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Swedish University of Agricultural Sciences

Department of Ecology

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– a study on skylark plots made in central Sweden

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Master's thesis
Ecology MSc programme
Uppsala 2012

Independent project/Degree project / SLU, Department of Ecology 2012:20

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Credits: 30 hec
Level: A2E
Course title: Independent Project/Degree Project in Biology - Master's thesis
Course code: EX0565
Programme/education: Ecology MSc

Place of publication: Uppsala
Year of publication: 2012
Cover picture: Skylark plot in Lohärad, Uppland, Sweden (photo by Mattis Jansson)
Title of series: Independent project/Degree project / SLU, Department of Ecology
Part no: 2012:20

Online publication: http://stud.epsilon.slu.se

Keywords: Skylark, conservation action methods, skylark plots, food availability, winter cereals, autumn-sown, birds, agricultural landscape, landscape heterogeneity

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Summary

Intensified cultivation of farmland is widely recognized to act negatively on many organisms, including birds as the Skylark (*Alauda arvensis*). During the last decades, this species has been showing a population decline of about 50-75 percent in northwestern Europe, including Sweden. One important factor that is considered to be a key driver of this decline is the switch from spring- to autumn-sowing of cereals. This change in farming practice has been shown to reduce food availability for skylarks and other species that rely on crop fields for foraging and nesting. To improve this situation, skylark plots (SPs), i.e. small (16-20 m^2) unsown patches within winter cereal crops, have been developed in Great Britain during the last decade. The idea with SPs is to make it easier for skylarks to forage, since the sparser vegetation in SPs makes it easier to find food (i.e. invertebrates). From Great Britain the method has been shown to work well, increasing the breeding success of skylarks. However, the extent by which SPs contribute to improve breeding opportunities in Swedish arable farmland is unknown. There are structural differences in the agricultural landscapes of Sweden and Great Britain, with a higher relative proportion of spring sown cereals in Sweden. This might indicate that SPs have a lower positive effect when applied in Sweden, since the high proportion of spring cereals (sparser vegetation) makes it possible for skylarks to find food anyway. Thus it is important to study if SPs have a positive effect on skylarks in Sweden, before applying the method in a huge scale.

In this study, the effect of SPs on the skylark territory density in autumn sown fields of wheat was studied. 15 study plots with SPs and 15 control plots without SPs situated on fields of similar size and surroundings were compared; temporal trends of invertebrate activity and vegetation height were used to examine whether the importance of SPs for territory density was there to be found and if this increased towards the end of the breeding season.

The results indicate that SPs have a positive effect on the territory density of skylarks (total breeding season average in SP-sites 3.30 territories/3.14 ha, SE = 1.49; in control-sites 3.19 territories/3.14 ha, SE = 1.82), an effect that becomes clearer as time goes by. This indicates that the presence of SPs is enhancing the breeding season, making it possible for skylarks to produce multiple clutches. Invertebrate activity increased over time, at the same time as skylark territory density was decreasing. However, the decline of skylarks in SP-sites was less relative to control-sites, indicating that SPs makes the availability of food supplies (i.e. invertebrates) to increase. This pattern does also explain why SPs seems to have an increased positive effect as time goes by (increased vegetation density and hence lower food availability). Studies made in Great Britain do, however, indicate that SPs may have a larger positive effect when applied on larger fields situated in homogenous areas, a fact that have to be kept in mind when applying the method in a larger scale.

1. Introduction

1.1. Background

The agricultural landscape of Northwestern Europe has changed during the last century (Blaxter and Robertson, 1995). An intense way of farming with large areas of monocultures is today the general conception of a thriving agricultural system. In addition, the majority of the fields are nowadays sown during the autumn instead of the spring (Chamberlain et al, 2000a), a fact that strengthens this apprehension even further; huge fields with the same crop and vegetation height. A large number of studies mainly performed in Great Britain show that this type of agricultural landscape and system has a negative effect on a number of groups of organisms, including birds (Fuller et al., 1995, Chamberlain et al, 2000a). Similar studies from other parts of Northwestern Europe, including Sweden, support this statement (e.g. Eggers et al., 2011).

Today we are aware of many of the factors underlying the decline of birds in the agricultural landscape. For instance, several studies propose reduced food supplies as an important reason (Potts 1986; Campbell et al., 1997; Evans et al., 1997; Brickle et al., 2000), e.g. reduced invertebrate abundance caused by the use of pesticides (Campbell et al., 1997). Other studies propose less suitable nesting habitats in general as an explanation (Wilson et al 1997; Chamberlain et al., 1999). Both these factors are connected to the change in crop structure; crops are growing faster and denser than before (Schläpfer, 1988; Chamberlain et al, 1999). A lot of studies state that the tall and dense vegetation most likely affects the bird fauna in a negative way, since it decreases the availability of invertebrates (i.e. food supplies) (Wilson, 1997; Weibel et al., 2001; Donald, 2004; Newton 2004; Wilson et al., 2005; 2009), which reduces the quality of nesting habitats. Higher and denser vegetation makes it harder for birds to actually find food, as compared to shorter and sparser vegetation. Other causes of decline are farming operations that lead to direct mortality of birds, as for instance nest failure caused by crop harvesting (Crick et al., 1994), which risks to kill the brood, and earlier grass harvest caused by the stepwise switch from hay to silage (Green, 1995). The latter has been shown to decrease the possibility for birds such as the Corncrake (*Crex crex*) to finish their breeding season before the harvest starts, since silage is harvested earlier than hay (Green, 1995).

Even though several of the underlying factors to the population declines of many bird species in the agricultural landscape are known, there is still a lack of knowledge about the relative importance of each individual factor and how they may interact with each other. Since there are many factors involved it is hard to know which ones that are important, thus making it important to study how different species or ecosystems are affected by them, separately and in combination. Knowledge about this will make it easier to direct conservation actions, thus increasing the possibility to overcome the negative condition of the agricultural landscape. This is important, since one challenge with conservation actions is to convince the public that they actually have desired effects; a challenge that has to be completed to get financial support and public confidence. To be able to do this, it is necessary to have evidence but also to direct actions and methods in the right way and only apply them when they really have an effect.

One of the bird species connected to the agricultural landscape, which has been decreasing in numbers during the last couple of decades, is the Skylark (*Alauda arvensis*) (Tucker and Heath, 1994; Fuller et al., 1995). Since 1980 the Skylark population in Northwestern Europe (including Sweden) has been suffering a decline of about 50-75 percent (Wilson et al., 1997; Wretenberg et al., 2006). The reasons to the decline are several, but one factor seems to be that an increased proportion of the fields are sown during the autumn instead of the spring (Wilson et al., 1997; Chamberlain et al., 1999). The vegetation of autumn-sown fields becomes denser and higher earlier than spring-sown fields and when skylarks arrive to their breeding areas in late March – early April, these fields fit their search image for breeding habitats very well. Skylarks prefer a crop height of 20-60 cm (Wilson et al., 1997), and thus autumn-sown fields fit their needs better earlier during the season than spring-sown fields. This height of vegetation makes it possible for skylarks to hide their nests and forage. However, studies made in Great Britain state that autumn-sown fields usually become hard to use for foraging at the end of May, since the vegetation has already passed the maximum limit height (and vegetation density) at this point (Morris et al. 2004), thus decreasing the availability of invertebrates. This reduces the possibility for skylarks to produce multiple clutches during the breeding season, as is common in spring cereals (3-4 breeding attempts in spring-sown fields and 1-2 breeding attempts in autumn-sown fields, according to Morris et al., 2004), as mentioned by Morris et al., 2004 and Kragten et al., 2008. This is because the lack of areas with shorter vegetation (i.e. spring-sown fields) makes it hard for skylarks to find food close to the nesting area established early during the breeding season.

Since there is an economical interest in having winter cereals instead of spring cereals, the chance of increasing the amount of the latter is rather low. How to deal with the population decline of skylarks has therefore been a question of debate during the last decade, especially since the Skylark may be seen as a flagship and indicator species in the agricultural landscape, with an ecological function that is not studied in an extensive way. Various suggestions and agri-environmental schemas have been tested (Wilson et al. 2009), such for instance winter cereals sown in wide-spaced rows (Morris et al. 2004). During the last couple of years, however, a rather cheap and easy-to-use conservation action method has been developed in Northwestern Europe; the creating of unsown patches in the fields, which mainly focuses on skylarks. In this method, patches of about 16-20 m^2 are left during sowing (*figure 1*). In total there shall be about two unsown patches per hectare, which does not affect the production heavily. The idea is to increase food availability by creating some kind of natural habitat in the fields, an increased heterogeneity (varied vegetation height and density, as common in natural grasslands) in the otherwise homogenous vegetation, which makes it more similar to the more extensively cultivated agriculture landscape of before. There the skylarks are able to find food and in that way reduce the potentially negative effect caused by the intensely cultivated agricultural landscape of today, since one important factor to the decline of skylarks seems to be decreased food availability. Even though the unsown patches in this case are made artificially, similar patches do occur naturally in fields and studies have shown that skylarks prefer fields with such kind of micro-structures (Odderskaer et al, 1997; Schön, 2011).

