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Flora and Fauna Changes During Conversion from Conventional to Organic Farming

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Preface and acknowledgements

In a project 1996-2000 the possible effects on flora and fauna of reducing pesticide dosages experimentally at large scale were investigated at five large farms in Denmark (Esbjerg & Petersen 2002). During the last field season (1999) the owner of one farm decided to convert from conventional to organic production. This decision opened a rare research opportunity of possible interest for environmental protection: To study the immediate influence of conversion on flora and fauna. Other investigations have demonstrated the value of organic farming in terms of richer nature but always on farms which had been organic for a number of years. In the present case the established knowledge of plants, arthropods and birds during three preceding years provided an excellent background for a study of possible changes in biodiversity the first two years after the conversion starting 2000.

On the above background the present project was planned and applied for to the Danish Ministry of the Environment which allocated the necessary funding. Like the preceding project – afterwards called the conventional period – also this project included three main areas, botany, entomology (arthropods), and ornithology.

The project was initiated while treatment of sampling data from the conventional period was still ongoing. The treatment of data and statistical analyses with comparisons of the two periods 1997-98-99 (conventional) and 2000-2001 (organic) were finalized in 2001.

The partners of the project were:

Botanical aspects: Dept. of Physiological Ecology, Botanical Institute, University of Copenhagen (Anne-Mette M. Jensen and Ib Johnsen)

Entomological aspects: Zoology Section, Dept. of Ecology, Royal Veterinary and Agricultural University (Peter Esbjerg and Søren Navntoft)

Ornithological aspects: Ornis Consult A/S (now: Hedeselskabet Miljø og Energi as) (Bo Svenning Petersen)

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Sammenfatning og konklusioner

Denne projektrapport omhandler to års undersøgelser af, hvilke ændringer flora, insektfauna og sanglærker udviser i omlægningsfasen til økologisk drift. Projektet har taget afsæt i en treårig undersøgelse af effekter af nedsatte pesticiddoseringer på fem godser på Sjælland og Møn. Her indgik afgrøderne vårbyg, vinterhvede og sukkerroer. Den nærværende undersøgelse hos den ene forsøgsvært, Oremandsgaard Gods, har benyttet det forudgående projekts resultater vedrørende vilde planter, insekter og fugle som sammenligningsgrundlag. Herved sammenlignes ikke kun konventionel drift med omlægningsperioden på den aktuelle ejendom; men der er også grundlag for at belyse den mulige indflydelse af de tre forudgående års doseringsniveauer: normal samt 50% og 25% af normal. Begge projekter er relateret til pesticidhandlingsplan I, og begge er blevet finansieret af Miljøstyrelsen.

I den økologiske undersøgelsesperiode på to år kunne kun vårbyg og vinterhvede inddrages. Som i det tidligere projekt blev plantetæthed og antallet af plantearter samt blomstring og frøfald anvendt som målestørrelser, og dertil blev så føjet biomassemålinger. Prøvetagninger af insekter og visse andre leddyr blev som tidligere foretaget med en sugemaskine (støvsugerprincip). Antallet af sanglærker og andre fugle blev optalt cirka hver femte dag ved en kombination af punkttællinger og linietransekter. På de samme dage blev der foretaget indsamlinger af lærkeekskrementer, som siden blev mikroskoperet for rester af insekter. Herved kunne vigtige fødeemner for sanglærken identificeres og kvantificeres.

Tætheden af ukrudtsplanter og antallet af plantearter viste sig at være højere ved økologisk drift end ved normal (fuld) dosering i den konventionelle periode. Dog blev der ikke mere ukrudt end ved reduktion af sprøjtemiddeldoseringerne til 25%. Andelen af blomstrende vilde planter steg fra 30% i den konventionelle periode til 70% i den økologiske periode. Da sommerfugle generelt blev hyppigere i takt med øget forekomst af blomster, anses denne stigning som vigtig for forekomsten af sommerfugle. En ca. 35 ganges øgning af frø på jordoverfladen efter omlægning betød mere efterårs- og vinterføde til lærker og andre fugle, men også en landbrugsmæssig bekymring. De øgede fødemængder for frøædende fugle er dog kun tilgængelige, så længe marken henligger som stub.

En række af de prædatorer, der lever på jordoverfladen, gik betydeligt ned i forekomst i hvede, måske som bieffekt af hyppige mekaniske ukrudtsbehandlinger kombineret med lav ukrudtstæthed. Til gengæld var der i byg efter omlægning signifikant øget forekomst af alle undersøgte planteædende insekter (50% eller mere) samt af bladlusspecialiserede rovdyr (mere end 50%) og edderkopper (50% eller mere). Dette betød samlet en øgning af såvel den samlede insektbiomasse som biomassen af egnet lærkeføde.

Antallet af sanglærker steg hele 55% efter omlægning, og det ville være naturligt at se dette i sammenhæng med forbedrede fødeforhold. Imidlertid kunne en sådan sammenhæng ikke påvises statistisk. Den udslagsgivende faktor var afgrødebiomassen, og dermed sandsynligvis vegetationens struktur i forhold til lærkers præference for relativt åbne afgrøder.

Undersøgelsen af ekskrementer gav interessante oplysninger om lærkernes fødevalg, men visse gruppers over- eller underrepræsentation i ekskrementer og sugeprøver (der belyste forekomsten i marken) gav fortolkningsmæssige vanskeligheder. Indholdet af insekter og andre leddyr i ekskrementerne ændrede sig fra maj til juli, hvilket i vid udstrækning afspejlede tilgængeligheden af byttedyr i marken. Dog var der altid signifikant forskel på indholdet af insekter og andre leddyr i ekskrementerne og indholdet i sugeprøverne.

Der kunne ikke i forekomsten af nogen af de undersøgte organismer konstateres nogen form for effekter af de tidligere doseringsområder. Det tilskrives frøpuljen, som kun ændres meget langsomt, og den mobilitet, som flertallet af dyr er i besiddelse af i et eller flere livsstadier.

Det kan konkluderes, at omlægning i sædskifter som det undersøgte fører til forholdsvis beherskede ændringer i biodiversitet, men dog til en værdifuld øgning af en række naturelementer i marker. F.eks. er stigningen i blomstring og frøfald bemærkelsesværdig, men næppe sammenlignelig med tilstanden ved vedvarende fravær af pesticider. En forøgelse af antallet af plantearter vil således kræve en længere tidshorisont, men værdien af den forbedrede plantestatus (mere blomstring indicerer mere biomasse) for det ikke-skadelige segment af planteædende insekter må alt andet lige regnes for betydelig. En ganske væsentlig del af forbedringerne af insektforekomsten må tilskrives fraværet af insekticider. Dette fortæller, hvor vigtigt det er at undgå insekticider så meget som muligt, hvad enten det er som del af et miljøforbedringstiltag eller blot i almindelig landbrugspraksis.

Trods den manglende korrelation mellem mængden af insektbytte for sanglærker og øgningen af lærkeforekomsten er der næppe tvivl om, at en øget andel af usprøjtede marker mellem de øvrige marker vil fremme levegrundlaget for fugle. Et sådant tiltag kunne være værd at overveje, hvis de landbrugsmæssige ulemper kan løses eller modvirkes økonomisk; men det skal bemærkes at de fundne resultaters gyldighed knytter sig til korndomineret planteproduktion.

Summary and conclusions

The present project involved two years of investigations of wild flora, arthropods and Skylarks immediately after conversion of large fields from conventional to organic farming on one estate. A prerequisite for this project was a detailed knowledge of flora and fauna stemming from another project on effects of reduced pesticide dosage levels during the preceding three years of conventional farming on the present estate and four others. Both projects, which are related to the Danish Pesticide Action Plans I and II, have been financed by the Danish Ministry of the Environment.

In the organic period of two years only two cereal crops, spring barley and winter wheat could be included. As in the preceding project the number of species, plant density, flowering and seed production were the flora variables studied, and in addition the plant biomass was assessed. Insects were suction sampled as before, and Skylarks were counted by a combination of point and transect counts. Also sampling of Skylark faecal pellets for investigation of insect remnants was included in order to identify important Skylark prey.

Both the plant density and the number of species were higher than at normal dosage during the conventional phase but at the same level as at 75% dosage reduction. The flowering increased from only 30% when exposed to herbicides to 70% under organic practice. This change presumably increased the abundance of adult Lepidoptera which showed a linear correlation to the occurrence of flowers. Naturally also seed production increased strongly leaving much more potential winter food for birds but also agricultural concerns. This food resource is only accessible as long as the field is left with stubble.

A group of ground dwelling predatory arthropods decreased considerably (50% or more) in wheat, maybe partly as a side effect of frequent mechanical weeding. In barley, however, there was a significant increase in abundance and biomass of all analysed herbivores (50% or more) as well as of aphid specific predators and spiders (more than 50%). This led to significant increases of both insect dry mass and Skylark prey.

The abundance of Skylarks increased by 55% in comparison with the conventional period. It would be natural to link this occurrence to the better food supply but there was no significant correlation. The main factor determining the presence of Skylarks was the crop biomass (negative correlation), indicating that the structure of the vegetation is very important.

The contents of faecal pellets gave an interesting picture of Skylark food choice but also involved some problems concerning the representative value of the different samples. Arthropod contents in the faecal pellets changed from May to July, reflecting seasonal changes in the availability of different arthropod prey groups. However, the composition of the faecal samples always differed significantly from the composition of the suction samples.

At the all over level the finding of no carry over effect from the previous dosage levels during the conventional period was important. This might have

occurred but was questionable from the beginning due to the existing large seed reservoir in the soil and the high or relatively high mobility of most of the insects.

In conclusion the changes in biodiversity were not pronounced but still the enrichment of nature in agricultural fields was noticeable. The improved flowering and subsequent seed production is remarkable. Further adding of plant species will require much more time but already at the present level the positive impact of improved plant status (biomass, flowering) on non-pest insect life is important. Part of the insect enhancement is most likely due to removal of insecticides, particularly benefiting herbivores and aphid specific predators in the canopy which are very exposed to treatment. This indicates how important it is to avoid insecticides as much as possible, not only as part of a several component environmental approach as e.g. a short organic period, but also in the broad common agricultural practice. Despite the lack of a significant correlation between arthropod prey abundance and Skylarks, the notable increase in Skylark numbers leaves little doubt about the potential improvement of population densities of Skylark (and maybe other birds) if such individual fields with improved prey availability are available scattered in between other fields. Noticing that the present results are mainly valid during conversion to organic practice in crop husbandry dominated by cereals, a sort of environmentally improving mosaic strategy might be worth considering if the agricultural drawbacks can be handled without economical problems of importance.

1 Introduction (Esbjerg, P. & Petersen, B.)

1.1 Background

The present project belongs to a series of pesticides research projects derived from the governmental Pesticide Action Plan I of 1986. The goal of this plan was to reduce the pesticide use in Denmark by 50% from 1987 to 1997 both in terms of amount and in terms of intensity, expressed as treatment intensity index.

In line with this plan and its purpose of reducing environmental pressure from crop production two major project areas have been A) changes in agricultural practises aiming at reduced pesticide use, and B) effects of reductions in pesticide use. Among the latter the very recent project "Effects of reduced pesticide use on flora and fauna in agricultural fields" (Esbjerg & Petersen 2002, later in this report mostly referred to as the conventional period) has demonstrated significant improvements of plant-, insect- and birdlife by use of less than half dosages of herbicides and insecticides. Earlier Braae ***et al***. (1988) and Hald & Reddersen (1990) found higher diversity and densities of plants, insects and birds at long established organic farms than at conventional farms but no studies had been dealing with an array of different organisms during the conversion phase. Such a possibility emerged when one of the five hosting farms, Oremandsgaard Gods, of the above mentioned project decided to convert from conventional to organic production immediately after the finalization of the project work. This possibility included the particular advantage of utilizing the former large-scale plots with three dosage levels of herbicides and insecticides in winter wheat and spring barley. Furthermore intensive studies had been carried out on wild plants, arthropods and birds during the three years prior to the conversion implying that the relevant biological history of the area was well established.

1.2 Aim and conditions

The over-all aim of the present project was to quantify changes in biodiversity of the flora and fauna in agricultural fields the first two years after the conversion from conventional to organic farming (afterwards mostly referred to as the organic period). This includes a series of underlying hypotheses:

- That the number of species of wild plants and their abundance will increase after conversion.
- That the abundance of insects and proportions between taxonomic units will change after conversion.
- That the number of birds will increase after conversion.
- That increases in plants and insects will reflect the preceding dosage.
- That increases will be correlated so that increases in bird density reflect increases in arthropod abundance, which reflect increases in density and diversity of wild plants (inter-trophic effects).

1.3 The study area

Oremandsgaard Gods, which as mentioned in the introduction was one of the host farms 1997-99 accepted the hosting of this project (2000 and 2001) also. The field area of relevance is shown on Fig. 1.1. The area has been grown conventionally for several decades in crop rotations dominated by cereals. Here it has to be underlined that dosage plots at large scale of at least 6 ha each (enabling the necessary bird counting) were established from the beginning of “the conventional period”. These plots were treated with three different dosages of herbicides and insecticides while fungicides were applied equally all over. Normal dosage was by definition the farmer’s own choice in the particular instance (based on his experience), and the two other plots were treated with 50% and 25% of normal respectively. The pesticides applied as well as application dates are listed in appendix A.

In the organic phase (2000-2001) the project used two crops, spring barley and winter wheat, obtained by using two of three fields at a time. In 2000 field 1 (Fig. 1.1) with spring barley (and undersown rye grass and clover as catch crop) and field 2 with winter wheat (sown autumn 1999) were used. As appears from appendix B (with details on field operations) field 3 was also cropped with winter wheat in 2000 but no results were taken from that field. In 2001 field 1 was not used for study, while field 2 for the second year had winter wheat (sown in September 2000), although a catch crop of rye grass and clover was sown in May. The project field with spring barley in 2001 was field 3, sown with barley mid April and further sown with a rye grass and clover catch crop late in May.

As regards the field area it may be described as generally rather uniform and flat with the exception of a slight undulation of the western part of field 3, which also has an old marl-pit (in the former half dosage plot). Such a pit can also be seen in field 2 outside the plot area. Along the western side of field 3 no tall vegetation is present, whereas the southern edge is along an old alley of ***Acer pseudoplatanus*** trees also edging field 2. Hedges of broadleaved bushes and small trees form the borders against north and east, the latter also being the edge of field 2. Between field 1 and 2 no natural vegetation is present, while field 2 has a beach forest on the eastern side and a field along the NE-corner. That field also neighbours field 1 up to the partly eastern and mostly northern forest belt dominated by deciduous trees. On the remaining north border and to the western side field 1 is aligned with a broadleaved hedge, very open and scattered along the southern part. Generally the hedges are 3-5 meters tall.

Among the field operations particularly the many mechanical weedings are noteworthy, 4 times in barley 2000 and 2 times in the already established wheat (field 2) of that year, while the wheat in the same field in 2001 was treated 3 times and barley 2001 (field 3) was treated 4 times.

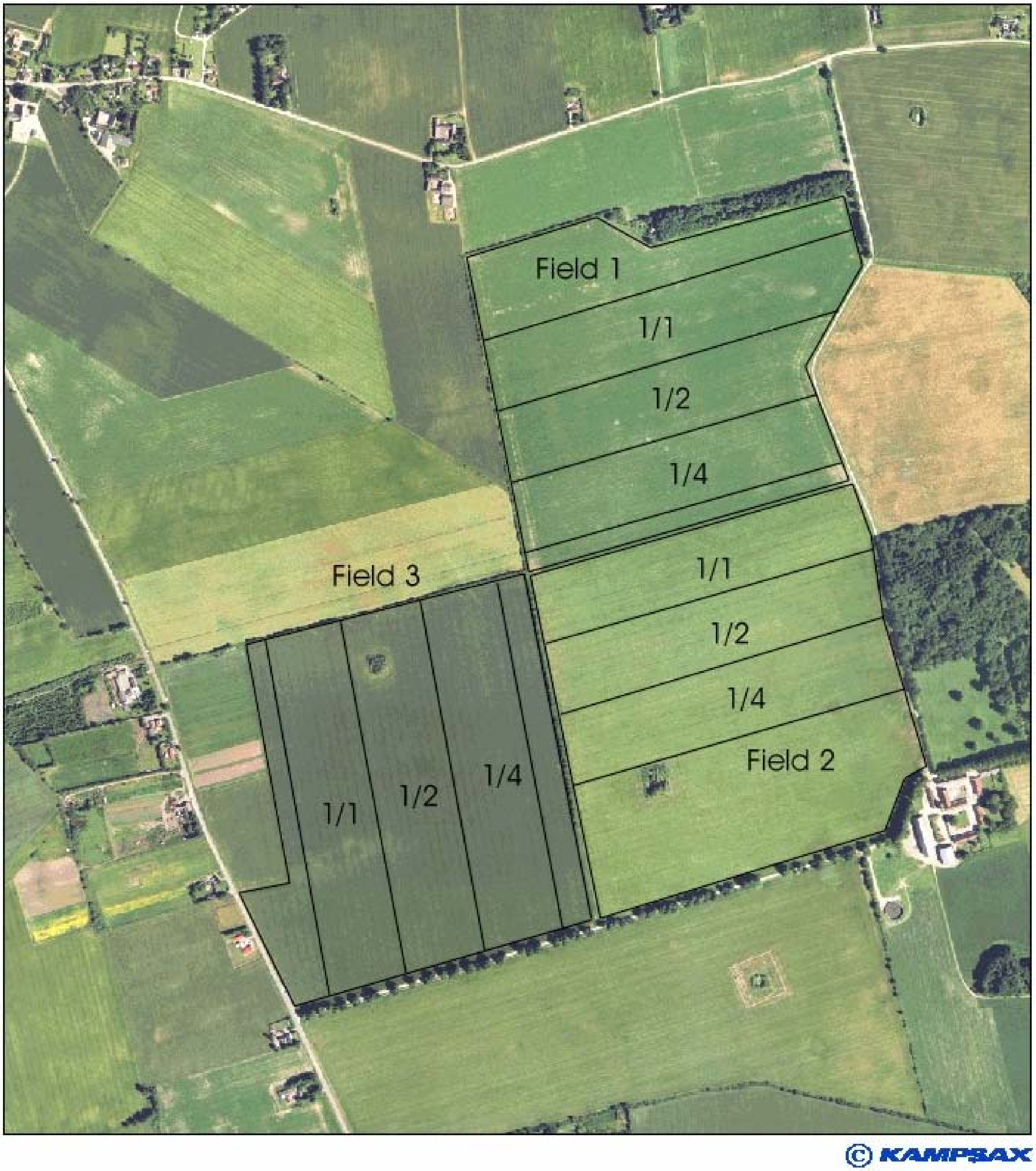

Fig. 1.1. Aerial view of the experimental fields at Oremandsgård with the dosage plots indicated. Large fields in a fairly open landscape. Single marl-pits, surrounded by trees and scrub, in Fields 2 and 3. Deciduous hedgerows, partly quite open, N and W of Field 1, between Fields 2 and 3, and N of Field 3. Alley with old, broad-leaved trees S of Fields 2 and 3. Old, deciduous wood E of Field 2 and farm buildings towards the SE. Photo by courtesy of Kampsax.

