weevil individuals/site for each management category. (For total numbers of species and individuals for each site see Appendix 1)

Category	N	Species		Individuals	
		Mean	Median	Mean	Median
Continous	6	18.50	17.50	76.17	71.00
Restored_old	6	20.17	19.50	88.17	65.00
Restored_recently	6	16.50	17.00	77.83	57.00
Abandoned	6	13.83	14.00	78.17	62.50

Vegetation height was the only significant variable, tested against the number of weevil species (p=0.001) (Table 3) and the number of weevil individuals (p=0.001, R-Sq=40.05), in the one-way ANOVAs.

Table 3 Summary of the one-way-ANOVAs. Potentially influencing variables (N=8) were tested individually against the number of weevil species (for definitions of environmental variable and covariables see Table 1).

Source	DF	Adj SS	Adj MS	F	P	R-Sq	R-Sq(adj)
Veg_h	1	490.74	490.74	13.88	0.001	38.69%	35.90%
Camp_abund	1	57.25	57.25	1.04	0.319	4.51%	0.17%
tAbandonment	1	34.08	34.08	0.61	0.444	2.69%	0.00%
Category	3	133.83	44.61	0.79	0.516	10.55%	0.00%
Prop_1	1	16.95	16.95	0.30	0.591	1.34%	0.00%
Count_pl	1	12.48	12.48	0.22	0.645	0.00%	0.98%
Prop_5	1	2.90	2.90	0.05	0.824	0.23%	0.00%
Area	1	0.37	0.37	0.01	0.937	0.00%	0.03%

Subsequently all explanatory variables were tested together in one model in a multiple regression backward selection against the number of weevil species (Table 4) and number of weevil individuals (Table 5), in order to see whether there are significant combinations of variables. It showed similar to the results of the one-way ANOVA that the vegetation height had a significant positive relationship with both the number of weevil species and the number of weevil individuals. Table 4 shows that for the number of species the explanatory variable describing *Campanula rotundifolia* abundance (F=6.5; p=0.018; Coef=0.55) together with vegetation height (F =21.89; p =0.000; Coef=0.43) have a positive significant relationship.

Table 4 Analysis of variance in a multiple regression backward selection for the number of weevil species.

Source	DF	Seq SS	Adj SS	Adj MS	F	P	Coef
Veg_h	1	490.74	618.26	618.26	21.89	0.000	0.43
Camp_abund	1	184.76	184.76	184.76	6.54	0.018	0.55
Error	21	593.00	593.00	28.24			
Total	23	1268.50					
S = 5.31394 R-Sq = 53.25% R-Sq(adj) = 48.80%							

Table 5 Analysis of Variance in a multiple regression backward selection for the number of weevil individuals.

Source	DF	Seq SS	Adj SS	Adj MS	F	P	Coef
Veg_h	1	29358	29358	29358	14.7	0.001	2.89
Error	22	43945	43945	1998			
Total	23	73304					
S = 44.6936 R-Sq = 40.05% R-Sq(adj) = 37.33%							

Another significant variable combination was obtained for the number of weevil species (Table 6) by vegetation height and time of abandonment (F=4.95; p=0.037; Coef=-0.134).

There were no significant results in differences of vegetation height between the management categories (ANOVA, p=0.936).

Table 6 Analysis of variance for the number of weevil species with the variable combination vegetation height and time of abandonment.

Source	DF	Seq SS	Adj SS	Adj MS	F	P	Coef
Veg_h	1	490.74	604.94	604.94	20.18	0.000	0.430
tAbandonment	1	148.28	148.28	148.28	4.95	0.037	-0.134
Error	21	629.48	629.48	29.98			
Total	23	1268.5					
S = 5.47497 R-Sq = 50.38% R-Sq(adj) = 45.65%							

The scatterplot (Figure 7) shows the relation of vegetation height on the number of weevil species for each site and the corresponding management category. The figure indicates that the increasing vegetation height has a stronger positive effect on the weevil diversity in continuously grazed pastures compared to the other categories (Figure 7). Therefore an interaction analysis was conducted in an ANOVA for Count of beetle species vs. Vegetation height*Management Category (ANOVA, p=0.652) and Vegetation height *tAbandonment (ANOVA, p=0.237), but no significant results were obtained. No further interaction analyses were conducted.