For reasons mentioned the method with unsown patches (from now on called skylark-plots or SPs), has become popular and studies made in Great Britain show that it has a positive effect on the breeding success of skylarks (Morris et al. 2004, 2007). However, the method does not seem to have any effect when applied on organic farms in Sweden (Berg and Kvarnbäck, 2011) and studies on conventional farms have not been done here. Thus it is of importance to investigate if the method is equally applicable in Sweden as in Great Britain, since there are structural differences in the agricultural landscapes of the countries in question (Wretenberg et al., 2006). In Sweden, the possible amount of autumn-sown fields is regulated by the climate in a

Figure 1. Example of a Skylark-plot (SP). Each SP is about 16-20 m^2 and it is recommended to apply two SPs/hectare. (Photo by Mattis Jansson)

greater extent, thus making the proportion of those in the agricultural landscape to be lesser in Sweden than in Great Britain (Wretenberg et al., 2006).

There are also uncertainties about how skylarks use SPs in reality and if the effectiveness of SPs is dependent on landscape structures, climate, time-scale etc., since this have not been studied in an extensive way. For instance it is unclear how the effect of SPs is affected by field size and adjacent areas of different vegetation and crop types, as well as forests and pastures (level of landscape heterogeneity). SPs may have different effects when applied on small fields of autumn-sown crops connected to fields of spring-sown crops, than when applied on large autumn-sown fields located in homogenous areas. The field size affects the distance Skylarks have to travel when foraging; large fields of autumn-sown crops makes the distances longer, since the skylarks have to travel to areas of shorter vegetation to be able to find food. Thus, SPs may have a larger positive effect on large fields relative to small field, since the flying distance is decreasing much more in the case of large fields. As stated by Berg and Kvarnbäck (2011) SPs do not have an effect on organic farms, where the heterogeneity level is generally higher (varied vegetation height and density) as compared with conventional farms. Since field size and vegetation type are affecting the level of heterogeneity, it may be that SPs have a lower affect in Sweden than in Great Britain; they are not increasing the invertebrate availability in an important way. It is therefore necessary to study which effect SPs have on skylark territory density on autumn-sown fields in Sweden, before the method is recommended as a way of dealing with the population decline of skylarks.

1.2. The aim of the study

The general objective with this study is to investigate if SPs have a positive effect on skylark territory density in autumn-sown fields. It will hence be investigated if the abundance of SPs in conventional autumn-sown fields is increasing the number of skylarks claiming territory relative to fields without SPs, if this depends on the availability of food and if the effect of SPs depends on the level of heterogeneity in the landscape. It will also be investigated if there are a lower amount of invertebrates (food) to be found in the SPs than in the field-vegetation, since one of the ideas with SPs is to increase the foraging opportunities for skylarks.

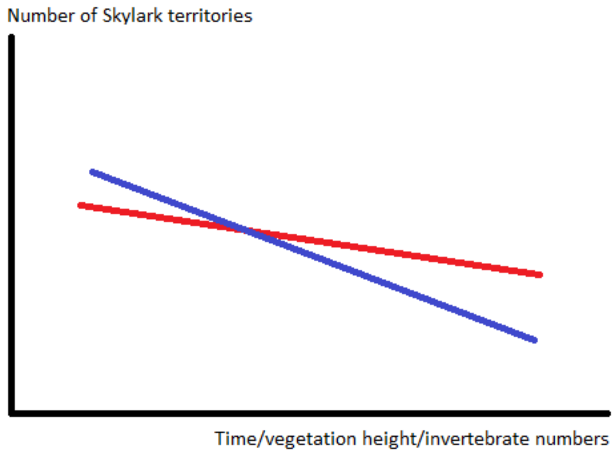

Figure 2. A scenario that is probable to expect. The presence of Skylark-plots will increase the amount of Skylark territories relative to fields without Skylark-plots. The difference between fields with Skylark-plots (red) and fields without Skylark-plots (blue) will increase as time goes by (increased vegetation height/number of invertebrates). Since Skylarks prefer a certain vegetation height, there will be fewer territories in SP-sites in the beginning of the breeding season (no vegetation in SPs, which reduces the useable area).

Similar areas (sites) of conventional fields sown during autumn (winter cereals) will be compared. On 50 percent of them SPs are created (SP-sites), whereas the other 50 percent are intact in their structure (control-sites). The idea is to study if skylarks are equally abundant or not in the different field types during the breeding season and if a possible pattern is caused by increased invertebrate availability caused by the presence of SPs.

Following predictions are tested in the study: (1) The presence of SPs is increasing the amount of skylark territories relative to fields without SPs and the pattern will get clearer as the vegetation gets higher and denser (*figure 2*). The breeding season is enhanced relative to fields without SPs, indicated by the increased effect of SPs as the vegetation gets higher. This is based upon earlier studies showing that skylarks prefer a vegetation structure similar to the one in SPs (Odderskaer et al, 1997; Schön, 2011). (2) The effect of SPs will depend on the density of them. This prediction arose during the planning of the study, since the number of SPs/site differed between the sites chosen for the project. More SPs increases the level of heterogeneity (varied vegetation structure and density) in the field, which may indicate increased food availability. Thus, more SPs will make it possible for more skylarks to coexist in the same area, since they may be able to find enough food closer to their nests. This will make the territories smaller and the population density higher. (3) The presence of SPs will make it easier for skylarks to forage, since the availability of invertebrates will increase. Thus, areas where SPs are applied will have a higher density of territories at a certain level of invertebrates (food) relative to areas without SPs (*figure 2*). It is thus expected that the density of skylark territories depends on the availability of invertebrates (food), not the abundance of them.

All predictions are in some way stating that invertebrate availability is a regulating factor that is describing the decline in skylark numbers during the breeding season. SPs are increasing the availability of invertebrates and it is therefore expected that their presence will affect skylark numbers in a positive way.

Benton et al (2002) are stating that there might be a negative relationship between number of birds and invertebrates in some cases (*figure 3*) and that this pattern may be caused by the vegetation structure. Autumn-sown fields are showing increasing vegetation densities at the same time as the invertebrates are increasing in numbers. Thus, more invertebrates do indicate decreased availability of food supplies since the skylarks are declining in numbers. Since SPs are increasing the availability of invertebrates it is expected that there will be fewer invertebrates there than in intact vegetation.

To make sure that invertebrate number may be used as a availability describing parameter, the raw data of invertebrates and skylarks will be plotted over time and compared with other describing parameters (time and vegetation height), before modeling it with skylark territory numbers. Invertebrate numbers (i.e. activity) in field vegetation and in SPs will also be compared with each to verify if there are differences in their abundances.

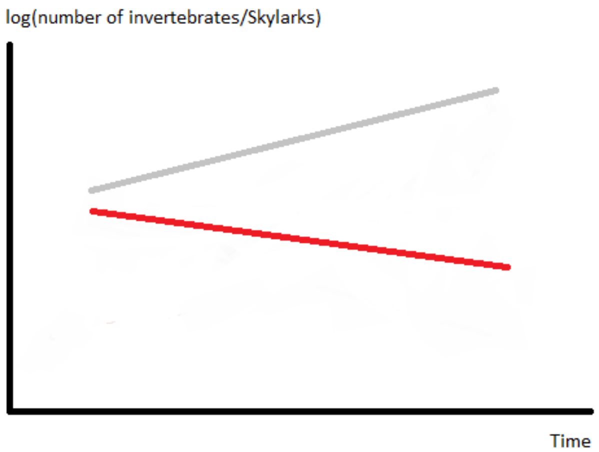

Figure 3. The predicted pattern of skylark numbers (red) and invertebrate numbers (grey) over time. The pattern is based on suggestions made by Benton et al. (2006). This makes it possible to use invertebrate numbers as a predictor of skylark numbers. Large numbers of invertebrates are indicating low food availability, thus few skylarks.