1.4 Weather

For the organic period of the present project, data on average temperatures and precipitation have been obtained from two substations of The Danish Institute of Meteorology. On this background the two years, 2000 and 2001, may briefly be characterized as follows. The late winter 2000 had a remarkably warm February (3.8°C in contrast to a normal mean of 0). Also

April 2000 was well above (8.5ºC) the normal (5.7ºC) and in addition rather dry (27 mm against 41 as normal). These April conditions may be of interest for that year's high level of aphids in barley at the end of May, which was in any respect very normal. Except fairly dry weather in July and August the rest of 2000 was an average year. In 2001 the first four months were normal but May was rather warm (12.1ºC, normal 10.8) and dry (21 mm, normal 48 mm). While the temperature was about average June 2001 was rainy (84 mm, normal 55), whereas July was rather warm (18ºC, normal 15.6) and dry (27 mm, normal 66). The dryness was followed by excessive rain in both August (103 mm, normal 67) and September (127 mm, normal 73). Temperatures were normal and so was the weather during the last part of 2001.

1.5 Data sampling

As in the conventional period non-destructive plant studies were carried out in at least four subplots within each of the three dosage plots per field. During the organic period biomass of crop, catch crop, and weed plants was sampled. In both periods the above-ground seed biomass was sampled in September.

Arthropod sampling was as previously carried out with the special suction device constructed for the samplings in the conventional period (Navntoft & Esbjerg 2002). During the organic phase better weather conditions permitted almost weekly samplings with a total in barley of 9 in 2000 and 13 in 2001, in both cases roughly between mid May and late July. The number of samplings was the same in wheat with the exception that 10 samplings were performed in 2000 (more details appear from table 3.1).

As during the conventional period standardized bird counts (point and transect) were performed at intervals of about five days in the organic period. Counting took place between 6 May and 5 August.

In the organic period Skylark faeces were collected and arthropod fragments identified in order to identify important arthropod food items for Skylarks. The collections were carried out on the same days the bird countings were performed.

1.6 Statistical analyses

During the years of conventional farming, the experiment was run as a Latin Square design with three crops rotating between three fields in three years (Esbjerg & Petersen 2002). Each field was divided into three plots, which received different pesticide dosages and constituted the basic experimental units. Although the plots did no longer receive different treatments after conversion to organic farming, they were retained as the experimental units because carry-over effects of differences in pesticide dosages could be traced in the analyses of the vegetation. After conversion only spring barley and winter wheat were left in the rotation so analyses had to be limited to these two crops, leading to an unbalanced and confounded experimental design (cf. section 1.3) with $n=30$ (5 years × 2 crops × 3 plots).

The main analytical purpose was to quantify and test the effects of the conversion to organic farming on selected response variables, representing different groups of organisms, with the null hypothesis that such effects were non-existent. This was done by comparing the conventional and the organic period (1997-1999 and 2000-2001, respectively), using the different years within each period as replications. Crop, field and dosage effects were also included in the model, together with the appropriate interactions, leading to the basic analysis of variance model shown in Table 1.1. Notice that it was not possible to include the interactions period×field and crop×field because they were confounded with period×crop and year, respectively. Starting with the full model, stepwise model reduction was carried out until the minimum adequate model was found.

Table 1.1. Factors included in the basic anova model, the nature of each factor (fixed/random), and the denominator (error term) used in the test of significance of each factor in a balanced design (see text). The tests of main effects period, crop and dosage assume that their mutual interactions are zero.

Source of variation	Fixed / random	Denominator in F test (balanced design)
Period	Fixed	MS(Year(Period))
Year(Period)	Random	MS(Residual)
Crop	Fixed	MS(Residual)
Crop×Period	Fixed	MS(Residual)
Field	Random	MS(Dosage×Field)
Dosage	Fixed	MS(Dosage×Field)
Dosage×Period	Fixed	MS(Residual)
Dosage×Crop	Fixed	MS(Residual)
Dosage×Field	Random	MS(Residual)
Dosage×Crop×Period	Fixed	MS(Residual)
Residual	Random	

The error terms in Table 1.1 are only fully valid in a balanced experimental design. Because the experiment was not balanced the F-tests had to be modified, causing the tests to be only approximate. The modifications were carried out by means of the RANDOM/TEST statement in the GLM procedure in SAS/STAT (SAS Institute 1990b), which prompts the use of Satterthwaite's approximation to adjust the denominator and the associated degrees of freedom.

Except for the analyses of flora composition and Skylark food preferences, all response variables were tested using this model or models derived from it. If necessary, variable transformation was performed in order to achieve an approximately normal distribution. Covariates were included if relevant, e.g. weed density was included in the model of weed species richness. Covariates were also used to model impacts of changes at one trophic level on another trophic level, e.g. possible effects of arthropod abundance on the number of Skylarks were tested by including arthropod biomass in the model of Skylark density.

Additional statistical procedures and further details are described in the individual chapters on the botanical, entomological and ornithological studies (chapters 2-5).

2 Wild flora (Jensen, A.-M.M. & Johnsen, I.)

2.1 Vegetation studies

The objectives of the studies were to detect any changes in the wild flora populations during conversion from conventional to organic farming, in particular changes in selected vegetation variables that might have an impact on the fauna on the fields.

Three different vegetation studies were performed during 1997-2001: 1) Non-destructive study of the density, the phenology, the number of species and the composition of the wild flora. 2) Destructive study of the aboveground biomass and the correlation between density and biomass. 3) Study of the seed mass available as food items for birds in autumn. Data were obtained from one field with spring barley and one with winter wheat each year from 1997 to 2001. In 1997-1999, fields were grown conventional and in 2000-2001, fields were grown organic (chapter 1).

2.1.1 Non-destructive method used to study the density, the phenology, the species richness and the composition of the wild flora

2.1.1.1 Sampling design

In each plot (Fig. 1.1), subplots of 25 m x 25 m were chosen at random with at least 12 m to other plots, hedges and habitat islands such as small game plantations, ponds etc. Non-sowed tramlines were avoided. Four subplots were chosen in each plot in 1997-1999, five in 2000 and 10 in 2001. Location of the subplots within a plot varied from year to year. Four sampling sites of 0.6 m x 0.4 m were placed at random within a subplot. These sampling sites were permanent within a season and used for the study of density, phenology, species richness and composition of the wild flora.

Because of results from former study (Jensen & Johnsen 2002), each sampling site was examined two times during the growing season, once before the first spring weed control (April-May) and once approximately three months later (July-August). The observations before spring weed control were used as a covariate in the analyses of density and species richness after weed control, thereby the effects of soil cultivation, weed control in autumn and initial germination from the seed bank were included in the covariate.

2.1.1.2 Weed identification

In this study, the wild flora is defined as all wild plant species inclusive volunteer plants of previous crops (e.g. oil seed rape plants in a winter wheat field). The term "weeds" is used as a synonym for the wild flora henceforward.

Weed seedlings were identified using Hanf (1990) or Haas & Laursen (1994), the vegetative grasses using Grøntved & Sørensen (1941) and the flowering plants using Hansen (1981). Nomenclature follows Tutin ***et al.*** (1964-1980). Determination of densities of perennial plants that either germinates from roots or from rhizomes (e.g. ***Elymus repens*** and ***Equisetum arvense***) was based on shoots more than 2 cm apart. Shoots that were closer than 2 cm were counted as one individual plant.

This study included identification of the weed species present as well as counting the number of individual plants per species within the sampling sites. The grown cereal and the undersown catch crop were not counted. Data from the individual sampling sites within the same subplot were summed up giving the total number of plants all together and per species as well as the number of species per subplot. Since the number of species found in an area is dependent of the area sampled, it has no meaning to calculate the species number for other areas than the investigated area - the subplot area (=0.96 m^2). For correlation with the fauna variables, the weed plants were grouped in dicotyledonous plants, monocotyledonous plants (including ***Equisetum arvense***), Cruciferae and ***Bilderdykia convolvulus*** and ***Polygonum aviculare*** together. An arithmetic mean of species richness per 0.96 m^2 and a geometric mean of the weed densities (expressed as individuals/m^2) were calculated for each plot. Geometric means were calculated for data not following a normal distribution.

2.1.1.3 Phenology

Before harvest in 1998 and 1999, the numbers of flowering plants were recorded in all sampling sites. In 2000 and 2001, both the number of flowering plants and the number of seed setting plants were recorded. A plant was defined as flowering if it was generative, i.e. if it had developed buds, flowers, fruits or showed any sign of fruit setting (e.g. empty sepals in ***Lamiaceae***). Thus flowering plants included seed setting plants. In 2000 and 2001 plants with mature fruits, developed seeds or other signs of being seed setting were recorded as seed setting.

The aim was to detect sublethal effects on fitness of weed plants, measured as ability to flower. In addition, flowering plants provide pollen and nectar for insects and later in the season seeds for insects, birds and small mammals, whereas vegetative plants provide less energy-dense food. The proportion of flowering plants per subplot was calculated as the number of flowering individuals in the subplot divided by the total sum of plants across all species in the subplot. An arithmetic average calculated per plot was used in the analysis.

2.1.1.4 Statistical analyses

Weed density, proportion of flowering plants and species richness

Differences between periods were tested on mean density (plants/m^2) for all weed plants, dicotyledonous plants, monocotyledous plants, Cruciferae, ***Polygonum aviculare*** and ***Bilderdykia convolvulus*** together, mean number of species per 0.96 m^2 and mean proportion of flowering plants using the model described in section 1.6. The density or richness in spring was used as covariates in the model for density and richness, respectively (cf. section 2.1.1.1). The density of weed plants might influence the number of species found, therefore the density of weed plants was used as a covariate in the analysis of species richness. Stepwise model reductions were carried out with $p>0.1$ as removal criterion.

For all variables tested, model assumptions were checked by plotting the residuals against the predicted values and by running the Shapiro-Wilk test for normality (SAS Institute 1990a). No indications of violation of model assumptions were found.

Flora composition

To evaluate the structural changes on the weed community brought about by a change in farming type the composition of the weed communities was analysed with multivariate statistics, detrended correspondence analysis (DCA) using the PC-ORD for windows (McCune & Mefford 1997). All observations of density of each species in each of the 162 subplots were used in the DCA. Data were not transformed prior to analyse.

2.1.2 Destructive method used to study the biomass and the correlation between weed density and biomass

The main aim was to correlate the biomass of weeds, catch crops and cereals with the presence of arthropods (section 3.2.4) and birds (section 4.2.2). Therefore, the biomass was sampled in the organic period 2000-2001. Aboveground biomass of weed, catch crop and cereals was harvested once per year in late June or early July. At this time, the weed biomass was expected to be close to its maximum value. Biomass was harvested in 50 circles (30 cm in diameter) in each plot (total area of 3.5 m^2 per plot). The circles were situated on lines perpendicular to the tramlines. These lines were placed with regular intervals along two tramlines in each plot. The circles were positioned of both sides of and with varying distance from the tramline. The weed plants, the catch crop plants and the cereals were harvested in each circle. The harvested plants were dried at 80 °C in 48 hours and weighed. Each weed species was weighed separately.

To reduce the amount of 0-observations of weed and catch crop, the 50 circles were pooled five and five resulting in 10 samples of biomass and density in each plot. A Pearson correlation was used to correlate biomass and density.

For correlation to the fauna the aboveground biomass was separated in several groups: 1) The cereals, 2) the undersown clover only, 3) the undersown ryegrass only, 4) all dicotyledonous weed species, 5) all monocotyledonous weed species (including ***Equisetum arvense***) and 6) the catch crops and the weeds together. Biomass data for these groups were given as geometric means except for the crop biomass, which was given as an arithmetic mean. The transformations stabilised variation and approximated the data to a normal distribution.

2.1.3 Method used to study the bird available seed mass

The bird available seed mass refers to the weight of seeds with a diameter greater than 0.5 mm, lying on the soil surface after crop harvest. It may be assumed that all seeds constitute a potential food resource for e.g. birds and mice, but seeds of some weed species might be poisonous or avoided for other reasons (Diaz 1990). The bird available seeds may also play a role as food resource after the seeds have germinated and become seedlings (e.g. Green 1980). Especially in winter, seeds on arable stubble fields constitute a major part of the food eaten by birds in the agricultural landscape (Steenfeldt ***et al.*** 1991, Donald ***et al.*** 2001). The number, composition and richness of seeds lying on the soil are very important for the structure of the vegetation in the following years. Most of the seeds enter the soil seed bank as a result of cultivation and then become a part of the potential future weed vegetation.

2.1.3.1 Field work

The seeds on the winter wheat and the spring barley stubble fields were sampled in August or September 1998-2001. Samples of the bird available seeds were taken once every year, depending on the weather and the time of straw collection. The samples were taken in dry and sunny weather, after the dew had evaporated, and at least five hours after rainfall. All samples from one field were taken on the same day. At each field, 18 samples (6 per plot at regular intervals) of 0.18 m^2 were taken with a C-vacuum sampler (Navntoft & Esbjerg 2002). Each sample was taken as ten 5-seconds suctions each covering 0.018 m^2. The samples consisted of surface soil, seeds, straw, awns and seed shells from the cereals. The samples were taken at least 12 meters from other plots, hedges etc. to avoid edge effects.

2.1.3.2 Laboratory work

In the laboratory, the samples were air dried at 20 °C, to avoid seed germination and seed predation by insects present in the samples. The dry samples were fractionated using a 2-mm and a 0.5-mm mesh sieve successively. Every particle over 2 mm was manually sorted into seeds or debris. Particles less than 0.5 mm were dropped to reduce the bulk and thereby save time in the laboratory. This was done with two arguments: 1) Seeds smaller than 0.5 mm in diameter are only eaten by very few bird species foraging in the agricultural land (Christensen ***et al.*** 1996). 2) The majority of weed seeds have a minimum diameter bigger than 0.5 mm (Holm-Nielsen 1998) and none of the dominant weed species present in this study had seeds that small. Species with small seeds are, however, very important with respect to other aspects of the vegetation dynamics.

After sieving, the samples were weighed and submersed in a flotation solution of potassium carbonate (K_2CO_3) with a specific density of 1.43 g/ml. Specific densities of weed seeds varied between species from less than 0.7 to 1.42 g/ml (Jensen 2001). The amount of flotation solution was between 1 and 2 times the volume of the seed samples. After 24 hours, the high-density particles precipitated and the low-density particles (organic material) remained at the surface. The supernatant was carefully transferred to a filter paper over a vacuum pump, which removed the remaining flotation solution. The filter paper with all the organic material was placed in a petri dish and air-dried at 20 °C. Then the material was spread in a thin layer under a magnifying stereoscope and all seeds were identified to species and counted. Seeds were identified by literature (Beijerinck 1947, Holm-Nielsen 1998) or by comparison with a seed reference collection made from mature plants in the fields. Some seeds were only identified to genus level, e.g. seeds from ***Lamium amplexicaule***, ***Lamium hybridum*** and ***Lamium purpureum*** were very difficult to identify (***pers. obs.***), and seeds from these species were all called ***Lamium*** sp. Seeds resisting the pressure from a pair of tweezers were registered as seeds with endosperm. Some seeds did not contain endosperm and therefore were not able to provide energy for birds; such seeds were excluded from the figures and analyses.

2.1.3.3 Data description

The seeds were divided in two groups: spilt grains and weed seeds. For each group, the biomass per square meter was calculated. The bird available seed mass was calculated by multiplying the seed weight of each species with the number of seeds per species and adding the mass for all species in a sample. The mean seed weight of most species is known from the literature (Korsmo 1926, Salisbury 1942, Gross 1990, Melander 1998) otherwise the seeds were weighed in the laboratory. A geometric mean for each plot was used in the statistical analyses. The number of bird available weed seeds and the mass of spilt grains and weed seeds were tested for effects of conversion to organic farming by analyses of variance with the same model as described in section 1.6.

2.2 Results

2.2.1 Results of the non-destructive method used to study density, phenology, species richness and composition of weed plants

2.2.1.1 Density analyses

Over all years and fields, the average density of weed plants was 60/m^2 in spring and 26/m^2 in late summer. The total weed density ranged from 3.1 to 463 plants/m^2 in spring and from 1.0 to 611 plants/m^2 in late summer.