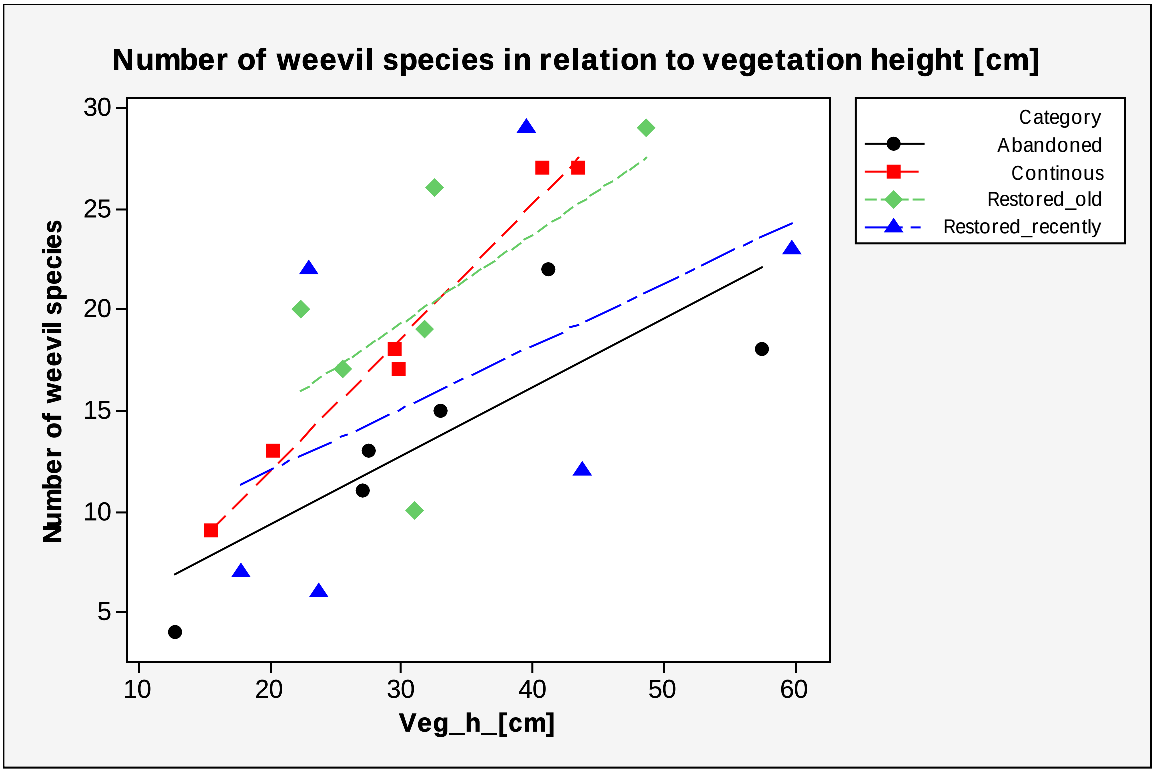

Figure 7 Scatterplot shows the total number of weevil species (plots) for each site (N=24) in relation to the vegetation height in cm and regression lines for the plots of each management category.

4.3 Species composition

In the ordination diagram Figure 8 the sample sites are arranged according to their gradual change in species composition where relative differences are shown in distances to each other. We found out that the continuously grazed sites were plotted relatively close to each other on the right side of the diagram (Figure 8) in contrast to the abandoned sites forming a cluster but on the left side. The restored sites are arranged in between. Therefore the DCA indicates that the species compositions of continuously managed pastures differ from the species composition of abandoned sites.

The total inertia in the DCA was 3.342. The first and the second axes explain together 25.4% of the total variance of the data. The gradient length measured the beta diversity in the extent of species turn over along the ordination axes (Leps & Smilauer 2003). Axis one has a gradient length of 3.357 sd-units. The gradient of axis two has a length of 3.152.

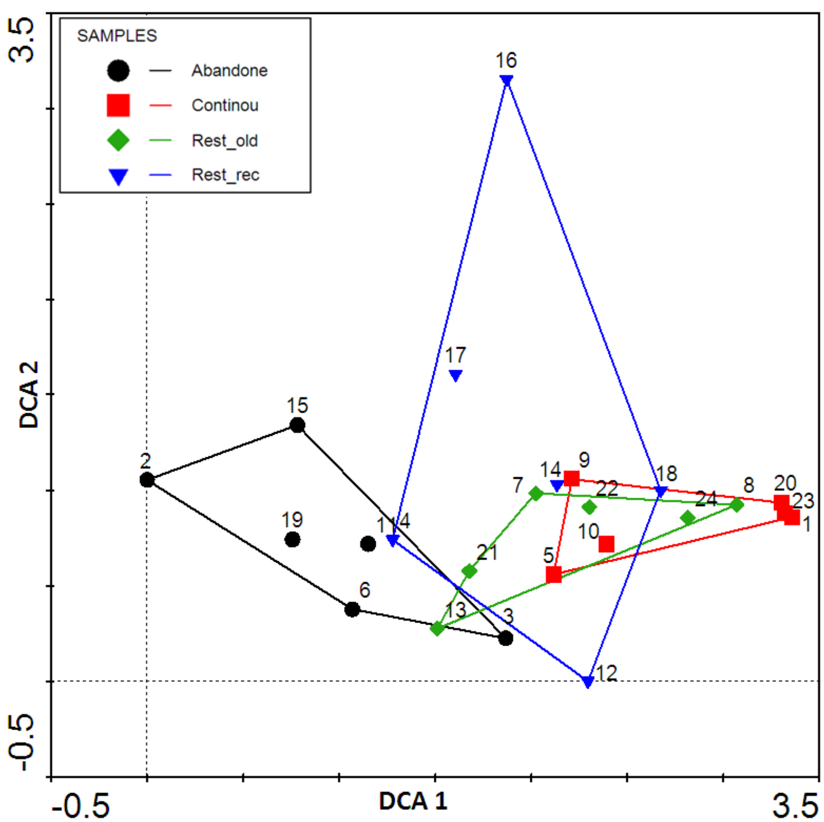

Figure 8 Detrended Correspondence Analysis (DCA) scatterplots of the study sites. The ordination diagram shows the arrangement of the sites according to their relative similarity in weevil species composition. Axis 1 and 2 explain 25.4% of the total variance (Total inertia = 3.342). (Site names see Appendix 1)