2. Methods

2.1. Study species

The Skylark, *Alauda arvensis,* is a widespread species in Europe (Glutz and Bauer, 1985). During the breeding season that reaches from the end of April to the mid of July, they inhabit large grasslands (e.g. agricultural landscapes), where they in extensively cultivated areas can be found in densities of about 0.8-1.1 territories per hectare (Glutz and Bauer, 1985; numbers from north of Germany/Poland). In more intensely cultivated areas the territory densities seems to be lower, with numbers of 0.4-0.6 territories per hectare (Glutz and Bauer, 1985; numbers from Great Britain). They are able to produce two clutches per breeding season and each clutch consists of 3-6 eggs (Glutz and Bauer, 1985). However, the number of clutches may vary geographically and fewer clutches are produced in winter cereals than in spring cereals (Morris et al., 2004 and Kragten et al., 2008). Studies made in Sweden indicate that it is common that Skylarks only produce one clutch per breeding season (Berg et al., 2009). Late breeding attempts (late of June) are probably caused by previous failures, making individuals to try once more (Berg et al., 2009).

2.2. Field work

2.2.1. STUDY AREA AND DESIGN

The field work was conducted in the southern and middle parts of Uppland, Sweden during 2012. In total five farms were included in the study (*table 1*), a number that was based on the amount of farms in the study area where SPs were applied. Each one of the farms was visited six times from 8th May-30th June (approximately nine days between each visit). The total number of sites was 30 (15 with SPs and 15 without), equally distributed over the five farms (i.e. three SP-sites and three control-sites/farm). To avoid pseudo replication, each site was placed at least 100 meters from another site. This distance is based on the predicted movement of food searching skylarks, which is about 75 meters (Eggers 2012, pers. com.).

Each site had the form of a circle with a radius of 100 meter; making the area approximately 3.14 hectares (*figure 4*). Due to the recommendation mentioned in the introduction, this would mean that each site should have six SPs. In the reality, however, this was not the case (*table 1*), thus made it interesting to test if the number of SPs affected the effect of them. Reasons that may describe the uneven distribution of SPs are discussed in the discussion part of this paper.

A transect was drawn through each site, which made it possible to stand in the middle of them, thus making sites comparable. To not affect the crop in a negative way, tractor tracks were used for walking. The placing of transects was therefore dependent on the presence of tractor tracks.

During each visit, the crop height was measured and noted. To avoid incorrect assessment caused by extreme heights of single straws, three measurements were conducted and the mean height of those was then used. Since the measuring required a movement of a few meters into the vegetation (i.e. three meters), three measurements were said to be enough as the crop should not be affected in a negative way.

The size of the fields where the sites were distributed varied between 10 and 100 hectares (*table 1*). Since fields with control-sites were of approximately the same size as the fields with SP-sites, this difference was controlled for within each farm. Landscape factors, such as amount of spring-cereals, connection to forest areas etc. were controlled for in the same way.

With the exception of two fields, all fields were sown with wheat. The two exceptions were sown with a hybrid of wheat and rye. The hybrid is very similar to wheat in height and vegetation density and thus this is presumed not affecting the result, even though both fields contained control-sites. Both these fields were located in Lohärad (*table 1*).

The visits were conducted during mornings (one hour after dawn until 12:00), with the exception of days with strong wind and heavy rain when the farms had to be visited during the afternoons. However, since both control-fields and fields with SPs were visited during the same day and conditions, this did not affect the outcome.

Table 1. The farms/areas included in the study showed a varied field area. This difference was controlled for between SP-fields and control-fields. Thus, it would not affect the result. In the column "Number of SPs/site", only the sites with SPs are included.

Farm/area	Crop	Field size (ha)	Number of SPs/site	Other
Sjöö	Wheat	50-100	5-11	No spring-cereals nearby
Villberga	Wheat	20	2-3	Spring-cereals nearby
Mora stenar	Wheat	15-20	3-5	Spring-cereals nearby
Östuna	Wheat	10-20	5-8	Spring-cereals nearby
Lohärad	Wheat/rye-hybride	25	3-6	No spring-cereals nearby

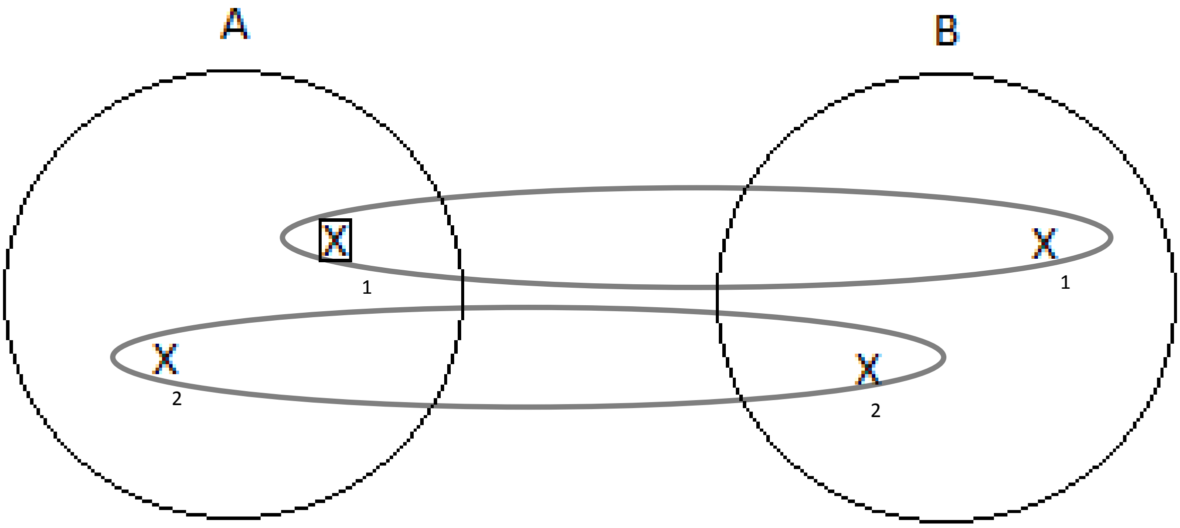

Figure 4. Two pitfall traps were placed in each site. In sites with Skylark-plots (A), one trap was placed in a Skylark-plot and the other one in the sown field. This made it possible to study the variation within a site. Circle B shows a control-site. The number 1 or 2 represents different categories to show which traps that were compared with each other. This was done to see if a possible difference was caused by the presence of SPs or not. Each site had a radius of 100 meters and an area of approximately 3.14 hectares.

2.2.2. THE INVERTEBRATE SURVEY

Two pitfall-traps with a diameter of ten centimeters were placed in each site, about 20 meters from each other (*figure 4* and *figure 5*). To avoid overflow caused by rain, a roof was placed over each trap. The traps were filled with water and detergent. They were emptied approximately every tenth day and the amount of invertebrates was then noted in numbers.

The idea with the pitfall-traps was to measure and compare the activity of invertebrates both in and between sites. The activity level was supposed to be correlated to the abundance; more invertebrates results in increased the activity. Thus, invertebrate numbers are the term used in this report, since it otherwise may be confusable. However, there might be an enhanced effect caused by the increased temperature during the period in question. The activity of invertebrates is increasing with the temperature, but since it is expected that the pattern is the same in SPs as in field-vegetation, this may be excluded when analyzing the data.

Figure 5. Upper picture: Skylark-plot with a pitfall-trap (indicated by the flag). Lower picture: Trap located in the field vegetation (indicated by the flag). (Photo by Mattis Jansson)

To be able to see if the variation in the sites was correlated with the presence of SPs, pitfall-traps were placed in the control-sites as well. The traps were divided into two categories (invertebrates 1 and 2). Category 1 (invertebrates 1) included one trap from a SP and one trap from the field, whereas category 2 (invertebrates 2) included two traps from the field vegetation (*figure 4*). This made it possible to conclude if differences were caused by the presence of SPs. The trap in the SP-site could be compared with corresponding trap in the control-site. Possible differences could then be seen and analyzed, since category 2 was used as control.

Figure 6. Singing Skylark, as they normally was observed during the survey. (Photo by Mattis Jansson)

It is important to mention that mollusks and worms were not counted, since the level of decomposition made it impossible to include these groups in the project. Even though these groups probably not are used as food for skylarks in an extensive way, this has to be mentioned. Presence of these organisms maybe makes other invertebrates to be more/less common (decomposed material may for instance attract invertebrates that feed on it).