The interaction between dosage and period had a significant effect on the weed density (Table 2.1). In the organic period, no differences in weed density were found as a function of former dosages. On the contrary, the dosage had a significant effect on the weed density in the conventional period (Fig. 2.1). The density at normal dosage in the conventional period was significantly lower than the density at quarter dosage and the density in the organic period.

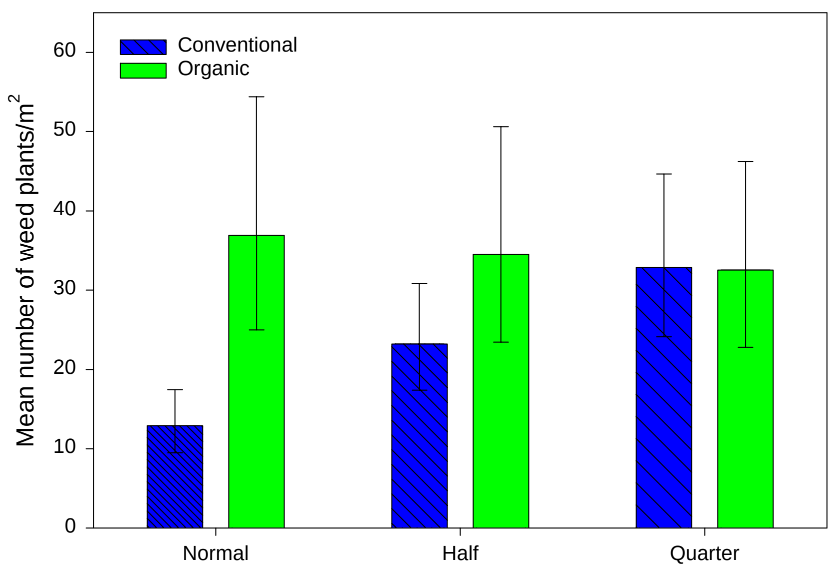

Figure 2.1. Mean weed densities at three different dosages in conventional and organic farming. In 2000 and 2001, the cereals were grown organic but the plots are still named normal, half and quarter dosage. The error bars represent the 95% confidence limits.

Significant differences in weed density were found between organic and conventional wheat only. The weed density was significantly higher in organic wheat (37 plants/m^2) than in conventional (16 weed plants/m^2 across dosages), whereas the weed density in organic barley (32 plants/m^2) was not significantly higher than in conventional barley (29 plants/m^2). Furthermore, the weed density did change dependent on field, year within the period and the varying weed density in spring (Table 2.1).

Table 2.1. Schematic summary of the analyses of weed density, proportion of flowering weed plants and species richness. P-values are given for explanatory factors included in the reduced model. Grey areas indicate factors not included in the full model. r^2 for the reduced model is given in brackets.

	Weed density (r^2=0.93) (n=30)	Proportion of flowering weed plants (r^2=0.93) (n=24)	Species richness (r^2=0.86) (n=30)
Species number spring			0.044
Weed density spring	<0.0001		
Weed density			<0.0001
Period		<0.0001	
Year(Period)	0.014		0.099
Crop		0.0099	
Crop×Period	0.014	<0.0001	
Field	0.012		
Dosage	0.059		
Dosage×Period	0.011		
Dosage×Crop			
Dosage×Field			
Dosage×Crop×Period			

The estimated mean densities of the four groups of weed plants varied with crop and period (Fig. 2.2). Density of the dicotyledonous weed plants was significantly higher in wheat fields in the organic than in the conventional period (Fig 2.2 A). The density of the monocotyledonous weed plants did not change significantly with the period (Fig. 2.2 B). On the contrary, the density of the Cruciferae was significantly higher in the organic than in the conventional period in both crops (Fig. 2.2 C). The density of ***Bilderdykia convolvulus*** together with ***Polygonum aviculare*** was only significantly higher in the organic period in the wheat fields (Fig. 2.2 D).

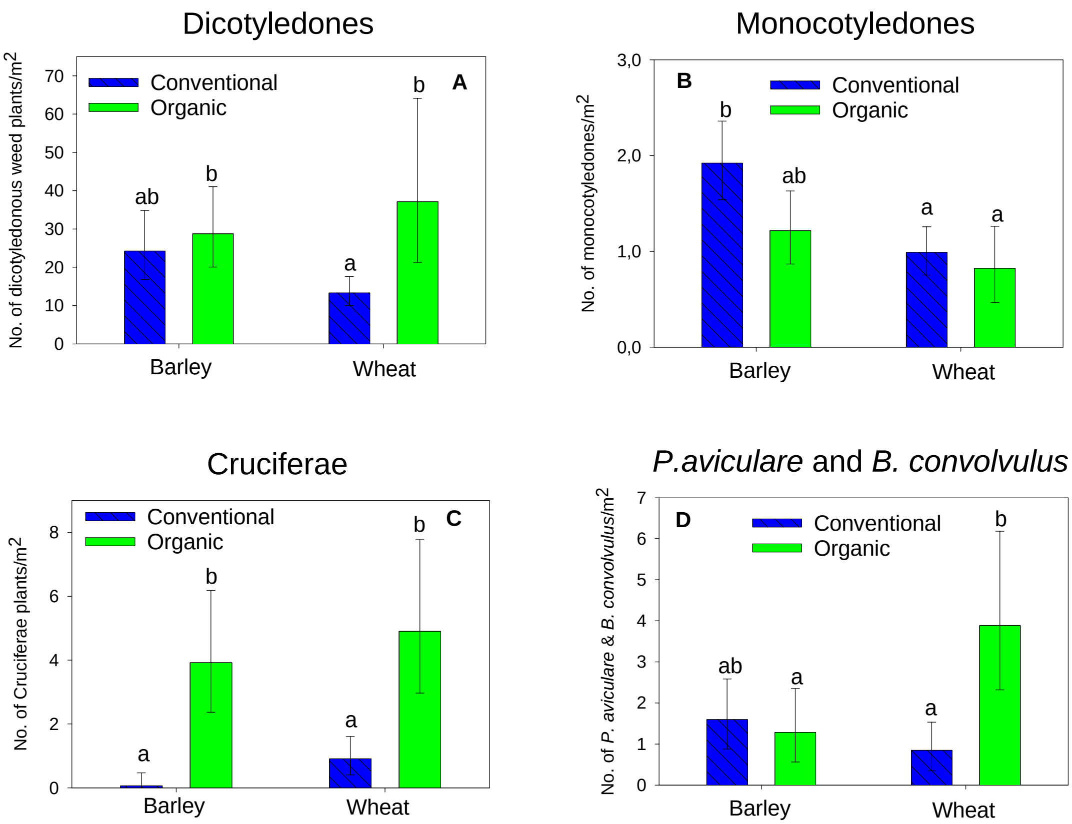

Figure 2.2. Estimated mean densities of dicotyledonous weed plants (A); monocotyledonous weed plants (including *Equisetum arvense*) (B); weed plants of the Cruciferae family (C); *Bilderdykia convolvulus* and *Polygonum aviculare* together (D); in spring barley and winter wheat fields grown conventional and organic, respectively. The error bars represent the 95% confidence limits. Significant differences are indicated by different letters ($p<0.05$, pairwise t-tests with Tukey-Kramer adjustment for multiple comparisons).

2.2.1.2 Proportion of flowering weed plants

The proportion of weed plants flowering in august was significantly higher during the organic (70%) than in the conventional period (30%). This was pronounced in both spring barley and winter wheat, however the proportion of flowering plants increased much more in wheat than in barley (Table 2.1 and Fig. 2.3).

In average, 33% of the wild plants was seed setting before harvest in the organic period across significant differences between year and crop (variance analysis not shown). Data for the conventional period was not available, but the percentage of seed setting plants must be lower than 33%, since only 30% of the weed plants had reached the flowering stage.

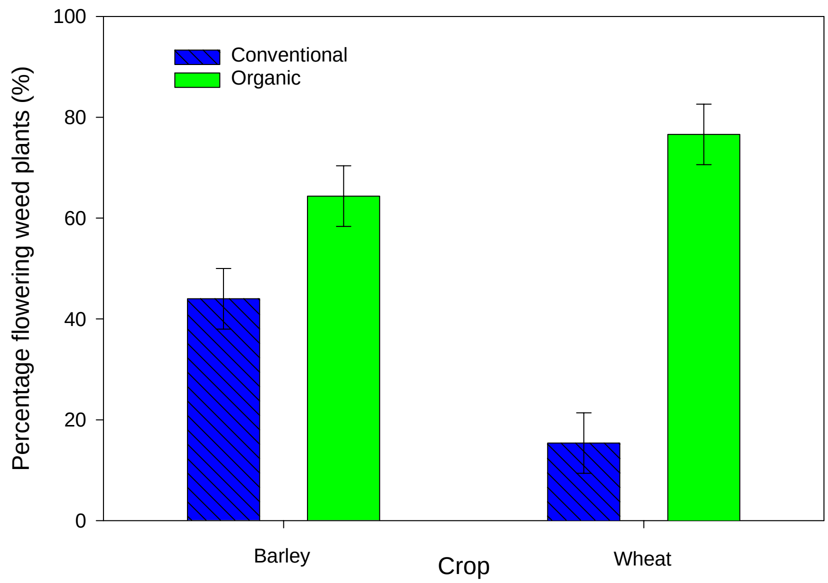

Figure 2.3. Proportion of flowering weed plants in spring barley and winter wheat grown organic and conventional. The error bars represent the 95% confidence limits.

2.2.1.3 Species analyses

58 different weed species were found in this study (Appendix C). Three of these were only found in spring. Five species were monocotyledons and one was a pteridophyte, thus 52 species were dicotyledons of which five were perennials. Thus, the fields were dominated by annual dicotyledonous weeds, both in terms of number of species and in number of individuals. None of the species is mentioned in the Danish Red-list for endangered species (Stoltze & Pihl 1998), however species as ***Chaenorhinum minus***, ***Euphorbia exigua, Kickxia elatine***, ***Silene noctiflora*** and ***Stachys arvensis*** are common in South-Eastern Denmark but not in the Northern and Western parts (Hansen 1981, Mikkelsen 1989).

The number of weed species was strongly related to the density of weed plants (Table 2.1). 76% of the variation in species richness was explained by the variation in the ln-transformed density (Fig. 2.4). Thus, species richness responds in the same manner as the weed density to a conversion from conventional to organic farming (cf. Fig 2.1). When weed density was excluded from the analysis, the mean number of species at normal dosage in the conventional period (4.4) was significantly lower than the species number at quarter and half dosage in the conventional period and the species number in the organic period (all between 6.9 and 7.6).

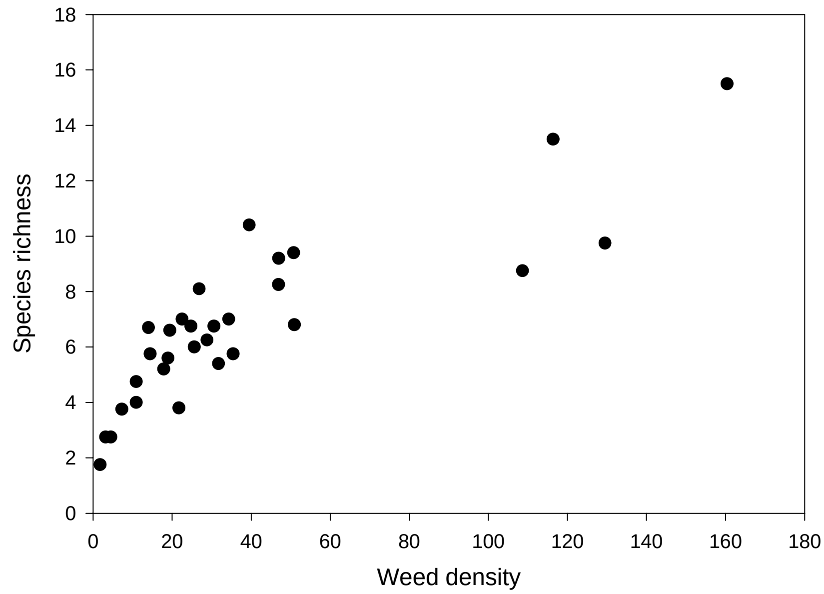

Figure 2.4. The logistic relationship between weed density and species richness.

2.2.1.4 Species composition

There was no clear separation between the structure of the weed flora in the organic and the conventional period (Fig. 2.5). The weed flora composition distinguished almost the three fields from each other.

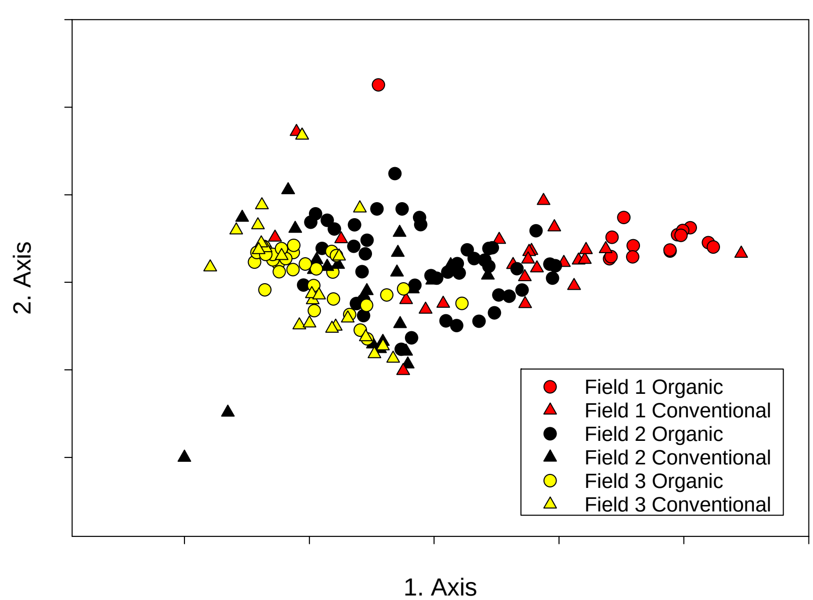

Figure 2.5. Ordination diagram based on detrended correspondence analysis (DCA) of subplots with the different fields and periods marked. All 162 subplots and all weed species were included in the analysis.

Field 1 was dominated by ***Sinapis arvensis***, ***Brassica napus***, ***Euphorbia exigua*** and ***Equisetum arvense***, the last was not found at all in Fields 2 and 3. The dominating weeds on Fields 2 and 3 were almost similar: ***Aethusa cynapium***,

Viola arvensis, ***Trifolium*** sp. and ***Bilderdykia convolvulus***. Furthermore, ***Sonchus*** sp. was present in Field 2 and ***Veronica agrestis/persica*** in Field 3.

2.2.2 Results of the destructive method used to study the biomass

2.2.2.1 Biomass

The biomass of cereal, weed and catch crop plants varied considerably between crops and years in the organic period (Table 2.2). The crop dominated the field biomass totally, having from 16-1500 times as high biomass as the weed plants (Table 2.2). When present the catch crop biomass of clover and ryegrass was of the same size as the weed biomass or lower. The average proportion of weed biomass relative to the total vegetative biomass (crop + catch crop + weeds) was 2% in spring barley and 0.2% in winter wheat.

Table 2.2. Biomass of cereals, weed and catch crop in early July in organic fields. The values given are least squares estimates of the mean dry mass (g/m^2). Significant differences within a column are indicated by different letters ($p<0.05$, pairwise t-tests with Tukey-Kramer adjustment).

Crop	Field	Year	Biomass (g/m^2) of					
			cereal		weed		catch crop	
Barley	1	2000	360	a	23	a	0.36	a
Barley	3	2001	830	b	1.5	b	2.1	b
Wheat	2	2000	1300	c	0.85	c	0	c
Wheat	2	2001	1100	d	3.8	d	0.77	d

Not surprisingly, the crop biomass was higher in winter wheat than in spring barley. The winter wheat plants were maturing the seeds at the time of biomass harvest (in both years) and the spring barley plants were in late flowering (year 2000) or early development of seeds (2001).

In total 1846 weed plants were harvested. The weed biomass was highest in the barley field in 2000, it was more than seven times higher than in the other fields. The biomass of this field was dominated totally by three species: ***Brassica napus***, ***Sinapis arvensis*** and ***Equisetum arvense***. The weed biomass in the other fields was distributed more evenly between more species (Fig. 2.6).

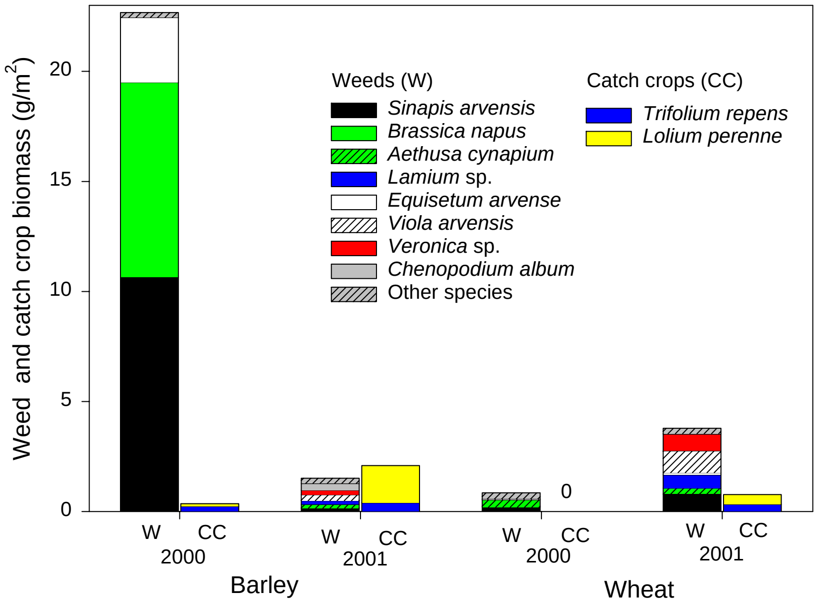

Figure 2.6. Species in the weed and the catch crop biomass in early July in organic spring barley and winter wheat fields.