The significance of covariables and the environmental variable [category] (Table 1) was tested in two separate ordination analyses with stepwise forward selection and Monte Carlo Permutation Test. The covariables were tested in a CCA (Canonical Correspondence Analysis), where the explanatory power of the explanatory variables for the weevil species abundance patterns is maximized. Axis 1 (Eigenvalue = 0.382) and axis 2 (Eigenvalue = 0.192) explained together 61.3% of the variance of species-environment relation (Total canonical eigenvalues = 0.937) and 17.2 % of the total inertia (3.342). The time of abandonment had a significant (p=0.032) effect on the species composition and it explained 23.4% of the variance of species-environment relation explained by covariables.

Table 7 Covariables (for definitions see Table 1) fitted in a stepwise forward selection in a CCA model.

Covariable	Variance explained%	P	F
tAbandonment	23.40	0.032*	1.57
Count_pl	17.02	0.318	1.12
Veg_h	18.09	0.186	1.21
Prop_1km	17.02	0.258	1.16
Camp_abu	13.83	0.562	0.91
Prop_5km	10.64	0.836	0.70

The significance of each variable was tested with Monte Carlo Permutation test (with 499 permutations). The variance explained (%) by each covariable is the percentage calculated from the variance of species-environment relation (Total canonical eigenvalues =0.94) explained by covariables. Significance level: *p<0.05

The effect of management category was tested in a partial CCA (Table 8), where the effect of the covariables on species composition was removed and following an ordination analysis was performed on the remaining variability of species composition. For this analysis the covariable describing the time of abandonment was removed from the model, because the values of this variable were strongly correlated with the management category. Thus it would take away the main variation explained by management category. Axis 1 (Eigenvalue = 0.306) and Axis 2 (Eigenvalue = 0.138) explained together 80.2% of the variance of species-environment relation (Total canonical eigenvalues =0.55) and 17.2% of the total inertia (3.342). 'Abandoned' was tested to significantly (p=0.016) explain 49.09% of the variance (Total canonical eigenvalues = 0.55) explained by management category.

Table 8 Partial CCA for the environmental variable management category fitted in a stepwise forward selection. The significance was tested with Monte Carlo Permutation test (with 499 permutations). One management category (Restored recently) was excluded from the model to avoid collinearity.

Env. Variable	Variation explained %	P	F
Abandoned	49.09	0.016*	1.86
Continuous	29.09	0.324	1.12
Restored old	21.82	0.600	0.86

In Figure 9 the nominal variable [Category] is plotted as centroids, which represent the means of the scores of samples belonging to this category (Leps & Smilauer 2003). The distance of the centroids to each other is thus determined by the position of the samples in the ordination diagram. The position of the samples is determined by their similarity in species composition. Here we can see that the centroid of [Abandoned] is relatively distant arranged from the continuously managed centroid. The restored sites are closer to the continuous sites with the category [Restored_old] closer.

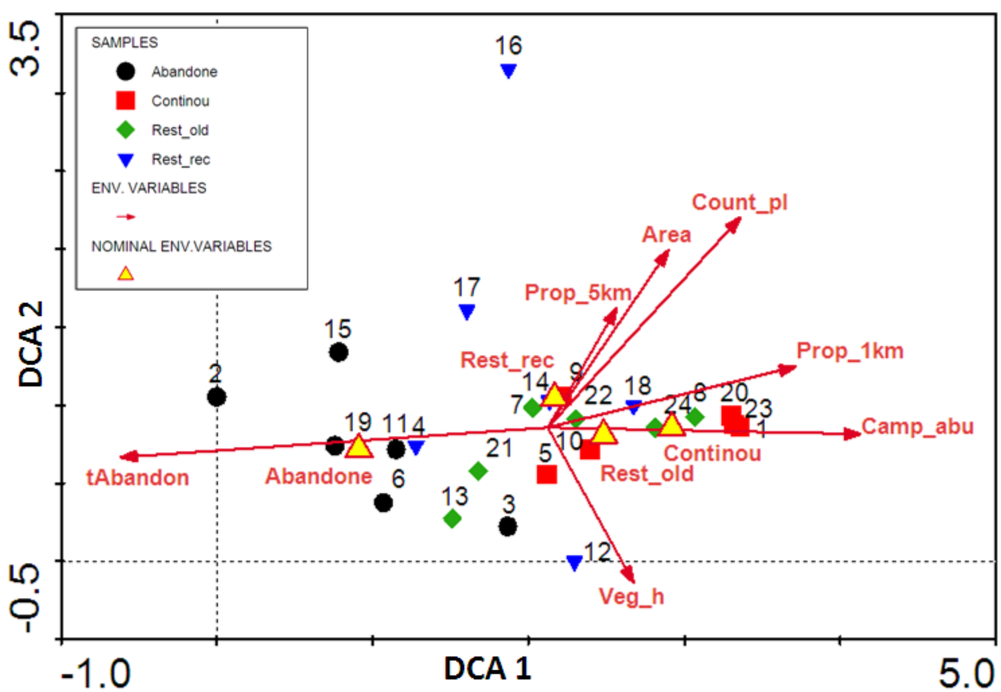

Figure 9 Indirect DCA biplot of study sites and explanatory variables. The nominal variables are shown as centroids.