2.2.3. THE SKYLARK SURVEY

During this part of the data collection singing and non-singing birds in a site was counted, with the aim of estimating the number of territories. If the number of singing skylarks exceeded the number of non-singing skylarks the total number of territories was said to be the same as the number of singing skylarks. If, however, the number of singing skylarks fell below the number of non-singing individuals, the number of territories was said to be the total amount of skylarks divided by two. For instance, if the number of singing birds was two, and the number of non-singing was four, the number of territories was said to be three ((2+4)/2 = 3). This way of estimating territories has been used by Donald et al. (2001) and the aim is to avoid underestimation. If only singing males are included it is possible that many males remain undetected. As noted in field, there are many territorial confrontations between individuals, but only a portion of those individuals are observed also when singing. Thus, this way of estimating territory density is preferable in this case. Since skylarks (singing and non-singing) were observed in flight and not on the ground

The number of territories gave information of the length of the breeding season, which indicated if multiple clutches possibly are produced. Since it is much easier to estimate territories than breeding success directly, this method was preferred, even though it causes some doubts about how to interpret the results (mentioned in the discussion of this paper).

2.3. Data analysis

Raw data from both the skylark and the invertebrate surveys were first presented to make sure that the predicted pattern of declining skylark numbers and increasing invertebrate numbers was present in this case. The data was then analyzed as generalized linear mixed models in MLwiN (version 2.11). The data were fitted using an extended Poisson distribution (with log link) to control for over-dispersion and fitted with hierarchical random parameters (i.e. farm, field, site and visit) to control for potential non-independence in sampling effort related to repeated sampling and site-specific effects. Even though landscape factors were controlled for in the field work design, a statistical control was done as well to make sure that potential effects could be neglected. The models were of the following general composition;

$$\mathbf{log(\pi) = \beta_0 x + \beta_1 + \beta_2 + \ldots}$$

, where π = number of skylark territories/invertebrates and β = parameters of different kind (i.e. treatment, time, number of skylark plots & invertebrate numbers), presented with values of mean and standard error. To compare models with different structures and hence identify the most important variables explaining skylark/invertebrate abundance, AIC_c-values according to the formula of Aikake's information criterion were used (Burnham and Anderson. 2002);

$$\mathbf{AIC_c = -2 * ln(likelihood) + 2 * K + (2 * K * (K+1))/(n-K-1)}$$

This version includes a bias-adjustment caused by the small number of observations (n) relatively to the total number of parameters (K). In all cases of this study n/K < 40 and thus an adjustment was required. The values of -2*ln(likelihood) were calculated in MLwiN and the AIC_c-values were calculated in Microsoft Excel (version 2010). The model with the smallest AIC_c-value was then said to be the model that explained the pattern the best. To be able to spot significant differences between models, Akaikes weight-index (w_i) was calculated according to the formula:

$$\mathbf{w_i} = \frac{\mathbf{exp}(-\mathbf{0.5}*\Delta\mathbf{i})}{\sum_{r=1}^{R}(\mathbf{exp}(-\mathbf{0.5}*\Delta\mathbf{r}))}$$

, where $\Delta_\mathbf{i}$ is the difference between the AIC_c of the model that describes the pattern best and that of model *i*. To be able to determine if more than one model could be said to explain the pattern, a method suggested by Royall (1997) was used. In this method, all models with a w_i within 10 percent of the highest (w_{imax}) are said to be candidate models for the pattern explanation ($0.10*w_{imax}$). Models with a w_i smaller than this value are not interesting for further discussions, thus parametric values of these models are not presented.

2.3.1. THE INVERTEBRATE SURVEY

To be able to investigate if the availability of invertebrates regulates the abundance of skylarks and if the abundance of invertebrates changes over time, the number of trapped invertebrates was modeled over time. If the number of invertebrates was increasing during the breeding season of skylarks (at the same time as the skylarks were getting fewer), the amount of invertebrates wasn't regulating the abundance of skylarks. The invertebrate number could then also be compared with time and vegetation height and used as a describing parameter when modeling with skylark territory numbers.

Mean values of raw data of caught invertebrates in the different trap categories (*figure 4*) were presented to visualize the pattern observed in field. By then using the data from traps of category 1 (including traps from SP-plots and field vegetation, (*figure 4*) it was possible to see if there were any differences between SPs and field vegetation. Models based on the material were done and compared with each other to see if there were any significant differences. To verify that the eventual differences were caused by the presence of SPs, the same models were done based on data from traps of category 2 (including two traps from the field vegetation, *figure 4*). This made it possible to see if any differences were caused by the SPs directly.

2.3.2. THE SKYLARK SURVEY

Different models based on the survey data were compared (AIC_c-values) and then plotted to see which one that explained the results most accurately. At first it was tested which one of the three describing parameters (time, invertebrate numbers and vegetation height) that best described the variance in skylark territory numbers during the breeding season. If a significant difference between the parameters could be seen, only the best fitting parameter was used when modeling the territory numbers and visualizing them in a graph. When doing this, the data was divided into control-sites and SP-sites, which made it possible to observe the difference in territory numbers between the site categories.

Since one farm (Sjöö) deviated from the others in field size (*table 1*), it was of interest to visualize if there were any differences in the effects of SPs between larger and smaller fields. However, since the data material was very limited this was not included in the result part. Instead it is presented in APPENDIX I.

Since the number of SPs/site varied between two and eleven (2-11), it was of interest to see if there were some differences in skylark territory abundance between sites with few SPs and the ones with more. To investigate this, only the data from SP-sites was used and the territory numbers were modeled according to the number of SPs/site. It was also interesting to see if the effect of SPs was constant during the breeding season, or if the interaction with the describing parameters (time, vegetation height and invertebrate number) was of great importance. This was done by comparing the different models used to describe the amount of skylark-territories during the breeding season. If the model that included the interaction term better described the varying number of territories, the effect of SPs is increasing over time.

3. Results

3.1. Presentation of raw data

To make sure that the predicted pattern is there to be found, the raw data is visualized (*figure 7*). This indicates that skylark and invertebrate numbers have different patterns over time and that high numbers of invertebrates do not have to mean high availability of food supplies, the factor that affects territory density of skylarks. The availability of food supplies is modified by the vegetation structure. To be sure that this pattern is true, statistical analyses are provided as well (*section 3.2 and 3.3).*

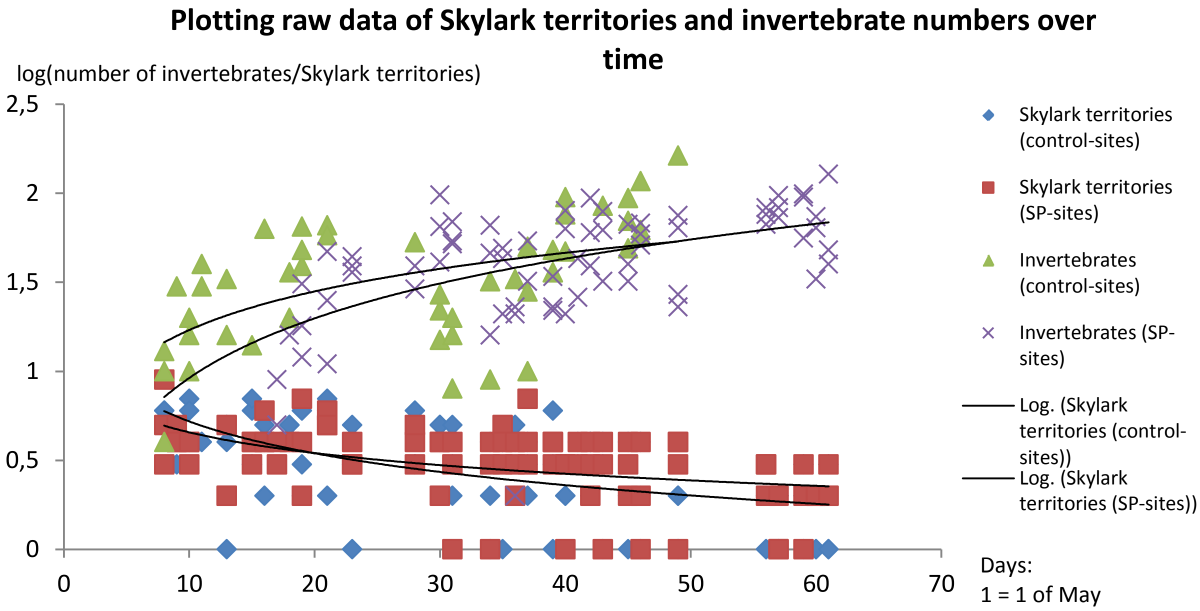

Figure 7.The predicted pattern of increased invertebrate numbers and declining skylark numbers over time is supported by the raw data, suggesting that invertebrate numbers may be classified as a parameter describing the food availability and thus skylark numbers. The invertebrate numbers are based on the material from trap category 1 (including one trap placed in SP and one placed in field vegetation).