2.2.2.2 Correlation between weed density and biomass

The weed biomass was significantly influenced by the weed density explaining 12 % of the variation in biomass (variance analysis not shown), however the weed biomass correlated weakly with the weed density (Fig 2.7). The correlation coefficient was 0.07 and non-significant for original data and 0.35 and highly significant for transformed data.

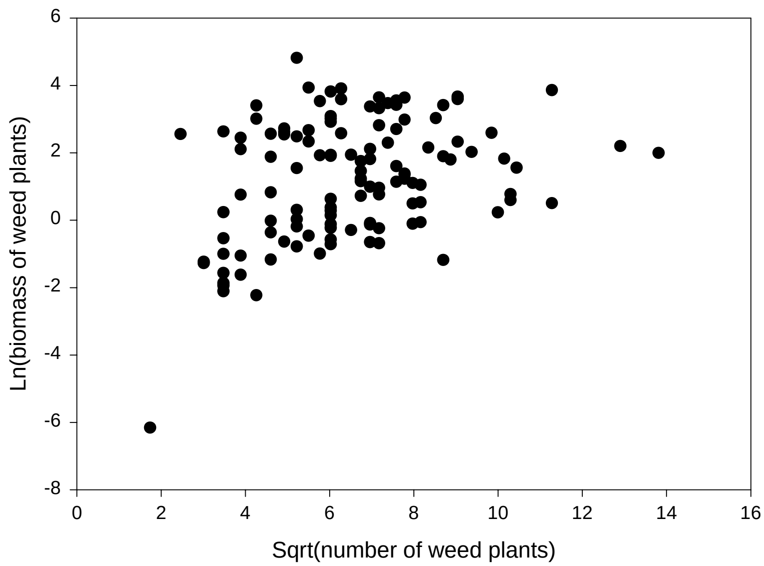

Figure 2.7. Correlation between weed density and biomass in early July in organic fields.

2.2.3 Results of the bird available seed mass

Over all years, there was on average 4.6 g spilt grains and 0.085 g weed seeds on the stubble fields after harvest. Thus, the weed seeds made up only 2% of the total biomass of bird available seeds on the stubble fields.

There was significantly higher weed seed biomass available on the soil surface in the organic period (0.95 g/m^2) than in the conventional period (0.026 g/m^2) (t-test of least square means, $p<0.0001$). The highest weed seed biomass was found in 2001 (Fig. 2.8) mainly because of the presence of ***Bilderdykia convolvulus*** seeds in the winter wheat (Field 2). ***B. convolvulus*** has very heavy seeds (7.5 mg/seed) compared to the other weed species found (Melander 1998) and made up 80% of the weed seed mass in the wheat field in 2001. Not only the seed mass but also the density of weed seeds was significantly higher in the organic (mean= 625 seeds/m^2) than in the conventional period (mean 36 seeds/m^2) (Table 2.3) (t-test of least square means, $p<0.0001$).

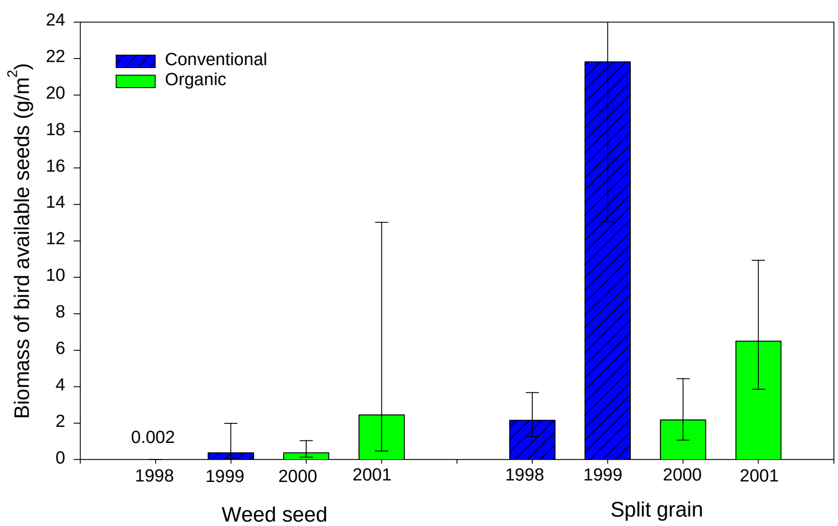

Figure 2.8. Bird available seed mass for weed seeds and for spilt grains in each of four years, where the fields were grown conventional in the first two and organic in the last two.

The biomass of weed seeds on the soil surface was also strongly influenced by the field (Table 2.3). The least square means of the biomass of weed seeds estimated from the model gave 23 g seeds/m^2 on Field 1, less than 0.0005 g seeds/m^2 on Field 2 and 0.28 g seeds/m^2 on Field 3.

The period had no significant effect on the biomass of spilt grain (Table 2.3), but the biomass varied considerably between years (Fig. 2.8). A higher biomass of barley grains than of wheat grains was found, even though wheat grains weights more than barley grains.

Table 2.3. Schematic summary of the analyses of bird available seed mass. P-values are given for explanatory factors included in the reduced model. r^2 for the reduced model is given in brackets.

	Weed seed mass (r^2=0.92) (n=24)	Weed seed number (r^2=0.95) (n=24)	Spilt grain mass (r^2=0.82) (n=24)
Period			
Year(Period)	0.017	0.0018	<0.0001
Crop		0.047	0.0087
Crop×Period			
Field	0.011	0.0007	0.079
Dosage			
Dosage×Period			
Dosage×Crop			
Dosage×Field			
Dosage×Period×Crop	0.0090	0.0005	

2.3 Discussion

2.3.1 Density

In winter wheat, the density of weeds after weed control was higher after conversion to organic farming than in the conventional period with normal dosage of pesticides, but it was not significant from the density in the conventional period when sprayed with reduced dosages of pesticides. Increased densities of Cruciferae and Polygonacea followed the higher weed density found during the organic period. In spring barley, no difference on overall density was found after conversion. This different response between crops might be due to the more intensive mechanical weed control in barley than in wheat. Thus, the weed control strategies used in organic barley production were shown to be as effective in killing the weed plants as normal dosage of herbicides.

The weed density before and after spring weed control was quite low in this study both before and after conversion. Still an increased density of weeds is normally typical of the early stages of conversion to organic farming (Kauppila 1990, Davies ***et al.*** 1997, Salonen ***et al.*** 2001). However, organic growers say that the weed problem diminishes with time (Davies ***et al.*** 1997); especially the presence of grass in the crop rotations reduces the weed density (Davies ***et al.*** 1997). Due to a very low weed density in the years before conversion, the seed banks do not contain a stock of weed seeds, which are able to germinate and increase the weed density drastically. Furthermore, it has been shown, that the intensive managed fields are not infested by seeds from outside the fields, especially not in the mid-fields (e.g. Marshall 1989). Therefore, it might take several years before the weed density increases. Density increase is dependent on the seed set of the weeds within the field.

2.3.2 Flowering

Since the majority of weed plants were annuals, the proportion of plants that was able to reach flowering reflect the fitness of the weed population. In this study, the proportion of flowering weed plants was much higher in the organic than in the conventional period. The proportion of flowering plants increased in both spring barley and winter wheat. There were more plants flowering in organic winter wheat than in organic spring barley, which might be due to a higher chance to survive early germination in an already established cereal field, where no blind-hoeing was performed and where the mechanical weed control was less intensive. This study shows that the weed population even though it has the same density in barley as in the conventional period was more fit when not sprayed. This may result in a higher seed production on average and an increase in weed density over longer time. The higher proportion of flowering plants produce more food items for the fauna. Since flowering plants are often larger and have developed more parts than vegetative plants, they increase the spatial structure and complexity of the vegetation and thereby support more living places for arthropods.

2.3.3 Species richness

The species richness of the weed flora reacted in the same way as the weed density on the conversion from conventional to organic farming, as they were highly correlated. After conversion a higher number of species was only found in the plots treated with normal dosage of herbicides during the conventional period; the species number reached the same level as in the plots treated with reduced dosages before conversion. Thus, the conversion to organic farming has not resulted in significantly more species than those present with reduced dosages of pesticides. A low level of herbicides before conversion to organic farming might be the explanation why Davies ***et al***. (1997) did not find any change in number of weed species four years after conversion. When old organic fields are compared with conventional fields, it is common to find a much higher species richness in the organic fields (Herrmann ***et al.*** 1986, Moreby ***et al.*** 1994, Hald 1999). Therefore, organic farming could be a way to preserve biodiversity (Elsen 2000, Rydberg & Milberg 2000) and prevent further decline in rare weed species (Albrecht & Mattheis 1998).

2.3.4 Weed composition

It is known that the intensity of herbicide use within the previous 10 years in a field can explain differences in weed flora composition (Salonen 1993). Therefore, it was expected that conversion from conventional to organic farming would change the weed composition as found by Hald (1999) comparing conventional and old organic fields. However, this could not be confirmed by this study. In this study, the main separator of the weed flora communities was the different fields, not the farming type. The field difference had also a significant influence on the density and diversity of the wild flora. The fields differ e.g. from each other by their different history of management (kind of crops, weed control, soil cultivation and so on), which have created the content of the different seed banks in the fields. The seed banks may contain seeds with a longevity of more than 20 years (Thompson ***et al.*** 1997) and since only 3-6 % of the seeds in the seed bank germinate each year (Roberts & Ricketts 1979) it is likely to take more than two years to change the composition of the seed bank and thereby the weed flora on the fields.

2.3.5 Biomass

The biomass was not sampled during the conventional period, so comparison between the farming types was not possible.

2.3.5.1 Crop biomass

However, Hald (1999) found that the crop biomass in cereal fields was 25% lower in old organic fields than in conventional fields.

In this study, the crop biomass was dependent on crop type and year. Winter wheat had a higher biomass than spring barley, because wheat plants at the time of biomass sampling in this study were closer to be mature than barley plants and because winter wheat on average yields more than spring barley. The differences between years cannot be a result of the stage of development at the time of biomass sampling, but may among other things be a result of different straw density.

2.3.5.2 Weed biomass

Other researchers have found that the weed biomass in organic fields is higher than in conventional fields (e.g. Hald 1999, Salonen 2001), but how quick after conversion this may be apparent is unknown. In this study, the organic fields were undersown with clover and ryegrass and it is a well-known phenomenon that intercropping may reduce the weed density, cover and biomass production markedly (e.g. Liebman & Dyck 1993, Breland 1996). Undersowing of ***Trifolium*** species in winter wheat has reduced the weed biomass up to 70% (Hartl 1989). Because the catch crop biomass was low in this study, it may not have suppressed the weed plants considerably. To sum up, it is very unsure whether the weed biomass found here was lower or higher than in the conventional period.

The highest weed biomass found was 23 g/m^2 compared to 34 g/m^2 in old organic cereal fields in Denmark (Hald 1999) and 47 g/m^2 found in organic spring cereal fields in Finland (Salonen ***et al.*** 2001). The biomass harvests were performed almost at the same time in the growing season, so the differences cannot alone be explained by differences in harvest times. A reason for a higher biomass found in those investigations could be the presence of perennial species with a high dry weight e.g. ***Cirsium arvense*** (which is a problematic weed species in organic farming). The presence of perennial species was as expected very low in this study. On average, only 2 % of the total biomass in the organic cereal fields was weeds, which is very low compared to the 12 % found in old organic cereal fields in Denmark (Hald 1999) and the 17 % found in spring cereals in Finland (Salonen ***et al.*** 2001). In 38 conventional cereal fields, Hald (1999) found an average weed biomass of 2 % of the total biomass, the same as in this study. Thus, the weed biomass was more like the level of conventional fields than organic fields. With such a low percentage of weed biomass, it is unsure how much the weed flora can influence the fauna. The weed vegetation is more or less like small islands in a large ocean of crops.

In this study, the total weed biomass correlated weakly with the weed density, which was also found by Salonen (1993). Kauppila (1990) found that changes in weed dry weights followed the changes in weed density by conversion from conventional to organic farming in Finland. Thus, the weed density might be an acceptable but very rough measure for the biomass. Weed density is the best vegetation variable to correlate with the fauna variables in this study, since biomass was not sampled in the conventional period.

2.3.6 Bird available seeds

The bird available seed mass on the soil surface in autumn consisted mainly of spilt grains as found by Jensen & Johnsen (2002). Berthelsen ***et al.*** (1997)

found that the Partridge prefer spilt grains rather than weed seeds, this may as well be true for other agricultural bird species of a certain size. The total seed mass varied considerably from year to year from 2 to 23 gram/m^2. The mass of weed seeds was much higher in the organic period than in the conventional, especially in 2001 where seeds from ***Bilderdykia convolvulus*** were the main contributor in weight. These seeds were eaten by many of the birds in the agricultural land (Christensen ***et al.*** 1996).

A higher weed seed mass and density in the organic period may be a result of the higher proportion of flowering plants and thereby a higher possibility to set seeds. Thus, the organic farming produces more food items in the autumn and more seeds to the seed bank than the conventional farming. This is confirmed by Davies ***et al.*** (1997), who found that the seed bank populations increased quickly after conversion.

3 Arthropods (Navntoft, S. & Esbjerg, P.)

The main purpose of the arthropod studies was to identify and quantify changes of the arthropod fauna occurring during conversion from conventional to organic farming, specifically for species being important prey items of birds and as natural enemies of crop pests.

The hypothesis was that the arthropod abundance generally would increase as a consequence of conversion, primarily as a result of no pesticide applications. Carry-over effects from the differentiated pesticide input during the conventional phase (normal, half and quarter dosage of herbicides and insecticides) were seen as a weak possibility hampered by high mobility of many species.

3.1 Methods

3.1.1 Data sampling

Suction sampling with a large-scale suction sampler was used throughout the experimental period as the predominant sampling method. The sampler was mounted on a small trailer with a 4WD vehicle as traction (Navntoft & Esbjerg 2002). Sampling was restricted to the main crop area excluding the plot margins (minimum 20 m) to reduce interference between plots and edge effects. Within each plot, 15 sub-plots (sub-plot: ±10 m from a marker stick) were selected in which sampling was carried out. The 15 sub-plots were evenly distributed along 3 tramlines to which the sampling machinery had to stay in order to minimise crop damage. Consequently the length of the suction tubes limited sampling to within 1.5 meters from the tracks. Sampling was only carried out in dry weather and the sampling of a particular field was always finished within 1 - 1.5 hour between 10.00h and 21.00h. Each sample comprised 10 sub-samples of 10 seconds application of the vac-nozzle (total area 0.2 m^2). The samples were immediately labelled and placed into cooling bags and then, later the same day, frozen.

Sampling was carried out in June, July and early August during the conventional period and in May, June and July during the organic period (Table 3.1). If possible sampling was conducted just before insecticide applications and no samples were taken until about one week after spraying.

After defrosting the samples were sieved through three grids (2.0, 1.4 and 1.0 mm laboratory test sieves, Endecotts Ltd. London) to extract animals from soil and debris. The arthropods were hand-picked from the grids and transferred to 70% alcohol. All arthropods, except Aphididae and Collembola found within the three grids, were collected. Animals passing through all grids were ignored because they were not important as Skylark prey (Chapter 5). The sample content was subsequently identified under binocular microscopes at 5 - 40 x magnification. The arthropods were identified at minimum to order, but preferable to more detailed taxonomic levels.

Table 3.1. Statistical information about the sampling in the experimental fields. For each combination of crop and year, the number of sampling dates is shown. Also, the period during which the sample collections were performed is shown together with the median sampling date.

Year	Barley			Wheat		
	No. of sampling dates	Sampling period	Median date	No. of sampling dates	Sampling period	Median date
1997	5	08.06-04.08	05.07	5	08.06-04.08	05.07
1998	6	03.06-01.08	03.07	6	03.06-01.08	03.07
1999	5	01.06-26.07	30.06	6	26.05-26.07	24.06
2000	9	16.05-31.07	25.06	10	10.05-31.07	21.06
2001	13	10.05-31.07	19.06	13	10.05-31.07	19.06

Collembola were not included because they require a comprehensive soil-sampling program. Aphididae attacks were estimated by counting cereal tillers with Aphididae. On each assessment and in each plot, 100 randomly selected wheat and barley tillers on a diagonal transect (Danielsen 1992) were inspected and the number of tillers with Aphididae was counted.

3.1.2 Statistical analyses

The variables 'dry mass' and 'density' were used to analyse for transition effects of the conversion from conventional to organic farming.

3.1.2.1 Dry mass analyses

Effects of conversion on estimated dry mass were analysed for three groups of arthropods: 1. Important Skylark prey (in the following ref. as 'Skylark prey'). 2. Carabidae and Staphylinidae and 3. All arthropods. Carabidae and Staphylinidae were analysed separately because it generally may be assumed that weed hoeing, which occurs repeatedly at organic farming, has a negative impact on arthropods (Holm ***et al.*** unpubl.) especially on ground/soil dwelling species.

The selection of arthropods included in the group 'Skylark prey' was based on the frequency of occurrence in faecal Skylark pellets collected in the experimental fields in 2000 and 2001 (Chapter 5, Table 5.1).

Arthropod dry mass was estimated from the formula $W = 0.0305 \times L^{2.62}$ mg, where L is the length of the arthropod in mm (Rogers ***et al***. 1977). The arthropod lengths used were obtained from the literature if the individual was identified to species and otherwise estimated by measuring between 50 to 100 randomly selected individuals (Navntoft & Esbjerg 2002).