The relation of variables with each other can be interpreted by looking at the angle between the arrows. A perpendicular angle means that there is no correlation. The first axis is strongly correlated with abandonment. The category continuously managed, proportion of similar habitat within 1km and the abundance of *Campanula rotundifolia* are positively correlated with each other. Furthermore the area of the site, the proportion of similar habitat within 5km and the number of plant species are positively correlated.

4.4 Feeding preferences

In order to investigate whether the management categories have weevil species compositions with different feeding preferences a CCA was conducted. The variable management category was the only variable included in this CCA. The species (N=93) were categorized according to their feeding preferences in the ordination space. The overlay of the weevil's feeding preferences in Figure 10 shows that monophagous species were more associated with continuously managed and restored sites and polyphagous species were more associated with abandoned sites (Figure 10). The distribution (Figure 11) of the three trophic guilds along the first ordination axis was tested for their means in a Kruskall-Wallis test (Table 9). The species ordination scores along the first axis were significantly different between monophagous and polyphagous (p=0.000) weevils as well as between polyphagous and oligophagous species (p=0.003). There was no significant difference between the monophagous and oligophagous species scores (p=0.246).

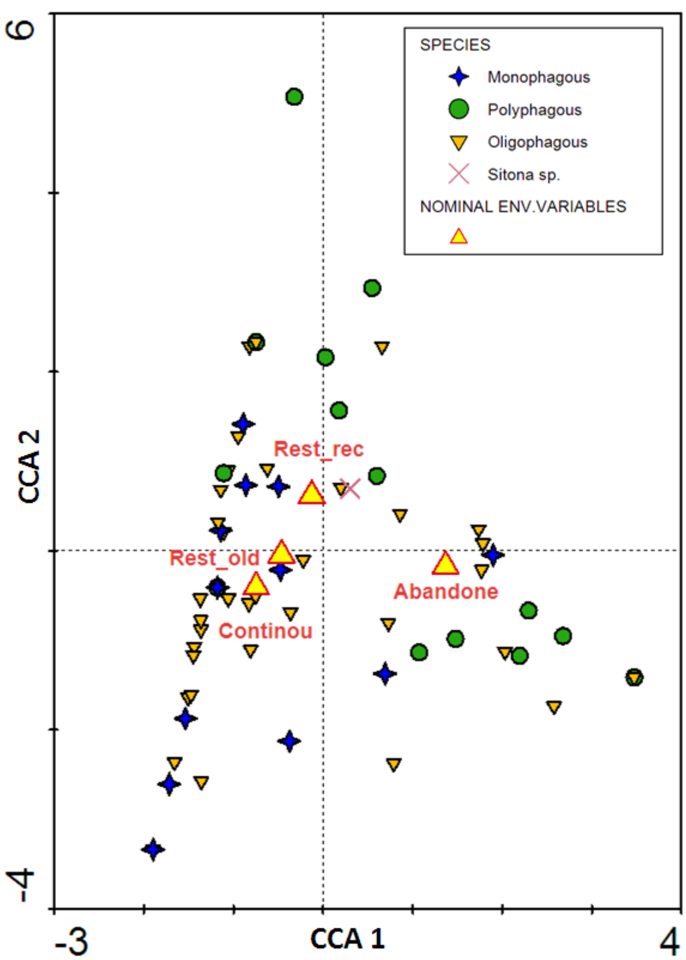

Figure 10 Overlay of dietary preferences at the position of weevil species and the nominal variable 'management category' along the first two axes of a CCA. Axis 1 (Eigenvalue=0.394) and axis 2 (Eigenvalue=0.121) explain 84% of the variance of species-environment relation (Total canonical eigenvalues = 0.614) and 13.7% of the total inertia (3.750).