The mean values of caught invertebrates in each trap category (*table 2*) are showing that there is no clear difference to be found in the raw data, only potentially higher values in trap placed in SPs. To be able to spot differences in invertebrate numbers between sites and trap categories, stochastic parameters have to be included. Statistical analyses are therefore required (section 3.2)

Table 2. Mean values of trapped invertebrates in each trap category. No clear difference is seen, indicating that statistical analyses are required to spot eventual differences.

	Invertebrates 1, control-sites	Invertebrates 2, control-sites	Invertebrates 1, SP-sites	Invertebrates 2, SP-sites
Mean	42.3	47.4	48.8	43.9
Standard deviation	31.8	40.0	26.6	35.9

The mean values of skylark territory densities of the breeding season in total were 3.30 territories/3.14 ha, SE = 1.49 (SP-sites) and 3.19 territories/3.14 ha, SE = 1.82 (control-sites). However, these values do not make it possible to visualize the predicted effect enhancement during the breeding season and are only presented to show the effect over the entire breeding season.

3.2. The invertebrate survey – modeling

When making models based on the data of invertebrates of category 1 (invertebrates 1) there is no indication that the presence of SPs (treat) may have a positive effect on the amount of invertebrates (*table 3* and *4*). However, in the case of invertebrates of category 2 (invertebrates 2), the "Treat + time + interaction"-model describes the results significantly better than the other ones, according to the AIC_c-values (*table 5* and *6*).

Table 3. The AIC_c-values show that the "Time"-model describes the data on invertebrates of category 1 best. However, the models are very similar and the only model that can be rejected is the "treat"-model. The other models are all with in the 10 percent of w_{imax}.

Model	K	AICc	Δ_i	Exp(-0.5*Δ_i)	w_i
Time	*4*	1056.239	0	1	0.436
Treat + time	*5*	1057.026	0.787	0.675	0.294
Treat + time + interaction	*6*	1057.196	0.957	0.620	0.270
Treat	*4*	1101.289	45.05	0.000	0.000
			Sum =	*2.295*	

Table 4. Three different models based on the data on trapped invertebrates of category 1 (traps from SPs and field vegetation). The standard error of the "treat"-parameter is in all cases very high, which may be caused by the fact that the data is collected from two types of traps.

Model →	Treat + time		Treat + time + interaction		Time	
Parameters	*Mean*	*SE*	*Mean*	*SE*	*Mean*	*SE*
Treat	0.1525	0.1159	0.4464	0.3724	-	-
Time	0.0281	0.0044	0.0322	0.0066	0.0281	0.0044
Treat*time	-	-	-0.0071	0.0086	-	-

Table 5. The AIC_c-values indicate that the "treat + time + interaction"-model describes the data on invertebrates of category 2 significantly better than the other models. This is strange and not expected, since category 2 is not including traps from SPs. It indicates on a difference between control-sites and SP-sites, even if the models are based on data from traps in field-vegetation.

Model	K	AICc	Δ_i	Exp(-0.5*Δ_i)	w_i
Treat + time + interaction	*6*	1026.746	0	1	0.934
Time	*4*	1032.860	6.114	0.047	0.044
Treat + time	*5*	1034.296	7.55	0.023	0.021
Treat	*4*	1040.729	13.983	0.001	0.001
			Sum =	*1.071*	

Table 6. Describing the increase in invertebrate numbers over time, presenting parametric values of the "treat + time + interaction"-model, the only model that are within the 10 percent of w_{imax}. The standard errors are rather high in the cases of the parameters "treat" and "treat*time".

Model →	**Treat + time + interaction**	
Parameters	*Mean*	*SE*
Treat	0.9543	0.7270
Time	0.0341	0.0130
Treat*time	-0.0226	0.0173

When dividing the data according to trap categories (invertebrates 1 and 2) and SP-/control-sites (*figure 8*), it is easy to see that there is no difference in invertebrate number between the traps in control-sites, as expected. However, the data from SP-sites reveals a pattern which is hard to explain. The increase in invertebrate numbers over the season is similar when using data from trap 1 (placed in SP) and trap 2 (placed in field-vegetation). In the case of the latter, the standard error is very high, which may indicate that the data is limited or affected in some way.

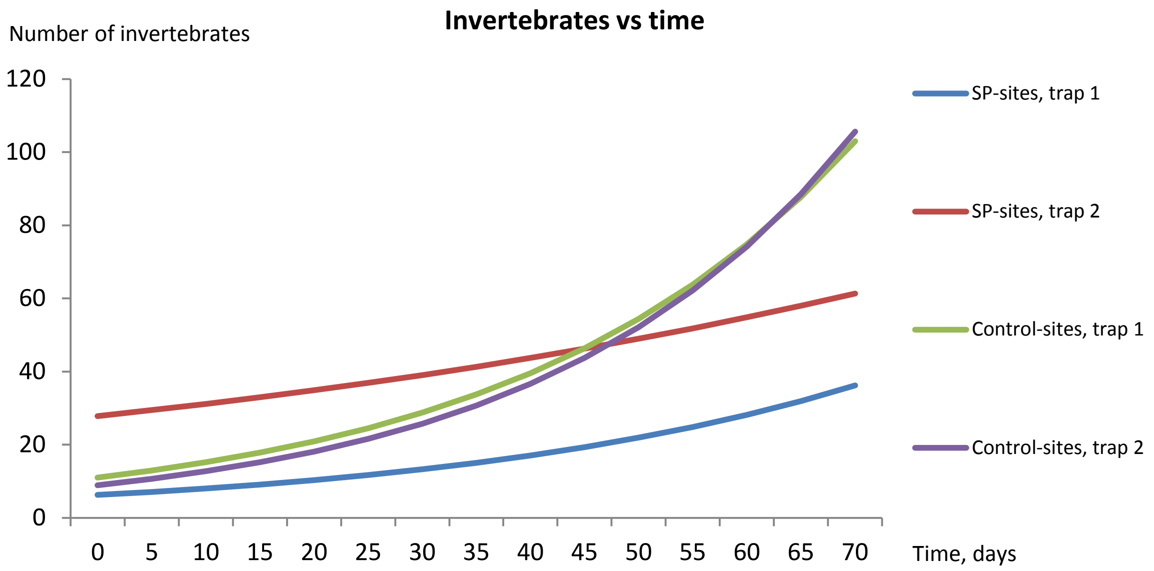

Figure 8. Modeling the number of invertebrates over time. This may indicate that the difference in invertebrate numbers between traps of category 1 is caused by the presence of SPs, since there are more invertebrates in the field vegetation (SP-site, trap 2) than in the SPs (SP-site, trap 1). In addition, the control traps are showing huge similarities (as expected), a pattern which is not seen when comparing the trap-categories in SP-sites, even though the increase over the season is almost similar. The invertebrate numbers presented in this figure will be used when modeling with skylark numbers (section 3.3).

3.3. The Skylark survey – modeling

Since the invertebrate number was positively correlated with time, it was treated as a time-describing parameter (like time and vegetation-height) and modeled to display the variance in skylark territory density (*table 7*). Due to this the number of invertebrates of category 2 (invertebrates 2) seems to be the parameter that best describes the pattern of territory numbers, as noted by the AIC_c-values. Thus invertebrates 2 is the only parameter that is presented with values (*table 8*). The reason why this category is a better describing parameter than invertebrates 1 is that the latter consists of traps from SPs and field-vegetation, whereas invertebrates 2 only consists of traps from field-vegetation. Thus, there are larger differences in invertebrates 1, making it to a more uncertain parameter.

Table 7. The AIC_c-values show that the model including invertebrates of category 2, treatment and interaction is describing the number of Skylark- territories during the breeding season best. The result is significant since no other model is within the 10 percent of w_{imax}.

Model	**K**	**AICc**	**Δ_i**	**Exp(-0.5*Δ_i)**	**w_i**
Inv. 2 + treat + interaction	7	526.123	0	1	0.970
Invertebrates 2	5	533.681	7.558	0.023	0.022
Inv. 2 + treat	6	535.824	9.701	0.008	0.008
Inv. 1 + treat + interaction	7	604.093	77.970	0	0
Invertebrates 1	5	607.358	81.235	0	0
Inv. 1 + treat	6	608.803	82.680	0	0
Vegetation height	5	735.747	209.624	0	0
Vegetation height + treat	7	736.729	210.606	0	0
Veg. height + treat + interaction	6	737.814	211.691	0	0
Time	*5*	751.259	225.136	0	0
Treat	*5*	752.169	226.046	0	0
Treat + time + interaction	*7*	752.779	226.656	0	0
Treat + time	*6*	753.529	227.406	0	0
			Sum =	*1.031*	

The interaction between the time-describing parameters and treat (SPs) shows that the effect of SPs increases during the breeding season (*table 8*).