Because suction sampling did not start until early June in the period before conversion to organic farming (late May in 1999), and ended late July after conversion (Table 3.1), only data from June and July were included in the analyses.

The experimental unit was a plot, each of which was represented by 15 samples per sampling date. The 15 samples were summarised and divided by three to form the dependent variable 'mg dry mass m^{-2}'. Thereafter the data were $\log_e(x+1)$ transformed in order to improve approximation to a normal distribution. The data sampling can be classified as repeated sampling (Stryhn 1996), which may violate the required independence of data. To avoid this a geometric mean of the $\log_e(e+1)$ transformed data across the sampling dates in June and July was used for the analyses, leaving only one figure per combination of year (5), crop (2) and dosage plot (3) (n = 30).

General Linear Models (GLM procedure in SAS/STAT) (SAS Institute 1990b) were used for the analyses of dry mass. As starting point the anova design shown in Table 1.1 was applied, and stepwise model reduction was used to reach the final model.

If no significant dosage effect or any interaction including dosage could be found, the basic model was simplified by replacing the fixed dosage effect by a random plot effect (Table 3.2). Pairwise tests between specific groups were carried out using a Tukey-Kramer adjustment for multiple comparisons of least-squares means.

Table 3.2. The factors included in the simplified anova (based on the anova presented in Table 1.1) of the occurrence of the estimated dry mass of various arthropod groups in June and July. The nature of each factor (fixed/random) and the denominator (error term) used in the test of significance of each factor are stated.

Source of variation	Fixed / random	Denominator in F test
Period	Fixed	MS (Year(Period))
Year(Period)	Random	MS (Residual)
Crop	Fixed	MS (Residual)
Crop×Period	Fixed	MS (Residual)
Field	Random	MS (Dosage×Field)
Plot(Field)	Random	MS (Residual)
Residual	Random	

In order to provide information about the development in available Skylark prey and arthropods in general during June and July, 2nd degree models were calculated using the REG procedure in SAS/STAT and presented in figures for both barley and wheat. As stated above only the differences between means, corresponding to the 0-degree models, were tested using the GLM-procedure, due to the high population-fluctuations of arthropods within and between years. ***Therefore, the 2nd degree models can only be considered descriptive and no final conclusions should be drawn from the models***.

3.1.2.2 Density analyses

The analyses were conducted as described for the dry mass analyses but instead of the estimated dry mass the dependent variable was 'mean density' (no. m^{-2}) (mean of samplings in June and July) of dominating arthropod groups.

To describe how the population of Aphididae specific predators (Coccinellidae, Syrphidae and Chrysopidae) developed during June and July, descriptive 2nd degree models were calculated and presented in figures. The method used is described above.

3.1.2.3 Arthropods in relation to vegetation

Dry mass analyses

To estimate a general effect of weeds and undersown clover and ryegrass on arthropods, anovas including covariates of vegetation dry masses were carried out using the GLM procedure in SAS/STAT (SAS Institute 1990b). Vegetation dry mass (mg dry mass m^{-2}) was only estimated in the period after conversion to organic farming (2000 and 2001) (cf. chapter 2), which consequently was the experimental period analysed.

The experimental unit was a plot and the dependent variable 'arthropod dry mass m^{-2}' (Skylark prey, Carabidae and Staphylinidae, all arthropods) was analysed in relation to the factors presented in Table 3.3. Only arthropod data from June and July were used to make the analyses comparable with analyses comprising the entire experimental period (cf. section 3.1.2.1)

Because dry mass data of vegetation was only available after conversion the factor 'period' could not be estimated. Furthermore, because of confounding it was not possible to include 'field' and 'plot' in the model (see Table 3.2). Also 'dosage' was excluded because the factor generally proved to be insignificant for the Arthropods (section 3.2). The last component 'vegetation covariate×crop' (Table 3.3) was included to test for a possible different regression coefficient for each crop.

Table 3.3. The factors included in the combined analyses of the occurrence of the estimated dry mass of various arthropod groups in June and July in relation to estimated vegetation dry mass. The nature of each factor (fixed/random) and the denominator (error term) used in the test of significance of each factor are stated.

Source of variation	Fixed / random	Denominator in F test
Crop	Fixed	MS (Crop×Year)
Year	Random	MS (Crop×Year)
Crop×Year	Random	MS (Residual)
Vegetation covariate		MS (Residual)
Vegetation covariate×Crop		MS (Residual)
Residual	Random	

Three different covariates were used to describe the vegetation: 1. Cereal biomass, as the dominating biomass. 2. Biomass of dicotyledonous weeds, because of its importance to herbivorous insects important as Skylark Prey (Moreby & Sotherton 1997). 3. Biomass of all vegetation beneath the cereals, which, except serving as a food resource, may provide refuges and improve the microclimatic conditions for arthropods living on the crop floor (Burn 1989). Except for the cereal biomass the covariates were $\log_e$-transformed.

To avoid problems with multicollinearity only one vegetation covariate was entered into the analyses at a time. Stepwise model reduction was used, with $p > 0.0167$ as removal criterion. The P-value of the removal criterion was adjusted by Bonferroni correction to estimate the correct level of significance ($\alpha' = 0.05/n = 0.05/3 = 0.0167$, with n being the number of covariates tested).

Density analyses

To estimate effects of weed density and diversity on arthropod densities (no. m^{-2}) (mean of samplings in June and July, cf. section 3.1.2.1) anova´s including the general covariates weed density (no. m^{-2}) (geometric mean of log_e-transformed data) and weed diversity (no. of weed species per 0.96 m^2) (arithmetic mean), were carried out using the GLM procedure in SAS/STAT (SAS Institute 1990b). The weed covariates were based on estimates in late July or early August (cf. chapter 2).

The procedure was as described in the above section, except that in this case the basic model was the model presented in Table 3.2 in order to include the effect of 'period'. This model was extended with a 'weed covariate' and a 'weed covariate×crop×period'. The last component was included to test for separate regression coefficients depending on 'crop' and 'period'. Stepwise model reduction was used and after Bonferroni correction the removal criterion was $p = 0.05/2 = 0.025$, because two covariates were tested.

Emphasis was put on the dominating herbivore groups foraging on weeds. The groups were: 1. Auchenorrhyncha, 2. Chrysomelidae, 3. Curculionidae and 4. Lepidoptera . The abundant herbivore group Symphyta was dominated by species also foraging on the cereal crop, and the group was therefore not expected to be correlated to the weed.

To test for more specific host plant – herbivore relationships, the density of Auchenorrhyncha was analysed in relation to the density of monocotyledonous weeds. Furthermore the density of ***Polygonum aviculare*** and ***Bilderdykia convolvulus*** was tested in relation to ***Gastrophysa polygoni*** and the density of Cruciferae was tested in relation to Ceutorhynchus. The density of flowering plants is known to be a limiting factor for insects feeding on nectar and pollen (Altieri & Whitcomb 1979). To elucidate such a relationship, the density of flowering dicotyledonous weeds (cf. chapter 2) was analysed in relation to the density of Lepidoptera adults. Data of flowering weeds from 1997 were lacking and this year was consequently not included in the analysis. The specific tests were carried out as described above.

3.2 Results

3.2.1 Dry mass analyses

No significant 'dosage' effects were found and consequently the data were analysed by the simplified anova design (Table 3.2). Furthermore, no significant 'period' effect across crops of the three arthropod groups analysed was found (Table 3.4), but for all groups there were clearly significant effects of 'year(period)' ($p < 0.0001$) and 'crop×period' ($p < 0.0001$). The interactions indicate that a difference between the two periods exists, but the effect varies between years and crops.

Pairwise t-tests (Tukey-Kramer adjusted for multiple comparisons) on the interaction 'crop×period' revealed a significantly higher Skylark prey biomass in barley after conversion to organic farming than the period before ($p = 0.0002$). Contrary, in wheat a significantly lower Skylark prey mass was found for the period after conversion ($p = 0.001$) (Fig. 3.1.A).

Table 3.4. Schematic summary of the analyses of the estimated dry mass means (mg m^{-2}) of various groups of arthropods collected in the experimental barley and wheat fields at June and July.

Source of variation	Skylark Prey	Carabidae and Staphylinidae	All arthropods
Period	ns[ab]	ns	ns
Year(Period)	< 0.0001	< 0.0001	< 0.0001
Crop	ns	ns	0.0126
Crop×Period	< 0.0001	< 0.0001	< 0.0001
Field	0.003	< 0.0001	0.0016
Plot(Field)			

[a] Ns: Not significant ($p > 0.05$) but factor included in the model.
[b] If 'period' is tested against MS (Residual) instead of MS (year (period)) the period effect is significant ($p < 0.05$).

A pairwise test on the dry mass of Carabidae and Staphylinidae revealed a significant decline in wheat after transition to organic farming ($p < 0.0001$) (Fig. 3.1.B), which also explains the decline in the Skylark prey in wheat after conversion, because the beetles constitute a significant part of the Skylark prey.

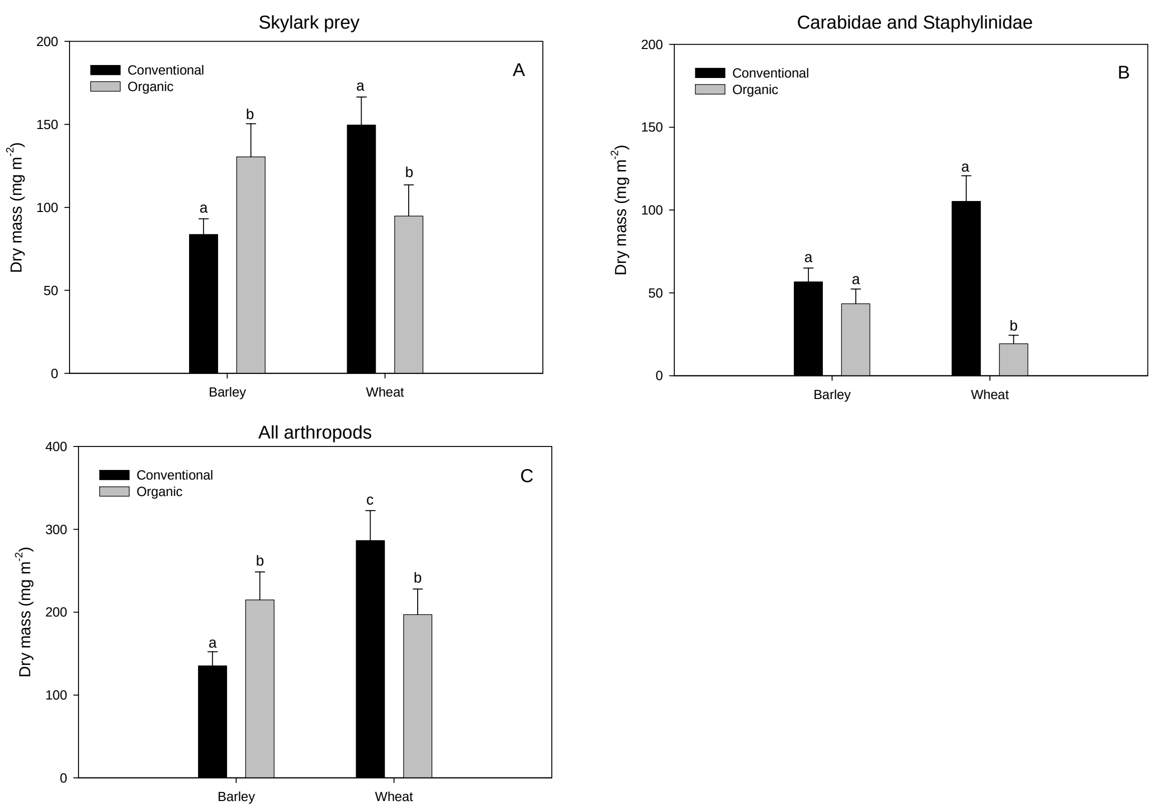

Fig. 3.1. Estimated mean dry masses of 'Skylark prey', 'Carabidae and Staphylinidae' and 'all arthropods'. The values given are least squares estimates of the mean dry mass (mg m^{-2}) in the period June-July. The error bars indicate the 95% confidence intervals (only upper bar shown). Significant differences are indicated by different letters ($p < 0.05$), pairwise t-tests with Tukey-Kramer adjustment for multiple comparisons).

Least-squares estimates and 95% CL of the ‘year(period)’ factor for the dry masses of Carabidae and Staphylinidae were: 1997 = 48 (40-57) mg m^{-2}, 1998 = 130 (108-156) mg m^{-2}, 1999 = 74 (62-89) mg m^{-2}, 2000 = 41 (34–48) mg m^{-2} and 2001 = 20 (17-25) mg m^{-2}. The estimates of both years after conversion were lower compared to conventional growing, especially in 2001. Wheat was grown on the same field (field 2, cf. appendix B) both years after conversion. In order to clarify the significant effect of ‘field’ on the Carabidae and Staphylinidae, least squares estimates and 95% CL are given: Field 1 = 33 (28-39) mg m^{-2}, field 2 = 67 (57-78) mg m^{-2} and field 3 = 48 (40-57) mg m^{-2}.

For the total dry mass a significant increase was found after conversion in barley ($p = 0.0002$), but a reverse effect was found in wheat ($p = 0.0022$) (Fig. 3.1.C).

In Fig. 3.2 descriptive models indicate the development over time (June and July) of the dry mass of Skylark prey, the dry mass of Carabidae and Staphylinidae and the total arthropod dry mass are presented. The dry masses of Skylark prey and all arthropods apparently started higher in organically grown wheat than in conventional wheat; Skylark prey about twice as high. When the season developed, however, the estimated dry masses in conventional wheat exceeded the corresponding amount in organic wheat mainly due to a stronger contribution of carabids and rove beetles. In barley, the models indicate that the dry masses of Skylark prey and all arthropods generally were higher in organic than in conventional barley, except at the beginning of the period were they tended to be at a lower level because of a higher dry mass of Carabidae and Staphylinidae in conventional barley.

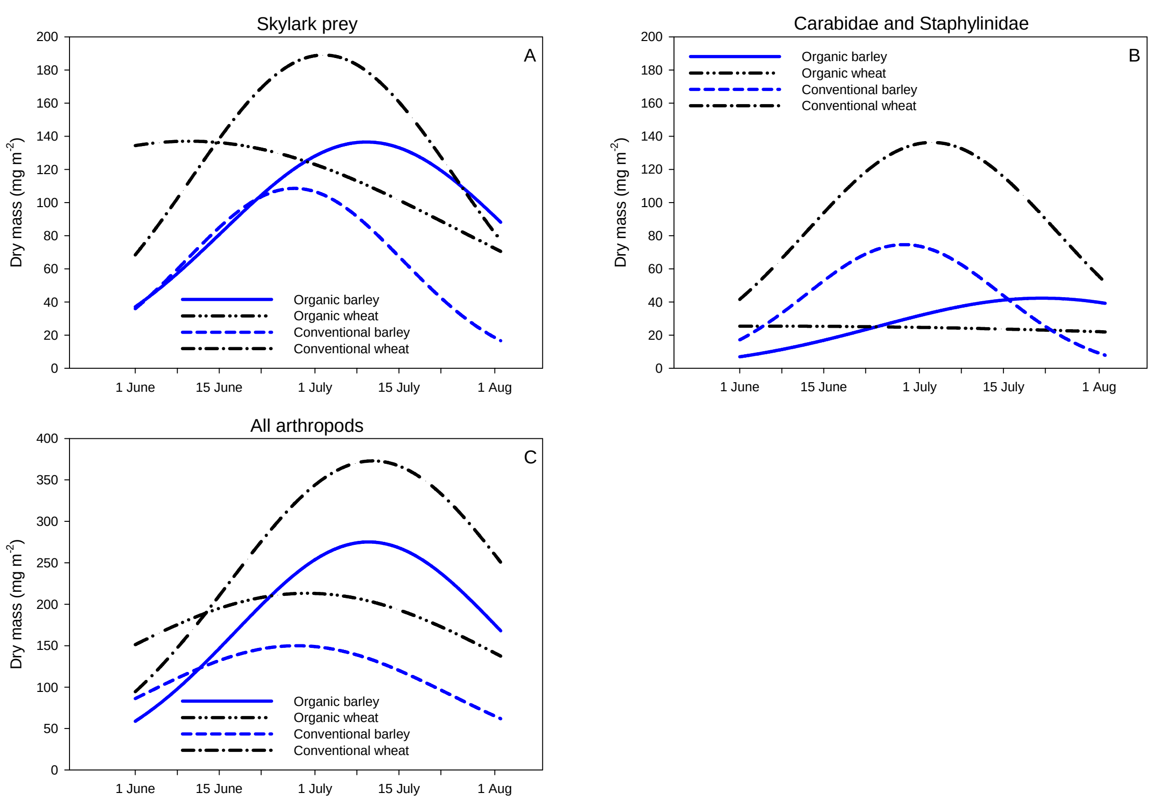

Fig. 3.2. Simple descriptive models of the development of estimated arthropod dry mass during June and July. The models are based on log-transformed data, so the dry masses indicated are not comparable with normal arithmetic means.

3.2.2 Density analyses

In this section the focus is put on herbivores important as Skylark prey, Aphididae specific predators as well as a couple of important generalist predators.

No significant effects of previous spraying intensity were revealed (no 'dosage' effect or interactions including 'dosage'). Furthermore, no general 'period' effect could be revealed across crops of the various population analyses. For all tested populations, however, a significant 'period×crop' effect was found ($p < 0.05$), indicating that a difference between the two periods exists, but that the effect varied between the two crops. Pairwise t-tests (Tukey-Kramer adjusted for multiple comparisons) on five groups of herbivores important as Skylark prey and 11 groups of important predators, Aphididae specific and generalists, on the interaction 'crop×period' are presented in Figs. 3.3, 3.4 and 3.5.