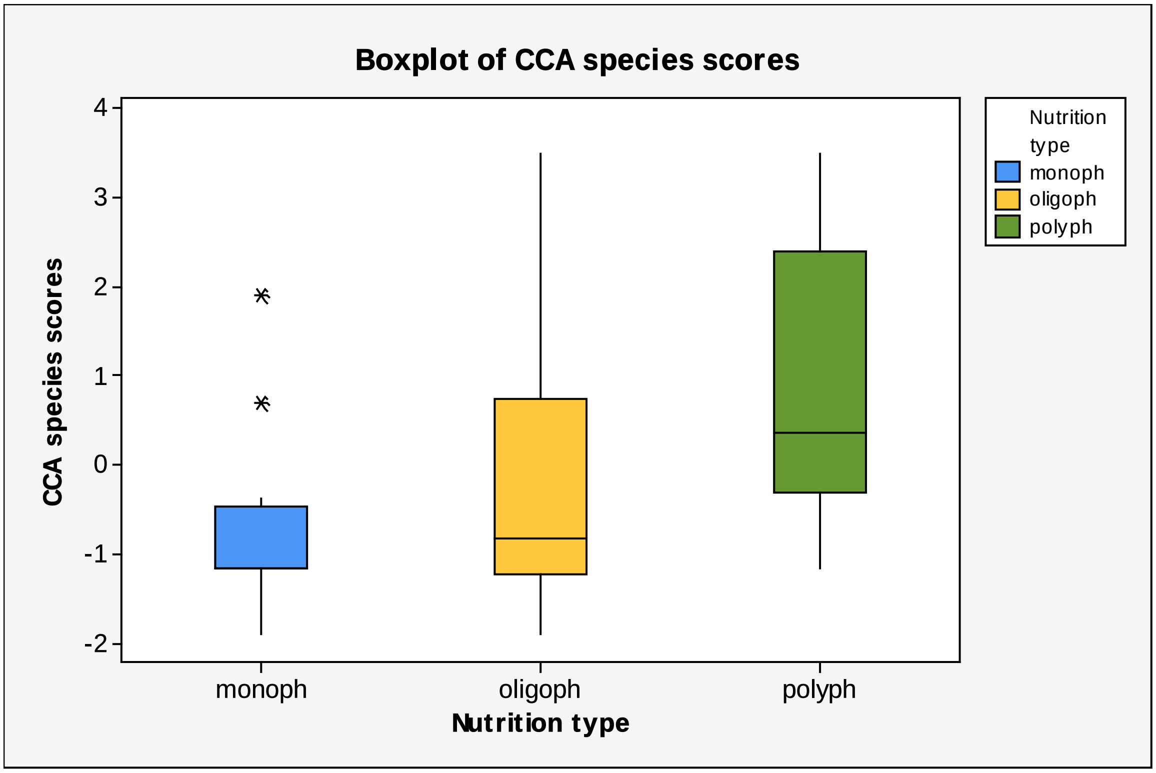

Figure 11 Boxplots of the ordination weevil species scores (CCA_scores) of the three dietary groups monophagous, oligophagous and polyphagous. The boxplots display the full range of variation (from min to max) of the CCA species scores in four quartiles, for each trophic group. The rectangles show the median line and represent 50 % of the data, from the second to the third quartile.

Table 9 Kruskal-Wallis Test: CCA species scores versus nutrition type of weevil species.

Nutritiontype	**N**	**Median**	**Average Rank**	**Z**
monoph	16	-1.16	33.6	-2.12
oligoph	54	-0.83	43.2	-1.42
polyph	22	0.36	64.0	3.52
Overall	92	46.50		
H = 14.00	DF = 2	P = 0.001		

5 Discussion

The results showed that there were no significant differences in weevil species richness between the management categories. Also the numbers of individuals per site were not significantly different between the categories. Further analyses of species composition in the management categories revealed that the species compositions of the abandoned sites differed significantly from the species compositions of restored and continuously managed sites. The captured weevils characterized as monophagous and oligophagous were mainly distributed in restored and continuously managed sites whereas the polyphagous species dominated the compositions of the abandoned sites.

5.1 Effects of vegetation height on species richness

There were no significant differences of beetle species richness between plots of different management categories.

Since many of the weevil species are specialized in terms of their food plants we expected that the number of plant species would have an effect on the beetle species richness. In contrast to my expectations this was not confirmed by the analyses (Table 3). Since the categories did not differ significantly in number of plant species the question of plant species composition should further be investigated.

The categories were also tested for differences in vegetation height but no significant differences were obtained. This can be led back to a high variation of management schemes within the categories.

The results of the several multi-regression analysis (Table 4) show that the number of weevil species and the number of weevil individuals increase significantly (Table 3) with higher vegetation. Similar results were obtained in a study by Öckinger et al. (2006) for butterflies and vascular plants in restored grasslands. The results are furthermore supported by the common hypothesis that the structural diversity of habitats is one important key factor determining the species richness of different habitats (Tews et al. 2004). Therefore one explanation for these results can be that higher vegetation provides more habitat and higher structural diversity and therefore a higher range of niches is available. Since vegetation height and plant species composition in semi-natural grasslands are strongly determined by the management regime, grazing species and the number of grazing domestic animals, it is important to develop the management strategies carefully (Öckinger et al. 2006).

It must be considered that sweep-netting might not be the most appropriate sampling method for short vegetated sites. Since the biomass of vegetation being sweep-netted is much higher in high vegetation. Additionally it is questionable if the species captured in short vegetated sites are representative for the site population since many of them might not be captured by sweep-netting. Although there are studies where sweep-netting was tested to be a poor sampling method for surface active arthropods (Norment 1987), there are several studies (Horváth et al. 2009) comparing insect diversities of habitats with low vegetation heights which only used sweep-netting as a catching method. To compensate this methodological limitation the use of a suction sampling device was planned as an additional sampling method. Due to time limitations it was not possible to carry out both methods.