Table 8. Parameter values of the model that best described the number of Skylark territories during the breeding season, as noted by table 2.

Model →	**Treat + inv. 2 + interaction**	
Parameters	*Mean*	*SE*
Treat	-0.3631	0.1530
Inv. 2	-0.0134	0.0027
Treat*inv. 2	0.0107	0.0033

Since the model including invertebrate number is the one that describes the pattern best (according to the AIC_c-values), the invertebrate-parameter is used to visualize the pattern of skylark territory numbers during the breeding season (*figure 9*). This shows a distinct decline in territory numbers, a decline that is lesser in SP-sites, even when keeping the difference between trap-category 1 and 2 (invertebrates 1 and 2) in mind. The pattern is similar when modeling with the “time”- and “vegetation height”-parameters (APPENDIX II). The reason why this was done was to visualize that the number of skylark territories are decreasing at the same time as the invertebrate numbers are increasing and that this pattern becomes clearer during the breeding season of skylarks.

As noted in *figure 9*, the trend lines are of different length. This is due to the fact that there are statistical differences in invertebrate numbers of the categories (*figure 8*), differences that have to be kept in mind when modeling skylark territory numbers.

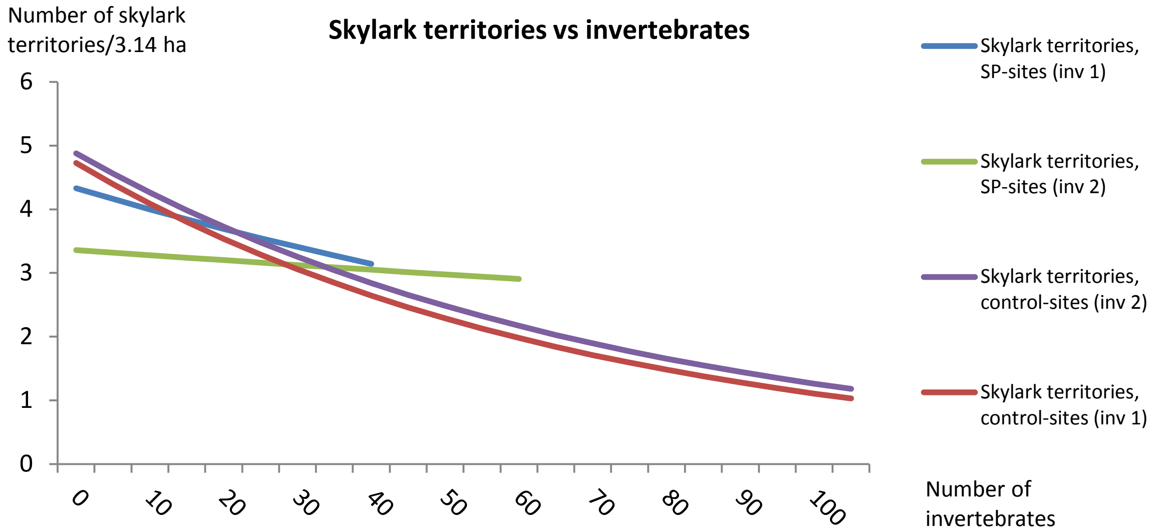

Figure 9. Modeling the number of skylark territories with the amount of invertebrates. This shows that the decline in territory numbers is lower in SP-sites relative to control-sites but also that there are more territories in control-sites in te beginning of the breeding season. The number (1 or 2) is indicating which category of invertebrates the model is based on. It is of most interest to compare the differences between the control-traps and SP-trap of category 2, since those are based on material from field-vegetation. As noted, lower numbers of invertebrates are reached in fields with SPs. These values are based on *figure 8*, which state that lower levels of invertebrates are found in fields with SPs relative to fields without SPs. This is also supported by Benton et al. (2002), suggesting that there in some cases are more invertebrates in fields of high vegetation density (low availability of food supplies).

When testing for effects caused by the number of SPs/site, no such effects are found (*table 9* and *10*). In addition, the loss of interaction between the number of invertebrates and the number of SPs shows that the number of SP/site does not have an increased/decreased effect over time. In several cases the standard errors are very large, a fact that may indicate that the data material is limited.

Table 9. The AIC$_c$-values reveals a rather unclear result. Several models can possibly explain the pattern. As noted by the standard errors in table 9 and 10 there are huge uncertainties in the parameter values, which may explain why no clear candidate model is found. This may indicate that the number of SPs does not have any effect.

Model	**K**	**AIC$_c$**	**Δ_i**	**Exp(-0.5*Δ_i)**	**w_i**
Invertebrates 2	5	226.207	0	1	0.631
Number of SPs + inv. 2	6	228.638	2.431	0.297	0.187
Number of SPs + inv. 2 + interaction	7	229.753	3.546	0.170	0.107
Number of SPs + inv. 1	6	230.886	4.679	0.096	0.061
Number of SPs + inv. 1 + interaction	7	233.719	7.512	0.023	0.015
Number of SPs	5	328.516	102.309	0.000	0.00
Invertebrates 1	5	345.913	119.706	0.000	0.00
			Sum =	*1.586*	

Table 10. Parameter data from the model counting on effects in skylark-territory abundance, caused by the number of SPs/site. Only models within 10 percent of w_{imax}. No effects of caused by the number of SPs are found.

Model →	**# of SPs + inv. 2 + int.**		**# of SPs + inv. 2**		**Invertebrates 2**	
Parameters	*Mean*	*SE*	*Mean*	*SE*	*Mean*	*SE*
Number of SPs	0.0041	0.0379	-0.0229	0.0252	-	-
Invertebrates 2	0.0001	0.0034	-0.0024	0.0017	-0.0024	0.0017
Interaction	-0.0004	0.0006	-	-	-	-

Some important notations were done during the field work and they will be mentioned here: (1) Observations of skylarks landing in the SPs. The number of observations is however limited and therefore excluded from analysis, (2) observations of territory establishing skylarks that were moving large distances, way over the safety distance of 100 meters and (3) skylarks establishing territories in sites located close to spring-sown areas tended to be found close to them. These notations will be treated in the discussion of this paper.

4. Discussion

Towards the end of the breeding season (high invertebrate numbers) there are more skylark territories in areas with SPs than in areas without them, at least there are very clear indications that point in that direction. Thus, it might be that skylarks prefer fields with SPs, a suggestion that is supported by the fact that skylarks seem to prefer fields where similar kind of micro-structures are occurring naturally (Odderskaer et al., 1997; Schön, 2011). There is also tendencies toward lower numbers of skylark territories in SP-areas in the beginning of the breeding season, a fact that may be caused by the search image of skylarks; the preference of a vegetation height of 20-60 cm (Wilson et al., 1997). These statements are supported when modeling territory numbers over time and vegetation height (APPENDIX II). A similar pattern is known from comparisons of autumn- and spring-sown fields, where autumn-sown fields showed decreased skylark densities toward the end of the breeding season relative to spring-sown fields (Eggers et al. 2011). This may be indirectly caused by the lower vegetation in SPs as well as in spring-sown fields, indicating that the availability of invertebrates is better there as compared with intact autumn-sown fields. As predicted the level of invertebrates increases during the breeding season of skylarks, during the same time as the skylarks are showing a decline in territory numbers. However, the decline of skylark territories in SP-sites is less steep relative to the decline seen in control-sites. This suggests that it might be the availability of invertebrates rather than the abundance that regulate the amount of skylarks, since the effect of SPs becomes larger as the availability of food supplies in general is decreasing (SPs becomes more important). In addition, lower levels of invertebrates are found in SP-sites than in control-sites, a fact that further strengthens this statement since it was predicted that high numbers of invertebrates indicates low food availability. This pattern was only observed when landscape factors were counted for statistically, indicating that there might be differences between the farms and areas used in the study. If this pattern is true even for spring-sown areas contra autumn-sown areas remains to see, but a probable guess is that the level of invertebrate availability is a regulating factor even in that case.