As seen from Fig. 3.3 the clearest effects on herbivores of conversion to organic farming were found in barley, in which all five tested groups occurred in significantly higher numbers after conversion. Contrary, in wheat only the density of Symphyta larvae were significantly higher after conversion, considerably higher than in barley.

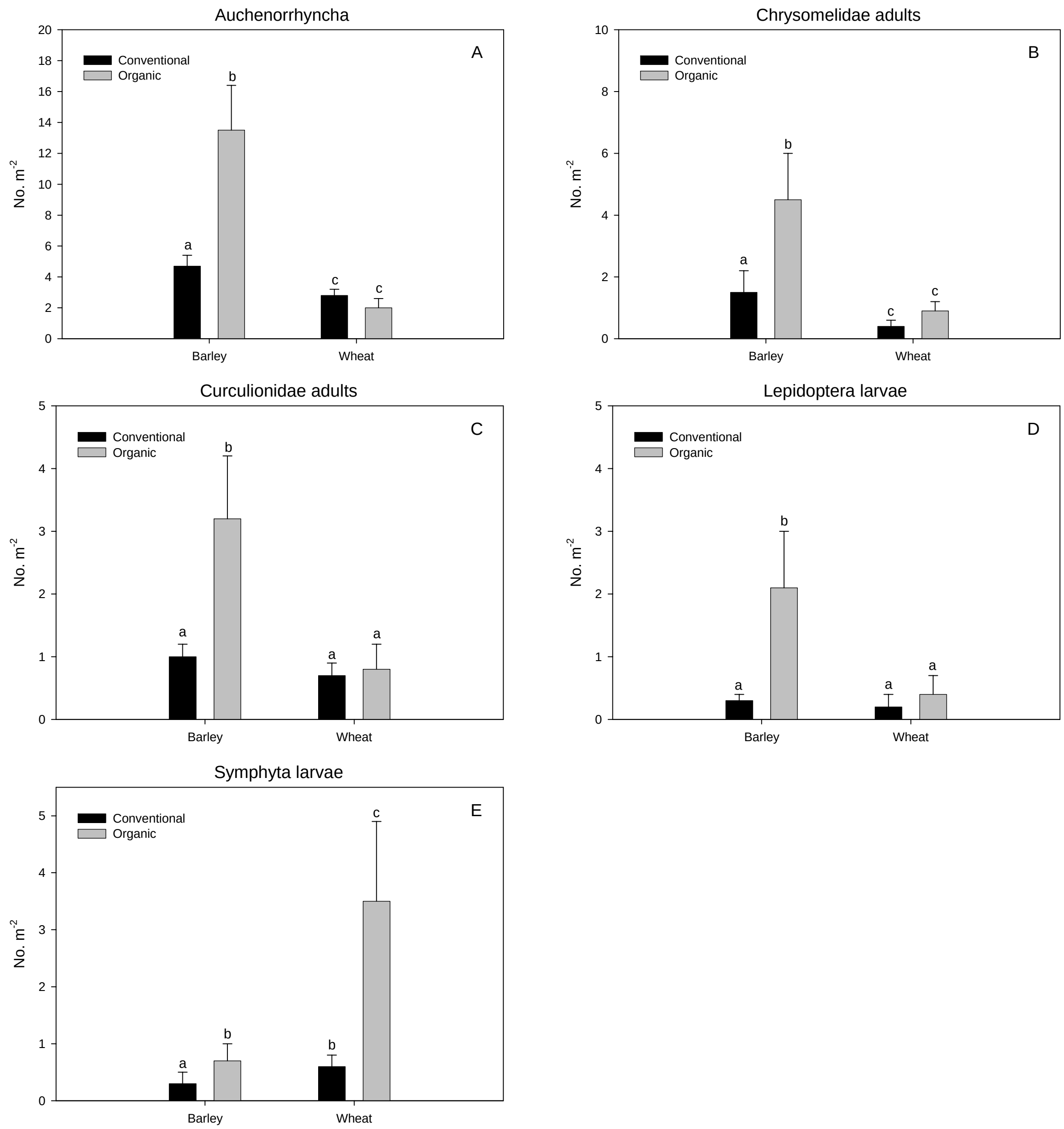

Fig. 3.3. Estimated densities of herbivores important as Skylark prey. The values given are least squares estimates of the mean no. m^{-2} in the period June – July. The error bars indicate the 95% CL (only upper bar shown). Significant differences are indicated by different letters ($p < 0.05$, pairwise t-tests with Tukey-Kramer adjustment for multiple comparisons).

The juvenile stages of the Aphididae specific predators in barley: Coccinellidae, Syrphidae and Chrysopidae benefited most of organic farming, with significantly higher density after conversion (Figs. 3.4.B, 3.4.D and 3.4.F). Generally, the trend of the Aphididae specific predators was higher abundance in the organically grown cereals (Fig. 3.4).

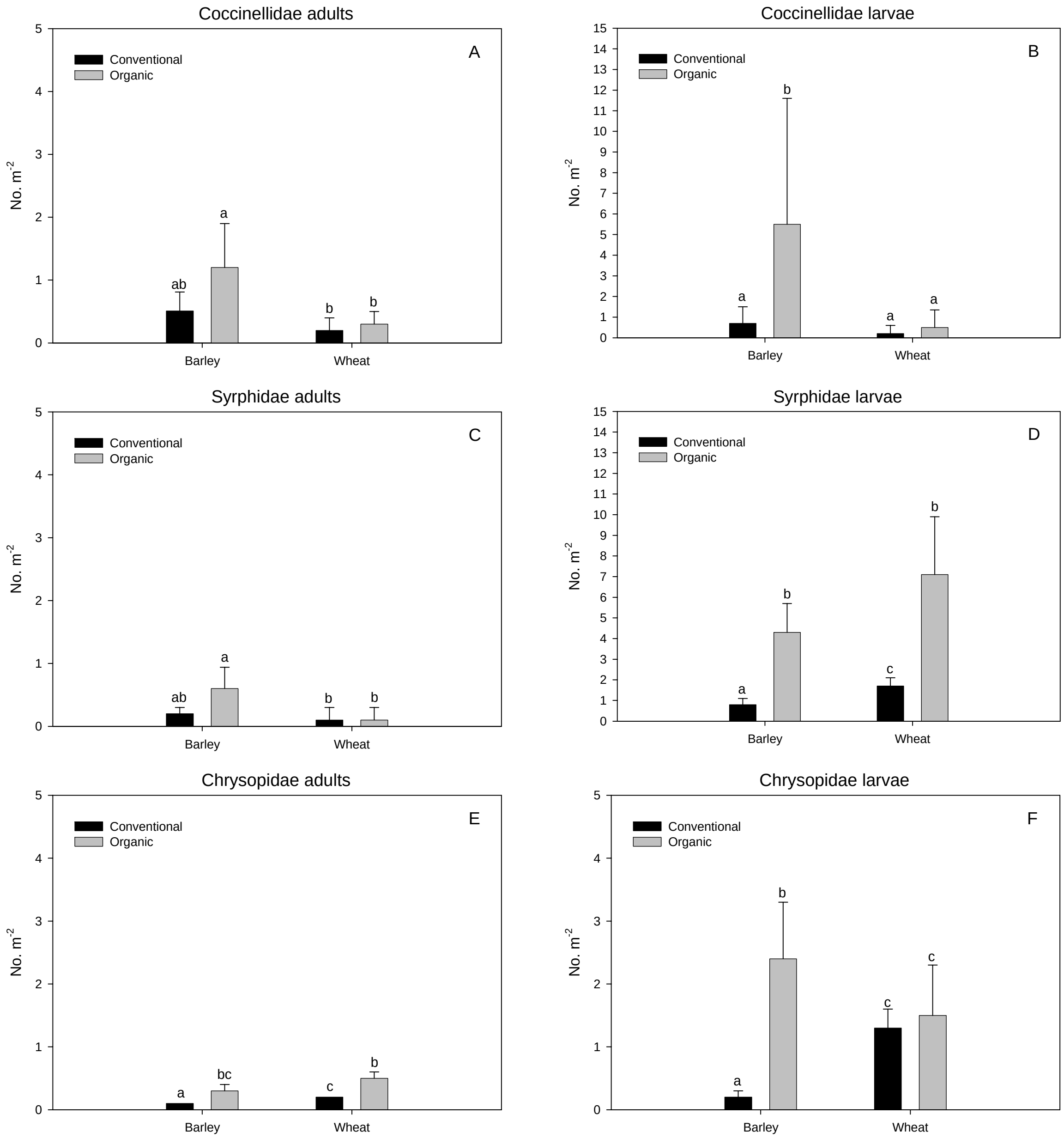

Fig. 3.4. Estimated densities of Aphididae specific beneficials. The values given are least squares estimates of the mean no. m^{-2} in the period June – July. The error bars indicate the 95% CL (only upper bar shown). Significant differences are indicated by different letters ($p < 0.05$, pairwise t-tests with Tukey-Kramer adjustment for multiple comparisons).

For the generalist groups Carabidae, Staphylinidae and Araneae, a significant decrease in the numbers of adult Carabidae and larval Carabidae was found in wheat after conversion to organic farming (Figs. 3.5.A and 3.5.B). The total catch of the adult Carabidae was dominated by ***Trechus*** spp. (74%) and ***Bembidion*** spp. (17%). Also the density of adult Staphylinidae decreased significantly in wheat after conversion but the density of Staphylinidae larvae diminished in both barley and wheat at organic growing (Figs. 3.5.C and 3.5.D). Furthermore, a significant increase in the density of Araneae was found in barley, but contrary there was a decrease in abundance of Araneae in wheat (Fig. 3.5.E).

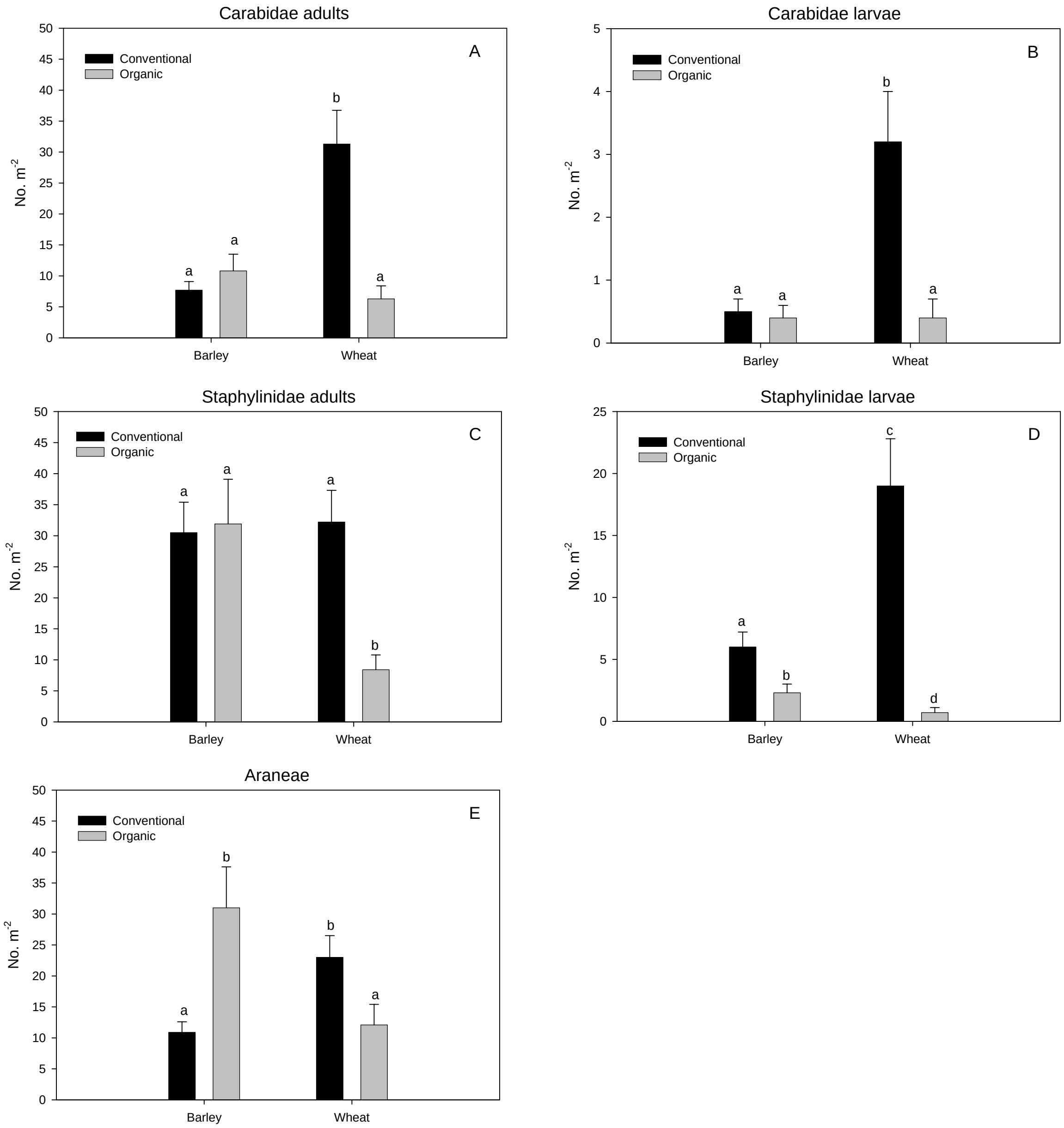

Fig. 3.5. Estimated densities of important generalist predators. The values given are least squares estimates of the mean no. m^{-2} in the period June – July. The error bars indicate the 95% CL (only upper bar shown). Significant differences are indicated by different letters ($p < 0.05$, pairwise t-tests with Tukey-Kramer adjustment for multiple comparisons).

In Fig. 3.6 the development during the season of the total number of Aphididae specific predators is indicated. The total population in conventional barley never seems to reach any size of importance, whereas the population of predators in conventional wheat peaks at the end of the period; about 14 days later than in organic wheat. The development in organic barley and organic wheat are quite similar. A steeper population build-up is indicated in June and the first half of July compared to the conventional cereals, and both populations peak in the middle of July; in barley about one week earlier than in wheat.

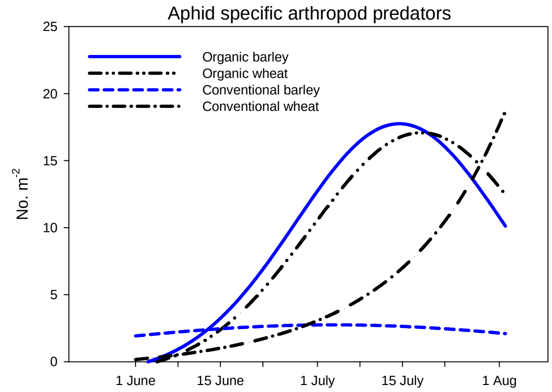

Fig. 3.6. Simple descriptive models of the population developments during June and July of the Aphididae specific predators: Coccinellidae, Syrphidae and Chrysopidae (total of all species and stages). The models are based on log-transformed data, so the populations indicated are not comparable with normal arithmetic means.

3.2.3 Aphididae

The estimates of Aphididae attacks are presented in Table 3.5. In wheat the dominating Aphididae was ***Sitobion avenae*** and in barley ***Rhopalosiphum padi***.

Table 3.5. Percentages of cereal tillers with Aphididae. The insecticide applications are included in the table. In 2000 and 2001 the cereals were grown organically, but the plots are still named 'normal, half and quarter dosage'.

Year	Wheat				Barley			
	Date	Normal	Half	Quarter	Date	Normal	Half	Quarter
1997	24 June	2	1	5	23 June	0	0	3
	7 July		Pirimicarb		25 June		Lambda-cyhalothrin	
	16 July	5	13	56	16 July	4	6	10
1998	15 June	55	39	43	15 June	98	100	100
	23 June		Tau-fluvalinat		16 June		Pirimicarb/Tau-fluvalinat	
	29 June	45	55	73	29 June	3	6	16
	13 July	2	17	47	13 July	0	0	12
1999	14 June	3	2	4	14 June	7	8	16
	15 June		Tau-fluvalinat		16 June		Tau-fluvalinat	
	23 June	3	3	3	23 june	11	1	1
	30 June	0	3	5	30 June	0	1	0
2000	02 June	0	0	0	02 June	93	96	99
	29 June	9	16	10	29 June	2	4	2
	19 July	36	58	52	19 July	4	5	6
2001	26 June	34	15	*	Aphididae attack in 2001 negligible			
	3 July	66	64	62				
	17 July	13	9	5				

* Data missing

3.2.4 Arthropods in relation to vegetation

3.2.4.1 Dry mass analyses

Significantly positive relationships were revealed only between 'dicotyledonous weed biomass' and 'Skylark prey' as well as between 'Cereal biomass' and 'Carabidae and Staphylinidae' (Table 3.6). The corresponding models based on parameter estimates of the significant factors are illustrated in Fig. 3.7.

Table 3.6. Schematic summary of the combined analyses of the estimated arthropod dry mass in relation to covariates describing the vegetation. Two significant relationships were found. Significant P-values are given (p < 0.0167 following Bonferroni correction). The percentage of variation explained by the reduced model is given in brackets.

Factor	Class / Continuous	Skylark prey (60%)	Carabidae and Staphylinidae (96%)
Year	Class variable		< 0.0001
Crop	Class variable	0.0164	< 0.0001
Year×Crop	Class variable		
Cereal biomass[a]	Covariate		< 0.0001
Cereal biomass×Crop	Covariate		
Dicotylodenous weed biomass	Covariate	0.0100	
Dicotylodenous weed biomass×Crop	Covariate		
Weed+catch crop biomass	Covariate		
Weed+catch crop biomass×Crop	Covariate		

[a] All three vegetation covariates were significantly correlated (p < 0.05, Pearson Correlation Coefficients, PROC CORR, SAS/STAT, SAS Institute 1990b).