However there have been several studies evaluating the efficiency of suction samplers in grasslands (Brook et al. 2008; Buffington & Redak 1998; Woodcock et al. 2010). Many of these studies suggest the suction sampling as a more efficient method for some insect taxons (Doxon et al. 2011; Brook et al. 2008) than for others, but equally efficient for beetles in scrub habitats (Buffington & Redak 1998). Therefore I suggest additional sampling with a suction sampler to also capture species which are living in near-to-soil levels of the vegetation. It would be interesting to compare the efficiency of both methods, sweep-netting and suction sampling, in habitats with high and low vegetation.

The regression lines in Figure 7 indicate that vegetation height has a stronger positive effect on the number of species in continuously managed pastures than compared to abandoned ones.

In contrast to other studies (Woodcock et al. 2008) our results did not confirm that the proportion of semi-natural grasslands in the surrounding environment of 1km and 5km have a significant effect on the weevil abundance and diversity.

The abundance of *Campanula rotundifolia* was significant for weevil diversity in combination with vegetation height. The positive coefficient (Coef=0.55) indicates that there is a positive relationship between the vegetation height in combination with the abundance of *Campanula rotundifolia* with the number of weevil species. Lindborg & Eriksson (2004) suggest that *Campanula rotundifolia* should be used as indicator species for improved habitat quality in restored semi-natural grasslands.

The time of abandonment was also significant in combination with vegetation height for the number of species. The negative coefficient (Coef=-0.134) indicates that increasing time of abandonment has a negative effect on the beetle species diversity. These results support the suggestions of Öckinger et al. (2006) to prioritize abandoned sites which are in an early post-abandonment succession stage for restoration actions.

5.2 Effects of management category on species composition and restoration success

The results showed that the abandoned sites inhabit a different species composition than the sites from other management categories. The ordination diagram in Figure 9 not only shows that the centroid of the abandoned sites is relatively distant from the centroids of the other groups. It also shows that the centroids of the restored sites are relatively close to that of the continuously managed centroid. Additionally by the CCA (Table 8) it can be pointed out that the sample scores of restored and continuously managed sites on the first axis are not significantly different from each other. This indicates that the restored sites have a similar weevil species composition as the continuously managed ones. Given the criteria that the continuously managed sites are model habitats in terms of species-rich semi-natural grasslands they act as a reference group in this study. Therefore one can conclude that there is a successional process from young restored species agglomerations in the direction of semi-natural grassland weevil communities and that the restoration of abandoned semi-natural grasslands was successful.

Furthermore the positions of the centroids indicate (Figure 9) that the species composition of old restored sites is more similar to the continuously managed sites than the recently restored sites are. This indicates that time since restoration is an important factor for the restoration success of weevils. Comparable results were obtained by other studies in Britain by Woodcock et al. (2010; 2008) and Sweden by Lindborg & Eriksson (2004). Woodcock et. al. (2010) trace their results back to the succession mechanism of the plant communities in restored grasslands, which show similar trends that time since restoration is a determining factor for the species composition in restored semi-natural grasslands. A strong interaction between specialized phytophagous beetles and their host plants was furthermore confirmed by Hemerik & Brussaard (2002), who found that the nutritional changes of sites induce changes of the plant communities and these affect the composition of the dependent phytophagous beetle community. Another study by Woodcock et al. (2008) states that the re-colonization of phytophagous beetles happens by natural immigration only. This suggests that the assessment of restoration success should be conducted after several years of restoration.

We also investigated whether the weevil species composition of plots differing by management category differ with respect to feeding preferences also. The tests showed (Figure 10 & Figure 11) that in view of the dietary groups there is a distinct pattern in the arrangement of the species along the successional gradient. It was shown that the continuously managed sites had more monophagous and oligophagous species than the abandoned sites. Furthermore, plots from abandoned pastures contained significantly more polyphagous species than plots from other sites. Since many polyphagous species feed inter alia more on woody plants (Rheinheimer & Hassler 2012) compared to mono- and oligophagous species it was expected that they will be found in a higher number in the overgrown abandoned sites. The results revealed that restored semi-natural grasslands inhabit beetle communities with a high proportion of specialist feeders whereas generalist beetles are dominant in the abandoned sites.

Similar results were presented by a study of Brown & Hyman (1986) who found that in later succession stages, which are represented by the abandoned sites in this study, more generalist weevil species were found. Dietary specialized butterfly species have been suggested to be of higher conservational concern than generalists (Dennis et al. 2005,). It would be interesting to investigate whether this hypothesis is also valid for weevils.

5.3 Limitations of the study and suggestions for further research

It must be mentioned that this study represents a snap-shot inventory of the weevil diversity since the sampling was conducted only once within two weeks in June and is therefore not representative as a full inventory of the weevil diversity in semi-natural grasslands. The study design initially included a second survey but due to limitations of time the samples could not be used in this study.

For further research it would be interesting to look at the plant species composition and investigate if there are similar patterns concerning the specialist/generalist distribution. It would also be interesting if other variables have influence on the distribution of specialist/generalists. Studies in this regard are currently under progress but not completed yet.

6 Conclusion

It was shown that an increasing height of the herbal vegetation layer has a positive effect on the number of weevil species. Successful management for a high diversity of phytophagous beetles as weevils should therefore aim to maintain a certain minimum vegetation height. Since different species of grazing animals affect different plant communities and structures it is suggested to carefully carry out the management plans for restored sites with the appropriate grazing species and density of grazers.