The invertebrate availability is negatively correlated to the vegetation height and density; dense vegetation makes it harder for skylarks to find invertebrates to feed their nestlings with. However, this needs to be further investigated, because of the complex relation between skylarks, invertebrates and vegetation density. Benton (2002) proposes that bird numbers and invertebrate numbers may be negatively correlated to each other, but that it varies with different groups of invertebrates, vegetation structures and landscape factors in general. To be able to make definite statements in this question it may be important to use direct measurements on the vegetation density, since this is directly correlated to the food availability. By comparing invertebrate numbers and skylark territory numbers with the vegetation density, it may be possible to conclude which factors that are correlated to each other. It may also be necessary to do more accurate studies on invertebrates. For instance it may be interesting to study if invertebrates avoid/prefer unsown areas (i.e. SPs), since this will affect the interpretation of the result. If important groups of invertebrates are avoiding SPs, they will be impossible to find and thus SPs are not affecting the availability. In addition, all invertebrates in this study were put together in one group to make sure that the data material was large enough. However, skylarks may not feed on all types of invertebrates present in the fields. With larger studies focusing on the invertebrate groups that mainly are interesting for skylarks it may be possible to make clearer statements in this question.

The number of SPs/site varied between two and eleven per 3.14 hectare as compared with the suggestion of six per 3.14 hectare (i.e. two per hectare). It was predicted that applying more than two SPs per hectare would result in a greater positive effect on the skylark territory density. This prediction was based on the fact that more SPs results in a higher availability of invertebrates, making it possible for more skylarks to coexist. In this study, no difference caused by the number of SPs/site was seen. Thus, applying more than two SPs per hectare won't have any positive effect on the skylarks, which indicates that the presence of SPs does not affect the territory density. However, this result may be caused by the rather high landscape heterogeneity of the farms included in this project. In Uppland, where this study was conducted, many fields are about 15-25 hectares in size. The surrounding landscape in this part of Sweden is also rather varied in its structure and many autumn-sown fields are connected to areas of spring-cereals as well as pastures. The level of heterogeneity is thus rather high which probably affect skylarks and the efficiency of SPs, a fact that makes it necessary to move on with studies in more homogenous areas, since the result might be different there.

If territory density is a good measurement on breeding success is hard to know. It is much easier to count and estimate territory numbers than it is to estimate survival rate of fledglings and number of eggs/clutch, but the accuracy of the first-mentioned method may be discussed. As mentioned by Hiron et al. (2012) the territory density of autumn-sown areas are showing much steeper declines during the breeding season relative to spring-sown areas. Similar results are also mentioned by Poulsen et al., (1998) and Chamberlain et al. (2000b). In combination with statements made by Berg et al. (2009), that a second breeding attempt probably is caused by a previous failure, the results of this study may indicate that it is possible for skylarks to make a second breeding attempt in fields with SPs (making the breeding season longer), while it is not in fields where SPs are not applied (where Skylarks have to move to new areas, since the availability of invertebrates are too low). This indicates that territory density might be a rather good measurement on the length of the breeding season and the number of breeding attempts that possibly can be performed. However, it does not give direct answers about the breeding success, even though it might be expected that more breeding attempts also results in a higher total production of fledglings.

As noted, many parameters are showing rather large standard errors. This may be explained by the small set of data that in the case of the invertebrate categories is enhanced by many missing values, since several traps were lost during the survey. Even though the missing values kept in mind when the data was analyzed, they still make the limited set of data even smaller. Thus, stochastic factors may affect the data, making the standard errors higher. Landscape variables were accounted for when designing the field study and they were also controlled for in the statistical analysis (making the standard errors even higher), but variance caused by pure coincidence requires a large set of data to not affect the outcome.

The mean values of caught invertebrates of the different trap categories are showing a different pattern than the one observed when doing statistical analyses on the data material. The difference between the median values may be caused by variance between farms, fields and sites. For instance the vegetation cover in SPs varied within and between sites, making it to a factor that probably affects the abundance of invertebrates. When statistically controlling for factors of that kind, the pattern changes. It might therefore be interesting to study the impact of vegetation cover in SPs on the invertebrate abundance, since it will tell when the vegetation cover is optimal for skylarks.

The observed treatment effect on invertebrates of category 2 is unexpected. It might be that the traps in SP-sites were located too close to each other, thereby making the presence of SPs to affect the invertebrate number in the trap located in the field vegetation. The traps were placed about 20 meters from each other, a distance that was supposed to be enough. Another possible explanation is that skylarks use skylark-plots for foraging in such an extensive way that it affects the number of invertebrates in the site, making questions about its ecological role to arise. Do Skylarks act as biological regulators of invertebrates in the agricultural landscape?

In several cases it was noted that skylarks that were establishing territories in a particular site suddenly made movements of up to 500 meters and then settled down in another field.

These observations clearly criticize the adequacy of the safety distance of about 100 meters, which was used in the project. Even though this kind of movements was noted several times, they were still far from common and therefore they were ignored in the analysis. However, it may be important to keep in mind that movements of this distance are present even among skylarks establishing territories. This behavior may be an indication of how flexible this species are when searching for breeding areas and that it is possible for them to move large distances when foraging. Observations of this kind shall be kept in mind when discussing the impact of landscape heterogeneity on the breeding success of skylarks. Studies made in Great Britain are stating that skylarks in autumn-fields are moving to other breeding areas when the vegetation becomes too high (Morris et al. 2004). Since the proportion of spring-sown areas is larger in Sweden than in Great Britain (Wretenberg et al., 2006), it may be easier for skylarks to find new breeding areas here, which probably reduces the importance of conservation action methods such as the application of SPs.

As noted in this study, skylarks in fields that were connected to spring-sown areas, tended to be found very close to those areas relative to the rest of the field. According to Hiron et al. 2012 the presence of adjacent spring-sown fields will not affect the abundance of skylarks in the autumn-sown field. It might, however, affect the effectiveness of SPs, since the skylarks probably forage in the spring-sown field. Landscape variables were controlled for when choosing fields for the study, but nevertheless they are important to keep in mind when making conclusions. For instance, the data from one farm that deviated from the others in size (Sjöö gård), did show a greater effect of the SPs than found in the other farms (APPENDIX I). Even though it is not possible to make general conclusions based on the limited set of data, there seems to be a tendency; SPs do have a positive effect on skylark-populations when applied on huge autumn-sown fields located in a homogenous landscape. Since the agricultural landscape in other parts of Sweden look like this, the work with SPs may proceed in those areas. This suggestion is supported by studies made in Great Britain (i.e. Morris et al, 2004; 2007) and also from observations, made in this study, of Skylarks landing in SPs. Even though the number of observation in this study was too small to generalize, it is nevertheless an indication of the potential of SPs and how they are used.

The rather large proportions of spring-sown areas nearby the fields used in the project may affect the result, indicating that SPs may have a larger effect in areas of low landscape heterogeneity. This statement is further strengthened by the result from Sjöö. However, since no definite evidence is found it is important to move on with further studies to be able to understand how surrounding landscape and biota affect the quality of autumn-sown fields as a habitat for skylarks. Misdirecting of conservation methods may make it hard to motivate upcoming ideas and thus it needs to be approved that SPs are used in the right way in the right areas. For instance it might be interesting to test the effect of tractor tracks and if they may work in a similar way as SPs do. Tractor tracks are covering a rather large proportion of fields, making the vegetation cover to vary even in fields where SPs are not applied, a fact that potentially have a positive effect on the food availability for foraging skylarks. However, wide-spaced rows of winter-cereals have been tested as a conservation action method, but no effect could be seen (Morris et al., 2004).

In this study, the potential effect of pesticides was not included as a parameter. The reason was simply that it was too difficult, especially since it involves many factors such as timing of pesticide application, how many applications and type of pesticides. It was therefore assumed that the farms and fields used in the project were similar in this case, even though there probably were differences in reality. However, the differences between farms and fields were controlled for in the statistical analysis. When doing a larger study it may be possible to control for it in the field work as well.

This study does confirm that SPs have a positive effect on autumn-sown fields in Uppland, Sweden. Since studies made in Great Britain state that SPs work well there (Morris et al.

2004, 2007), applying SPs in more homogenous agricultural areas would probably increase the positive effect of SPs, even though this is not tested in this study. Thus more studies are needed to make further conclusions in this question. For instance it would be interesting to make a study on the effect of SPs along a north-south gradient in Sweden, taking landscape factors such as field size and proportion of spring-cereals and pastures in consideration. As mentioned, SPs probably will have a larger positive effect in more homogenous areas, thus being more efficient in the south of Sweden, where the agricultural landscape is more similar to the one in Great Britain. A study like this may be important to perform, especially since it is important to direct conservation action methods in the right way. In a broader perspective, more knowledge about when and how to apply SPs will make it easier to convince the public that conservation action methods make difference and that it is possible to combine them with production interests.

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APPENDIX I:

The data from Sjöö (*table 11*) shows a similar pattern as the entire data material (*table 4* and *5*). When plotting the data on skylark observations from Sjöö (*figure 10*), it is possible to see that it is a steeper decline of territory numbers in control-sites as compared with the entire set of data (*figure 7*). The decline in SP-sites is conversely very similar. However, the set of data is very limited in this case and no general conclusions can be made.