Considering 'Skylark prey', 45% of the explained variation between plots came from differences between the 'crops' and 55% from differences between the 'dicotyledonous weed biomass'. Regarding 'Carabidae and Staphylinidae', 41% of the explained variation was due to differences between 'years', 33% due to 'crop' differences and 26% because of variation in the 'cereal biomass'.

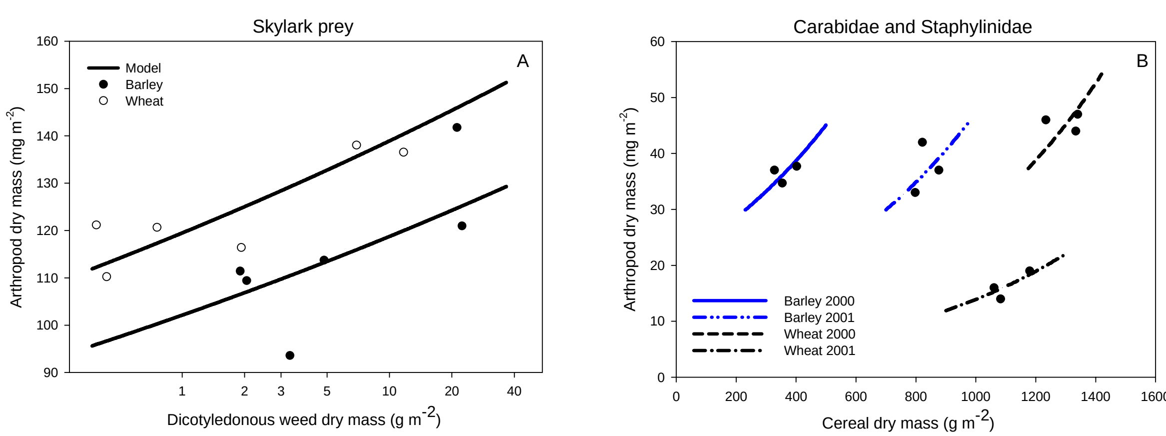

Fig. 3.7. Models of the relationships between estimated vegetation dry mass and arthropod dry mass at organic farming. Notice that the model graphs do not show the range of variation and that the log-transformed dry masses are not comparable with normal arithmetic means. The high position of the wheat curve in Fig. A, which is in contrast to Fig. 3.1.A is due to the following: In Fig. 3.1.A the dry mass has been statistically adjusted for the effect of 'field' while it was not possible to include this correction in the figure above because the effects of crop and field were confounded.

3.2.4.2 Density analyses

No significant relationships were obtained between the two general covariates density and diversity of weeds and density of herbivorous arthropods. Neither were any significant relationships revealed from the specific host plant – herbivore analyses. However, a significant relationship was found between the density of flowering weeds and Lepidoptera adults (Table 3.7). The corresponding model based on the parameter estimates of the significant factors is illustrated in Fig. 3.8.

Table 3.7. Schematic summary of Lepidoptera densities analysed in relation to the density of flowering dicotyledonous weeds. P-values of significant factors are given ($p < 0.05$). The percentage of variation explained by the reduced model is given in brackets.

Factor	Class / Continuous	Lepidoptera adults (93%)
Period	Class variable	
Year(Period)	Class variable	<0.0001
Crop	Class variable	
Crop×Period	Class variable	
Field	Class variable	0.0004
Plot(Field)	Class variable	
Density of flowering weeds	Covariate	0.0053
Density of flowering weeds×Crop×Period	Covariate	

Of the explained variation the covariate of flowering weeds only accounted for 6%. For the class variables 33% of the variation came from ‘period’ (although not significant), 44% from ‘year(period)’ and 16% from ‘field’.

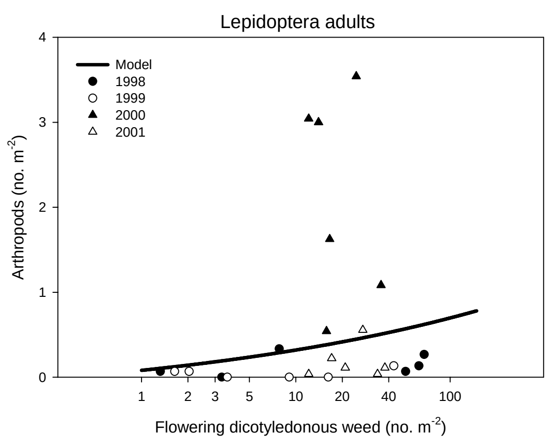

Fig. 3.8. Model of the relationship between the density of flowering dicotyledonous weeds and the density of Lepidoptera adults. Notice that the model graph does not show the range of variation and that the log-transformed densities are not comparable with normal arithmetic means.

3.3 Discussion

In a multi-trophic context the present arthropod studies identifies temporal trends in a variety of arthropod groups during conversion from conventional to organic farming analysed by means of dry mass and density estimates.

In spring barley there was, in agreement with the working hypothesis, a clearly positive effect on the estimated Skylark prey dry mass and the total arthropod dry mass as a result of conversion to organic farming (Figs. 3.1.A and 3.1.C). Fig. 3.2 indicates that the difference was a result of higher estimated dry masses from the middle of June onwards at organic farming. Contrary, lower corresponding dry masses were found in winter wheat after conversion (Figs. 3.1.A and 3.1.C), mainly as consequence of a lower dry mass of Carabidae and Staphylinidae (Figs. 3.1.B and 3.2.B). Actually in wheat the estimated dry masses of Skylark prey and all arthropods were higher at organic farming in the first half of June. Afterwards, however, both dry masses in wheat at conventional farming exceeded the dry masses at organic farming (as indicated by Figs. 3.2.A and 3.2.C) due to a higher contribution of the epigaeic beetles (as indicated by Fig. 3.2.B).

Before conversion to organic farming, Carabidae and Staphylinidae constituted 68% of the estimated dry mass of Skylark prey in barley and 70% in wheat. After conversion these shares declined to 33% in barley and 20% in wheat (Fig. 3.1). In barley this was mainly due to a higher abundance of the other arthropod groups, which were part of the Skylark prey (Figs. 3.3, 3.4.D and 3.4.F). In wheat the effect was a result of reduced abundance of the polyphagous predators (Fig. 3.5) and a higher abundance of the other Skylark prey groups. Only two of the groups presented in Figs. 3.3 – 3.5 benefited, however, significantly from organic farming in wheat. This was Symphyta larvae (Fig. 3.3.E) and Syrphidae larvae (Fig. 3.4.D), which both were part of the Skylark prey.

Wheat was grown in the same field both years after conversion to organic farming, and the statistical effect of ‘field’ was therefore especially in wheat an important factor. Least squares estimates of the dry mass of Carabidae and Staphylinidae in the three fields revealed that the lower abundance of the epigaeic beetles was not due to a generally lower occurrence in field 2 (section 3.2.1). It should also be noticed that the actual observations of the estimated Skylark prey in organic wheat actually was higher than in organic barley (Fig. 3.7.A). However, when comparing the conventional and organic periods there are statistically adjusted for differences between fields. Therefore the estimated dry mass means for organic wheat becomes lower than for organic barley (Fig. 3.1.A). Still, if the field factor is excluded from the models (although significantly) the estimated dry masses of organic wheat do no exceed conventional wheat.

There was a tendency towards higher populations of Aphididae specific predatory insects in the organically grown period, especially of juvenile stages in barley (Figs. 3.4 and 3.6). Contrary, Fig. 3.6 indicates that the population of Aphididae specific predators in conventional barley never managed to build maybe because of lethal effects of insecticide applications and indirectly because of food shortage. The dominating Aphididae species in barley was the early occurring ***R. padi***. That species never occurred in high numbers during the second half of the sampling season (Table 3.5), thereby providing no food for the predators.

In conventional wheat, the reason for the late peak in the population of Aphididae specific predators could be, that the predators were able to recover from the insecticide applications. This was probably because the dominating Aphididae species, ***S. avenae***, occurred later in the season compared to ***R. padi*** despite insecticide applications (Table 3.5).

Due to the very distinct differences of the infestation level it is difficult to reach any conclusion regarding conversion effects on Aphididae. However, the heavy infestation in barley early in 2000 resulted in yield loss (M. Tved pers. comm.). Contrary, the infestation in barley in 2001 was negligible.

Insecticides may have a major impact on the observed differences in arthropod abundance between the two farming regimes. A possible reason for the pronounced effect found on herbivores in barley compared to wheat is that the arthropod fauna may have been depressed more by insecticides in barley than in wheat. That was because of the more open structure in barley, allowing insecticides to penetrate deeper into the canopy. The two groups, which occurred in significantly higher numbers in organic wheat, Symphyta and Syrphidae larvae, are both highly sensitive to insecticides (e.g. Sotherton 1990, Hassan ***et al.*** 1987), which may explain the increased density at organic growing. However, Moreby & Sotherton (1997) stated that weed diversity and density and other less obvious factors including crop variety, crop rotation, past history of pesticide use, cultivation techniques, fertilizer type and level could all have an effect.

No effect of the previous pesticide dosage level was found on the arthropods. Even before conversion to organic farming there was no significant effect of dosage on the arthropod abundance. However, if a dosage effect was found in the conventional phase, it is doubtful if a carry-over effect could have been revealed after conversion. That is because most of the field inhabiting arthropods are very mobile and therefore overshadow effects of previous treatments. Higher weed populations in the reduced dosage plots, however, could have lead to an indirect carry-over effect due to a higher supply of host plants but that was not the situation.

The lower abundance of Carabidae observed in winter wheat in this experiment is in agreement with findings by Moreby & Sotherton (1997) based on D-vac samples. They also found that Carabidae tended to be more numerous on the conventional fields compared to the organic fields, which have been pesticide-free for at least two years. As was the case in this experiment Moreby & Sotherton (1997) found, that significantly higher densities did occur in the organic winter wheat fields for some of the “chick-food” insect groups, but generally the number of individuals were similar in both farming regimes.

Moreby & Sotherton (1997) found that a greater diversity of broad-leaved weed species might have influenced the abundance of “chick-food” insects positively in organic fields by the provision of host plants for phytophagous species of Chrysomelidae, Lepidoptera, Heteroptera and Tenthredinidae. In line with this, the present study revealed a significant positive relationship between the dry mass of dicotyledonous weeds and dry mass of Skylark prey (Fig. 3.7.A). It should, however, be stated that the analysis is based on few observations, raising questions about the validity of the model. The effect indicated could be due to a combination of improved food availability for herbivores and a more favourable microclimate. Dry mass data of weeds, however, was only available after conversion to organic farming (cf. chapter 2). It is therefore not possible to validate if the relationship can explain the conversion effects on the arthropod fauna.

A significant relationship was also revealed between the cereal dry mass and the dry mass of Carabidae and Staphylinidae (Fig. 3.7.B); again only for the period after conversion. However, the combination of few observations and a large variation between years (Table 3.6) leads to that no straight foreward can be made. Although no data are available on the crop dry mass at conventional farming, the yield data are given (appendix B). If assuming that yield is positively correlated with dry mass, the dry masses of both wheat and barley are markedly lower after conversion to organic farming. This supports the relationship since lower dry masses of Carabidae and Staphylinidae were observed after conversion, although only significantly in wheat (Fig. 3.1.B). It is doubtful if this correlation alone can explain the diminished abundance of the epigaeic beetles at organic growing. Other factors like weed hoeing may also be important (see below). The relationship, however, between crop biomass and the epigaeic beetles is supported by results of Krooss & Schaefer (1998). They found that because of high weed cover under extensive cropping of winter wheat (no fertilizer, no pesticides but mechanical weed hoeing), high species richness and high population density of Staphylinidae should be expected. However, the opposite effect was found (as in this study). Species richness was poor and fewer beetles were caught compared to other cropping systems. The lack of fertilization reduced the number of wheat plants per square-meter and the remaining stalks were much thinner. Consequently, the yield decreased to 50% compared to conventional farming (in our study the decrease was about 40%). The weed cover could not compensate for the change of microclimate because of the sparseness of the crop. Hence, accordingly to Kroos & Schaefer (1998), unfavourable microclimatic conditions may have caused low population density at extensive farming.

No significant relationships could be revealed between the density and diversity of weeds and the density of important herbivores (section 3.2.4.2). The reasons could be several. Only in wheat a higher weed density was observed after conversion (cf. chapter 2). Contrary the least effects of conversion on herbivores were found in wheat. A possible reason is, that the occurrence of weeds was too low to support measurable population changes. Even at low levels, organic barley had a ten times higher weed biomass than organic wheat (cf. chapter 2). This was reflected on the abundance of herbivores, which, for the four dominating herbivore groups dependant on weed, Auchenorrhyncha, Chrysomelidae, Curculionidae and Lepidoptera, was several times higher in organic barley that in organic wheat (Fig. 3.3). Furthermore the weed diversity generally did not increase as a result of conversion (cf. chapter 2) and it could therefore not explain the conversion effects on the arthropods. Of the more specific host plants included in the analyses the density of Brassicaceae increased significantly in both crops after conversion as did the density of ***P. aviculare and B. convolvulus*** in wheat (cf. chapter 2). However, according to the combined analyses those increases did not lead to higher densities of related insects, at least not within the time frame of this project. Even though weed density and diversity may not be complete measures of the flora, it leaves an impression that the insecticides had a larger impact than the weed flora for the conversion effects observed on the arthropods. The weed density in the present study was low even after conversion (cf. chapter 2) and a successful weed control at organic farming may explain the lack of positive relationships. However, the higher number of flowering dicotyledonous weeds at organic farming (chapter 2) apparently did affect the pollinating and nectar feeding insects right after conversion, exemplified by the positive relationship with Lepidoptera adults (Fig. 3.8). Conclusions based on this model, however, should also be treated with caution because the factor ‘density of flowering dicotyledonous weed’ only accounted for 6% of the explained variation.

It is questionable whether the catch crops affected the arthropod fauna during the sampling season. When present the catch crop mostly constituted only a fraction of the already low weed biomass (cf. chapter 2). However, naturally the growth picks up as the cereals mature. It is therefore possible that the impact of the undersown crops on the arthropods increases towards the end of the sampling season. Otherwise its significance can not be expected until after harvest.

It is possible that the ongoing weed hoeing at organic farming generally has a negative impact on ground/soil dwelling species. This may be particularly apparent for winter wheat in which no tilling operations normally are carried out in the spring at conventional growing. Reasons for the pronounced negative effect on the epigaeic beetles especially in wheat may therefore be disturbance and changed microclimate. Lorenz (1994), however, found no negative response of Araneae, Carabidae or Staphylinidae to mechanical weed control. His results, though, were obtained in sugar beets. Beets already harbour low densities of epigaeic beetles (Navntoft & Esbjerg 2002), a fact which probably makes it difficult to detect an effect. Contrary Holm ***et al***. (unpubl.) found, that it may generally be assumed that soil-tilling has a negative impact on arthropods. Furthermore, Fadl ***et al***. (1996) found that catches maid during the main emergence phase of the new generation of the carabid ***Pterostichus melanarius*** were lower in spring-cultivated fields compared to uncultivated or autumn fields. Apparently the reason was reduced larval/pupal survival because of the spring soil cultivation. Weed hoeing may also result in food depletion for the ground dwelling predators and thereby indirectly suppress the populations. Weed hoeing may e.g. reduce the density of Collembola. These soil-inhabiting arthropods are an important prey group for generalist predators (Sunderland 1975) and the hygrophilic species are generally vulnerable to desiccation (Sjursen et al. 2001), which most likely follow mechanical weed hoeing. The results in our experiment, however, may be biased by the more ‘gentle’ suction it was necessary to perform in the organic wheat, because large amounts of soil accumulated in the collecting jars as a consequence of the weed hoeing. In conventional wheat a hard shell was created on top of the soil, which made it possible to suction sample more intensively at the soil surface level. Furthermore, suction sampling often underestimate nocturnal species, which include most of the carabids found in agricultural habitats (Thiele 1977). Especially populations of larger species may be underestimated.

4 Birds (Petersen, B.S.)

4.1 Methods

4.1.1 Bird counts

Standardized bird counts were performed at intervals of about five days between 6 May and 5 August in all five study years. All species seen or heard at the study fields were recorded.

Before the counts began in early May, four subplots of 1.5 ha were demarcated within each plot (Fig. 4.1). The birds within each subplot were counted by means of a combination of point and transect counts. Firstly, a 10 minutes point count was carried out while the observer was stationary at the edge of the subplot. Then the observer spent 5 minutes walking through the subplot to the border of the next, adding to his list of records any birds within the subplot that had not been recorded from the census point. During the 15 minutes spent in each subplot, all birds seen or heard within or immediately above the subplot were recorded. Care was taken not to count an individual more than once. If a bird was recorded in more than one subplot, the observer assigned it to one, and just one of these. The chosen subplot should be the one where the bird did most of its feeding, not necessarily the one in which the nest was assumed to be located.

Fig. 4.1. Example of the delimitation of subplots within plots. Aerial photo by courtesy of Kampsax.

All counts began at 8.00 a.m. Countings were not performed during unfavourable weather conditions (notable precipitation, reduced visibility, wind speed > 9 m/s). To avoid systematic biases from changes in the birds' activity during the day, the starting subplot varied from count to count according to a rotating scheme. In 1997 and 1998, a total of 17 counts were carried out in each field, whereas in 1999, 2000, and 2001, 18 counts per field were performed.

4.1.2 Statistical analyses

Although all species were recorded, only Skylarks occurred in sufficient numbers to make a reliable statistical analysis possible. For each count, plot totals were calculated by summing up the number of larks recorded in the four subplots within each plot.