The plots from different management categories did not differ in species richness but differed concerning the feeding preferences and species composition. This implicates that in terms of assessing restoration success of phytophagous beetles in semi-natural grasslands it is more important to focus on species compositions and the feeding preferences of the beetle species involved. An additional important aspect is the time of assessment. I suggest that the assessment of restoration success concerning the weevil community should not be conducted too shortly after restoration but rather after several years.

The comparisons of the species compositions suggest that if we want to target a species composition typical for semi-natural grasslands the restoration of abandoned pastures appears to be a successful approach and this justifies the expenses connected with such restoration measures.

7 Acknowledgements

First and foremost I want to thank my supervisor Mats Jonsell for his valuable advice and constructive feedback during the whole time of this project. I always felt encouraged and motivated after our meetings and I sincerely appreciate his support in carrying out my own project.

I also want to thank Erik Öckinger and PhD student Marie Winsa for including me into their project and for their input throughout the project.

Besides that, I am very grateful to Gerhard Karrer, from BOKU, for his valuable feedback and Håkan Ljungberg for his help in determination of difficult specimens.

Special thanks to the Entomological Society of Uppland, Sweden, for supporting this study with a scholarship.

Additionally I want to thank all members of the EnvEuro-family, especially Brenda Vidal for her incredible big-hearted nature, Theresa Rosenkranz for all the fun moments, Aleksandra Marsz for all the countless Fikas and interesting anecdotes about Poland, Milda Norkuté for her generosity, Matthias Bacher for being a source of all kinds of information, Juliane Krenz for her special intelligent sense of humor, Willem van Hoesel for the brainstorming and his enthusiasm when it comes to nature and Lisa Waselikovsky for her open mind and the “workalizing”, for making this period of thesis writing even more enjoyable and for being a family when we were far away from home. I wish you all good luck for your future where ever you may end up and I hope to see you all soon for another epic reunion. Besides I want to thank Christian Bugge Henriksen, from the University of Copenhagen, and Jan Lagerlöf, from SLU, for their dedication to make the EnvEuro program so excellent and unique.

I also want to thank evolution for establishing awesome creatures such as weevils are.

Finally I want to express my deepest gratitude to my beloved family, especially my parents, Eva and Reinhard Steiner, for their unconditional support and encouragement throughout my studies and since the day I was born.

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9 Appendix 1: List of variables (for definitions see Table 1)

Ordination site number	Site_ID	Site_name	Category	Age (restoration)	area_[ha]	prop_5	prop_1	Count_plant spec	Camp_abund	Veg_h_[cm]	tAbandonment	No_weevil_sp.	No_indiv	Square root Indiv
1	1	Läby	Continuous	-	1,748	0,011	0,021	54	17	20,25	0	13	73	8,54
2	2	Forkarby	Abandoned	-	2,812	0,027	0,003	46	0	27,50	22	13	64	8,00
3	3	Storsätra Vänge	Abandoned	-	1,827	0,012	0,003	39	0	57,50	51	18	91	9,54
4	5	Tjälinge Skogstibble	Restored_recently	6	0,787	0,020	0,000	47	9	23,00	35	21	89	9,43
5	7	Graneberg Litslena	Continuous	-	2,731	0,021	0,079	52	2	40,75	0	26	69	8,31
6	8	Kungs Husby	Abandoned	-	2,662	0,019	0,001	37	5	27,00	40	10	51	7,14
7	9	Tjärns Hage	Restored_old	13	5,182	0,052	0,138	70	0	31,00	41	9	68	8,25
8	10	Sjöängen Engsö	Restored_old	17	4,064	0,065	0,157	69	17	32,50	28	25	121	11,00
9	11	Långholmsbryggan Engsö	Continuous	-	5,893	0,054	0,067	68	4	29,50	0	17	68	8,31
10	12	Blänkhemshagen Kungsör	Continuous	-	2,546	0,023	0,070	47	3	15,50	0	9	19	4,36
11	13	Jordmarken Kungsör	Abandoned	-	3,614	0,029	0,118	39	1	12,75	51	4	5	2,24
12	14	Reutersberg	Restored_recently	6	2,811	0,022	0,159	43	1	23,75	47	6	7	2,65
13	15	Tyringe	Restored_old	10	1,652	0,016	0,088	36	0	31,75	43	19	62	7,87
14	16	S Lunger	Restored_recently	7	5,071	0,011	0,001	47	4	59,75	46	23	133	11,53
15	19	Grän rasbo	Abandoned	-	2,724	0,025	0,122	38	0	33,00	43	15	61	7,81
16	20	Ahlezons hage	Restored_recently	4	5,371	0,010	0,000	57	0	17,75	37	7	16	4,00
17	21	Borgardalsbadet	Restored_recently	5	1,032	0,014	0,000	37	0	43,75	48	12	25	5,00
18	22	St Tadinge	Restored_recently	3	1,393	0,019	0,074	41	3	39,50	42	29	197	14,04
19	24	Eke Vidbo	Abandoned	-	2,763	0,015	0,003	47	0	41,25	51	22	197	14,04
20	25	Norrby Vidbo	Continuous	-	3,577	0,026	0,024	46	0	29,75	0	17	88	9,38
21	26	Ändeberga Bålsta	Restored_old	12	4,543	0,024	0,012	39	4	25,50	30	17	38	6,16
22	27	Forsbacka Rimbo	Restored_old	12	2,492	0,011	0,027	62	14	22,25	14	22	66	7,35
23	28	Ekeby Norrtälje	Continuous	-	0,846	0,004	0,000	37	0	43,50	0	23	126	11,79
24	39	Focksta 2	Restored_old	13	7,601	0,018	0,078	54	3	48,75	40	29	186	13,64