Table 11. Estimating territories by the invertebrate numbers of different sites and trap categories.

	Skylark territories, control-site (1)		**Skylark territories, control-site (2)**		**Skylark territories, SP-site (1)**		**Skylark territories, SP-site (2)**	
Parameter	*Mean*	*SE*	*Mean*	*SE*	*Mean*	*SE*	*Mean*	*SE*
Invertebrates	-0.0239	0.0061	-0.2020	0.0054	-0.0079	0.0035	-0.0098	0.0030

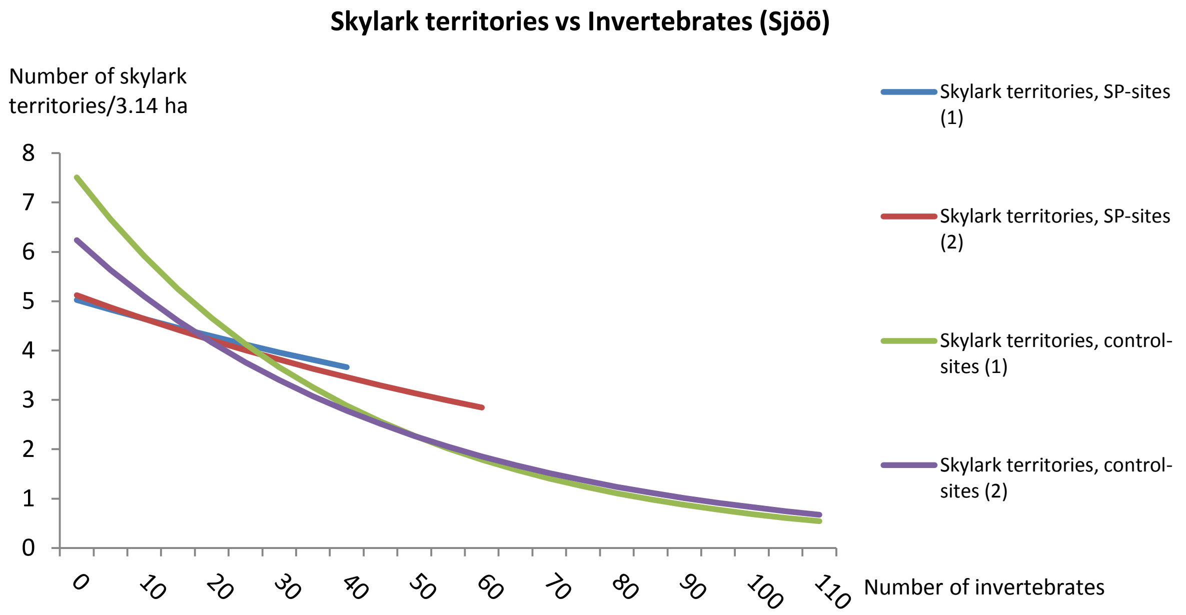

Figure 10. Number of skylark territories at Sjöö. The data material is limited but there seems to be a steeper decline in control-sites relatively to the entire data set (*figure 7*). The number of invertebrates is based on *figure 6*.

APPENDIX II:

The number of skylark territories modeled over time (measured in days) shows that the decline is lower in SP-sites than in control-sites (*figure 11*). The same result is reached when modeling with vegetation height (measured in cm) (*figure 12*). This confirms the pattern that is seen when modeling with invertebrate numbers (*figure 9*).

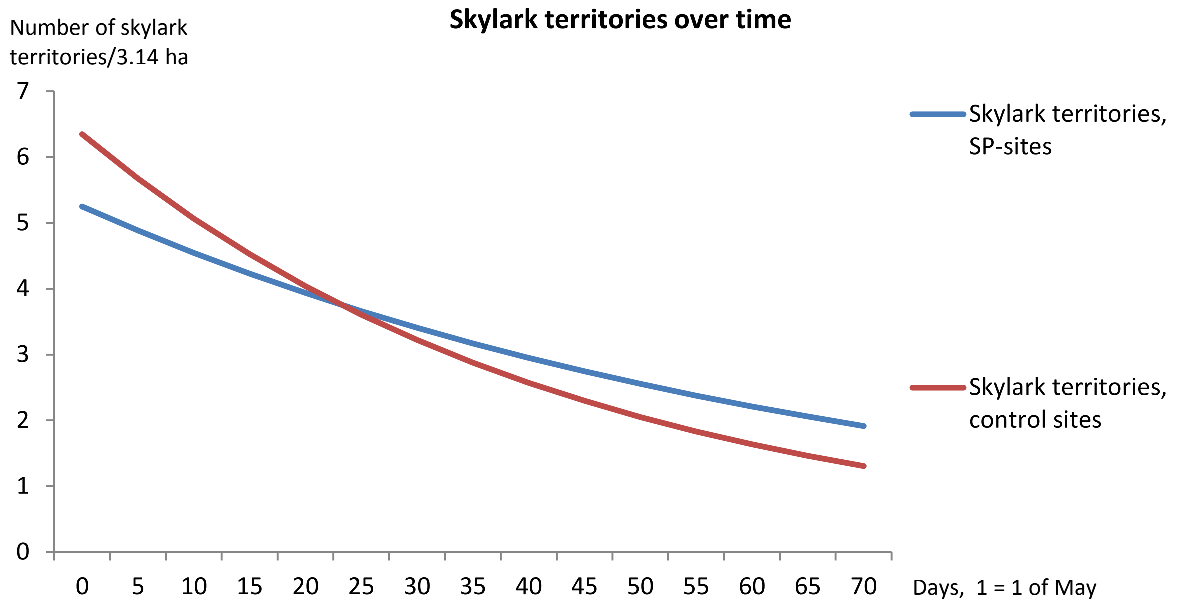

Figure 11. The number of skylark territories modeled with time. The decline in territory numbers is lesser in SP-sites than in control- sites.

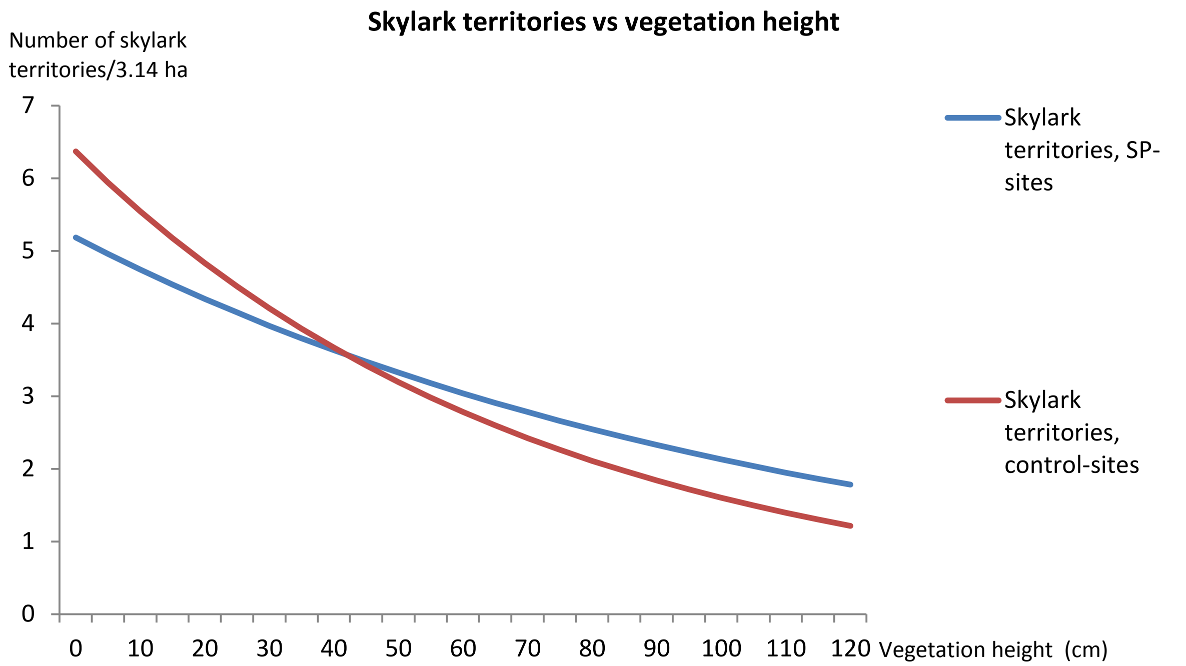

Figure 12. The number of skylark territories modeled with vegetation height. The decline in territory numbers is lesser in SP-sites than in control- sites.