10 Appendix 2: Weevil species list including sum of counts per site and diet preferences

Species	Läby	Forkarby	Storsätra Vänge	Tjälinge Skogstibble	Graneberg Litslena	Kungs Husby	Tjärns Hage	Sjöängen Engsö	Långholmsbryggan Engsö	Blänkhemshagen Kungsör	Jordmarken Kungsör	Reutersberg	Tyringe	S Lunger	Grän rasbo	Ahlezons hage	Borgardalsbadet	St Tadinge	Eke Vidbo	Norrby Vidbo	Ändeberga Bålsta	Forsbacka Rimbo	Ekeby Norrtälje	Fockstа 2	Grand Total	CCA_scores	diet type
Aizobius sedi								1	2																**3**	-1,657	oligoph
Anthonomus humeralis																								1	**1**	-1,179	oligoph
Anthonomus phyllocola		15	1	1				2	2															2	**23**	2,031	oligoph
Anthonomus rectirostris																					1				**1**	-1,179	oligoph
Anthonomus rubi															1					1					**2**	0,787	oligoph
Anthribus nebulosus													1												**1**	-1,179	polyph
Apion cruentatum								1																	**1**	-1,179	oligoph
Apion frumentarium																				1					**1**	-1,896	oligoph
Apion haematodes	1							1																	**2**	-1,537	monoph
Archarius pyrrhoceras																	1								**1**	-0,321	oligoph
Barynotus obscurus																			1						**1**	3,471	polyph
Barypeithes pellucidus		14		5							2				17								2	5	**45**	2,294	polyph
Barypeithes trichopterus		11																							**11**	3,471	polyph
Betulapion simile				1								1	1								3				**6**	-0,893	monoph
Brachysomus echinatus		1	2					2						2			1	1	1	1				1	**12**	0,597	polyph
Catapion meieri				1				1	3	1			3					5	2					1	**17**	-0,498	monoph

Ceratapion onopordi																1								1	**2**	-0,750	oligoph
Ceutorhynchus atomus																				1					**1**	-1,896	oligoph
Ceutorhynchus obstrictus																								1	**1**	-1,179	polyph
Cleopomiarus sp.					2	1		1	1			1	2	1									1		**10**	-0,829	oligoph
Coeliodes transversealbofas-ciatus																	1								**1**	-0,321	oligoph
Cyanapion afer					1					1									1		1				**4**	-0,375	monoph
Cyanapion spencii					2									2				3			1				**8**	-0,822	oligoph
Eutrichapion ervi		3	3	1	1								5	3			1		2					1	**20**	0,860	oligoph
Eutrichapion facetum																1			3			1			**5**	1,782	oligoph
Eutrichapion punctiger			4	3			2					1	5											1	**16**	0,198	oligoph
Eutrichapion viciae	1				4			3	2				1	2				3	14	2		1			**33**	0,728	oligoph
Glocianus punctiger					1													1							**2**	-1,109	oligoph
Gymnetron melanarium																							2		**2**	-1,896	oligoph
Gymnetron rostellum	1					1														2		3	7		**14**	-1,359	oligoph
Hypera meles				1															1				1	2	**5**	-0,221	oligoph
Hypera miles														3											**3**	-0,321	oligoph
Hypera nigrirostris			1	1	1																		1	1	**5**	-0,364	oligoph
Ischnopterapion loti									3													2		1	**6**	-1,364	oligoph
Ischnopterapion virens					2		1	1						3								1		9	**17**	-1,112	oligoph
Mecinus pascuorum						10		3	4									1		2		3			**23**	0,693	monoph
Synapion ebenium			2	6											1								1		**10**	-1,179	oligoph
Tachyerges pseudostigma													2												**2**	-0,321	oligoph
Trachodes hispidus																	1								**1**	-0,321	polyph
Trachyphloeus bifoveolatus																		1							**1**	-1,896	polyph
Trichosirocalus troglodytes																				1					**1**	-1,109	monoph
Tropiphorus elevatus																		1					1		**2**	-1,450	polyph
Tychius picirostris	9			1				5					1	2				6		12	1	1	9	4	**51**	-0,756	oligoph
Tychius quinquepunctatus													10						1						**11**	-1,179	oligoph

Tychius stephensi																								1	**1**	1,735	monoph
Zacladus geranii		4		5				1						7					27			4		5	**53**	0,849	oligoph
Grand Total	**73**	**64**	**91**	**89**	**69**	**51**	**68**	**121**	**69**	**19**	**5**	**7**	**62**	**133**	**61**	**16**	**25**	**197**	**197**	**88**	**38**	**67**	**126**	**186**	**1922**	-	-