The repeated counts of a certain plot during the season were not statistically independent. One way of dealing with this is to reduce the repeated measurements to a few, preferably mutually independent, summary statistics and carry out the analyses on these (e.g. Stryhn 1996). In the present case, 1st and 2nd degree polynomials were fitted to each sequence of counts (the graphs relating plot totals to census date), using the REG procedure in SAS/STAT (SAS Institute 1990b). The mean, the slope of the 1st degree polynomial, and the curvature (quadratic term) of the 2nd degree polynomial were used as summary statistics describing the development in Skylark numbers.

The summary statistics were analysed for differences between periods (conventional/organic), crops (barley/wheat) and pesticide dosages (normal, half, quarter) using the anova model described in section 1.6. If the analyses showed that dosage effects (including interactions dosage×period, dosage×crop and dosage×crop×period) were insignificant ($p > 0.10$) it was assumed that dosage did not affect the distribution of Skylarks, neither before or after conversion. The dosage factor was then replaced by a plot factor, yielding the simpler model shown in Table 4.1 as a basis for further model reductions. A significant dosage×field interaction, indicating a dosage effect that varied between fields, was interpreted as a plot effect.

Table 4.1. Factors included in the anova of Skylark occurrence if no dosage effect was apparent. The nature of each factor (fixed/random) and the denominator (error term) used in the test of significance of each factor in a balanced design are shown. The tests of main effects period and crop assume that the crop×period interaction is zero.

Source of variation	Fixed / random	Denominator in F test (balanced design)
Period	Fixed	MS(Year(Period))
Year(Period)	Random	MS(Residual)
Crop	Fixed	MS(Residual)
Crop×Period	Fixed	MS(Residual)
Field	Random	MS(Plot(Field))
Plot(Field)	Random	MS(Residual)
Residual	Random	

For all variables tested, model assumptions were checked by plotting the residuals against the predicted values and by running the Shapiro-Wilk test for normality (SAS Institute 1990a) and Levene's test for homogeneity of variance (SAS Institute 1996). No indications of violation of model assumptions were found.

4.1.2.1 Analyses with inclusion of covariates

Possible relationships between the number of Skylarks, the amount of arthropods, and the density and diversity of weeds were tested using analysis of covariance. Two summary statistics were used as dependent variables (one at a time): the mean number of Skylarks recorded over the whole season and the mean number recorded after 1 July (***latemean***). The latter statistics was used as a measure of the larks' tendency to remain on a field throughout the summer.

As a measure of arthropod availability per m^2, the mean of the log-transformed dry biomass plot totals was used to indicate arthropod abundance in each plot and year (section 3.1). Only samples from 1 June onwards were used in order to make the data from different years comparable. In addition to the total arthropod biomass, the biomass of a subset of arthropod taxa known to be important Skylark food items was calculated.

Six different covariates were used to describe the weed flora within each plot (section 2.1.1): species richness in May and in August (arithmetic mean) and densities of dicotyledonous and monocotyledonous weeds in May and in August (mean of logarithmic densities). Total weed density was not included because it was closely correlated with the density of dicotyledons ($r > 0.99$).

As the analyses of variance of Skylark numbers did not in any case indicate an effect of dosage (section 4.2.1), the simplified model in Table 4.1 was used as a basis for the analyses of covariance. The eight covariates were included in this model, one at a time, and stepwise model reduction was carried out. The inclusion of a covariate×crop×period term in the models allowed the relationship to vary between crops and periods. To protect the experimentwise error rate with eight different covariates being tested, Bonferroni correction of the removal criterion was used ($p > 0.05/8 = 0.0063$).

Data for crop and weed biomasses were only available from 2000 and 2001. Thus, analyses of possible relationships between vegetation biomass and Skylark densities had to be limited to these years, i.e. to the period of organic farming. Biomass was measured in early July for the cereal crop, undersown grasses (if any), undersown clover (if any), dicotyledonous weeds and monocotyledonous weeds (section 2.1.2). Except for the cereal crop, all biomass calculations were based on log-transformed data.

A very simple model with crop, year and crop×year (i.e. without a field factor) had to be used as a basis for the analyses because the effects of crop and field were confounded (section 1.6). In the first step, only cereal biomass was added to the basic model as a covariate. For both Skylark variables this clearly improved the model (in terms of a reduction of the model p value) so cereal biomass was retained. Next, seven additional covariates were added, one at a time, to this model: the four vegetation biomass variables mentioned above, a summary variable describing total biomass of weeds and catch crops, and the two arthropod biomass variables. In all cases, a covariate×crop interaction term allowed the relationship to vary between crops. Stepwise model reduction was carried out with Bonferroni correction of the removal criterion ($p > 0.05/7 = 0.0071$).

4.2 Results

4.2.1 Analysis of Skylark numbers

Pesticide dosage did not significantly affect the distribution of Skylarks. The factor dosage (including the interactions dosage×period, dosage×crop and dosage×crop×period) was eliminated at $p > 0.10$ in all analyses. Even when data from the conventional period were tested separately, significant dosage effects were not found. The basic model was therefore reduced to the model in Table 4.1. The results of the analysis of variance of each of the three summary statistics describing Skylark occurrence are summarized in Table 4.2.

Table 4.2. Summary of the anovas of the occurrence of Skylarks on the study fields before and after conversion to organic farming. P values of significant factors are shown. A "ns" indicates that the factor was included in the reduced model but was not itself significant. For each of the three summary statistics tested, the percentage of variation explained by the reduced model is given in brackets.

	Mean (62%)	**Slope** (75%)	**Curvature** (38%)
Period	< 0.0001	ns	
Year(Period)		0.0019	
Crop	0.0066	ns	0.0003
Crop×Period		0.0028	
Field			
Plot(Field)			

The ***mean*** number of Skylarks recorded in the fields differed significantly between the conventional and the organic period. Numbers increased from 8.6 per 6 ha before conversion to 13.3 per 6 ha after conversion. Mean numbers also differed between crops, with 11.6 per 6 ha in barley and 9.3 per 6 ha in wheat. The effects of period and crop on mean numbers were additive as evidenced by the lack of a significant crop×period interaction. A partitioning of the sums of squares showed that 50% of the total variation in mean numbers was explained by differences between periods while 12% was explained by crop differences.

Phenology (slope and curvature) also differed between periods and crops (Fig. 4.2). After conversion, Skylark numbers peaked later in the season than before conversion. A major part of the variation in ***slope*** (39%) was explained by differences between periods, but the difference was not significant, due to large variation between years (explaining 23% of the total variation). Also the crop×period interaction was significant and explained 12% of the total variation in slope. The difference between periods was significant in barley ($p < 0.0001$, negative slope before conversion, positive slope after) but not in wheat. The ***curvature*** (quadratic term) was only significantly affected by crop which explained 38% of the total variation. There was a strongly negative curvature in barley whereas the curvature in wheat was not significantly different from zero.

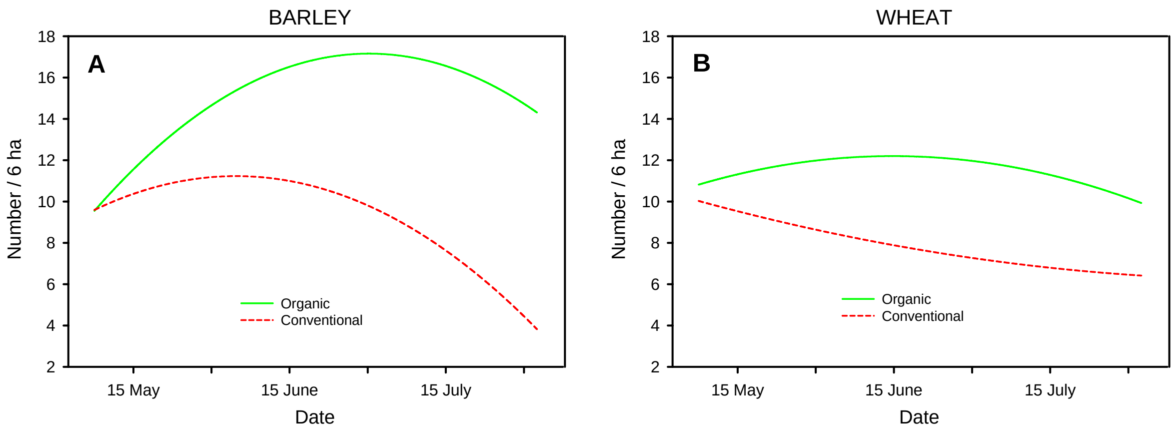

Fig. 4.2. Models of the development in Skylark numbers on the study fields from early May to early August in relation to crop and period (before/after conversion). A: Spring barley. B: Winter wheat.

There were no significant differences in mean, slope or curvature between the three study fields, nor were there any differences between the plots within each field.

4.2.2 Skylark numbers in relation to vegetation and arthropod abundance

Analyses of covariance of Skylark numbers 1997-2001 in relation to arthropod biomass and to density and diversity of weeds did not reveal any significant relationships. The analyses of Skylark occurrence 2000-2001 showed a significant, negative relationship between cereal biomass and Skylark densities for both ***mean*** and ***latemean*** (Table 4.3). No other covariates reached the Bonferroni-adjusted level of significance when included in the models.

Table 4.3. Summary of the analyses of covariance of Skylark occurrence 2000-2001 in relation to vegetation biomass. For each of the two dependent variables (*mean* and *latemean*), the percentage of variation explained by the reduced model is given in brackets. P values of significant factors are shown.

Factor	Class / continuous	Mean (90%)	Latemean (74%)
Crop	Class variable	0.017	
Year	Class variable		
Crop×Year	Class variable		
Cereal	Covariate	< 0.0001	0.0003
Cereal×Crop	Covariate		

Considering only counts performed after 1 July, 74% of the variation in Skylark densities between plots could be explained by differences in cereal crop biomass (as calculated from a partitioning of the sums of squares). No other factors had significant effects. Thus, the relationship between crop biomass and Skylark densities was the same for wheat and barley. When counts from the whole season (starting 6 May) were included in the analyses, the relationship was crop-dependent (Fig. 4.3). However, cereal biomass still explained 73% of the variation in mean Skylark densities with only 13% being accounted for by other crop differences. Variation in biomass of catch crops, weeds and arthropods did not affect Skylark densities significantly.

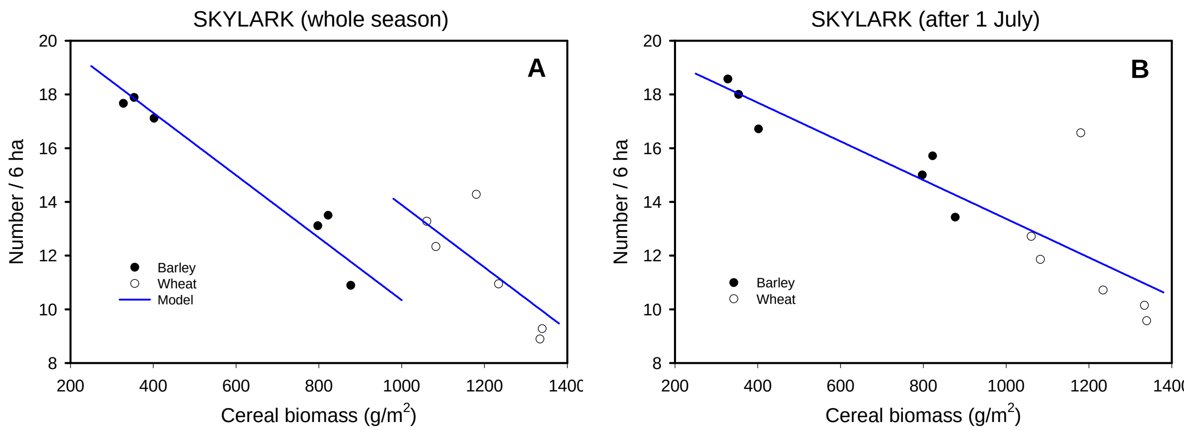

Fig. 4.3. Skylark densitites in relation to cereal crop biomass for all counts (A) and late counts only (B). Data from the period of organic farming (2000-2001). Lines indicate densities predicted by the analysis-of-covariance model.

Before the inclusion of covariates and the subsequent model reduction, highly significant crop and crop×year terms were present in the models for both dependent variables, explaining between 31% and 54% of the total variation. However, the effect of the crop factor was greatly reduced and the effect of the interaction term almost completely disappeared when cereal biomass was added as a covariate. This indicates that variation in crop biomass explains a large part of the difference in Skylark densities between wheat and barley and most of the variation between years within each crop. Variation between plots within each field could not be included in the model, but Fig. 4.3 suggests that even some of this variation may be due to differences in crop biomass.

4.3 Discussion

Following the conversion to organic farming, the number of Skylarks increased significantly in both crops. Averaged over the season Skylark densities were 55% higher after conversion than before, but the exact magnitude of the breeding population increase is unknown. The increase was apparent already in the first year after conversion and must have been caused by local factors, because the Danish breeding population of Skylarks declined by 15% from 1999 to 2001, according to data from the Danish Bird Census Group (E.M. Jacobsen pers. comm.).

Comparative studies in organic and conventional farmland have generally revealed significantly higher bird population densities on organic farms. Braae ***et al.*** (1988) found that Skylark territory densities in Danish agricultural areas were between 1.5 and 3 times higher on organic farms than on conventional farms. In British studies (Evans ***et al.*** 1995, Wilson ***et al.*** 1997), 2 to 3 times higher Skylark territory densities were found in organic cereal fields than in conventional ones. All these studies were carried out in areas that had been organically farmed for several years. The present study is the first to show that sizable differences exist already in the first year after conversion.

Fig. 4.2 indicates that the number of birds occurring in the study fields in early May was the same before and after conversion. Thereafter numbers in barley rose more quickly and stayed high for a longer period after conversion than before. In organic wheat, numbers increased until mid-June whereas there was a steady decline in numbers throughout the season in conventional wheat. In line with this, Odderskær ***et al.*** (1997a) found that Skylarks continued breeding for a longer period in unsprayed fields and that the late breeding attempts here were more successful than in sprayed fields. They suggested that the lower food abundance in sprayed fields led to a poorer body condition of the females, enabling them to carry out fewer successful breeding attempts. Evans ***et al.*** (1995) also found fewer Skylark nest failures and higher chick growth rates on their organic farm and ascribed this to a higher availability of food items.

In the present study, the biomass of arthropods suitable as Skylark prey increased significantly after conversion in barley, but not in wheat (chapter 3). The later and higher peak in Skylark densities in organic barley fields nicely reflected a similar difference in Skylark prey biomasses (compare Figs. 3.2 A and 4.2 A). However, as such a relationship was not present in wheat, the analyses of covariance did not show any significant correlations between densities of Skylarks and their arthropod food. Other attempts to relate Skylark population parameters to arthropod densities have also been unsuccessful. Benton ***et al.*** (2002) found that Skylark population densities in Scotland were high in years where arthropod numbers (measured by tower-mounted suction traps) were low. Odderskær ***et al.*** (1997a) were also unable to relate Skylark nestling survival to food abundance (measured by D-vac sampling) in their regression analyses.

By contrast, the analyses of covariance revealed a very strong, negative relationship between Skylark densities and cereal crop biomass in both spring barley and winter wheat. When only late-season counts were considered, this relationship alone explained 74% of the total variation in Skylark density between crops, years and plots. Apparently, no previous investigation has related Skylark densities to crop biomass. In many studies, however, Skylark distribution and densities have been analysed in relation to crop height and/or coverage (e.g. Schläpfer 1988, Jenny 1990c, Wilson ***et al.*** 1997, Chamberlain ***et al.*** 1999, Toepfer & Stubbe 2001). From these studies it may be concluded that a crop height of 15-40 cm and a ground coverage of 35-50% are optimal. Toepfer & Stubbe (2001) noticed that the negative effect of a dense vegetation was sometimes compensated by a low vegetation height (and vice versa) and stressed the necessity of considering the two measures together. Crop biomass combines these two parameters into a single measure and thus meets this request.

In a British study, crop height alone explained 67% of the variation in Skylark territory densities (Donald & Vickery 2000). Noticing that data from spring- and autumn-sown cereals fell along the same regression line, Donald & Vickery suggested that the observed differences in Skylark density could be explained entirely in terms of differences in crop height. Using the same argumentation, it may be concluded that differences in crop biomass were the main factor responsible for the differences in Skylark population densities observed in the present study. The underlying mechanism is probably that Skylark locomotion and foraging are severely impeded in a tall and dense crop (Jenny 1990a).

Unfortunately, data on crop biomass were not available from the conventional period in this study. Therefore, it could not be directly tested to what extent the higher Skylark densities after conversion might be explained by differences in crop biomass. Using data from several Danish farms, Hald (1999) found mean crop biomasses of 1368 and 1024 g/m^2 in conventional and organic cereal fields, respectively; a 25% decrease. This translates to an increase of 2.5 Skylarks per 6 ha in July if Hald's values are entered into the analysis-of-covariance model in the present study, corresponding to 53% of the actual difference found. It is not known whether the crop biomasses given by Hald are representative for the situation at Oremandsgård. Average yields in barley and wheat declined by 42-43% after conversion (appendix B), suggesting (but nothing more!) that the decline in crop biomass was at least as great as indicated by Hald's average values.

Although more than half of the increase in Skylark densities may thus be explained by changes in crop structure (less dense crops after conversion), other factors probably also play a role. A greater abundance, diversity and predictability of the birds' arthropod food resource in organic fields than in conventional fields (Hald & Reddersen 1990, Moreby ***et al.*** 1994) has traditionally been suggested as a major cause of the differences in bird population densities and breeding success between the two farming systems (e.g. Petersen 1994). In the present study, such a difference in the occurrence of Skylark prey items was found in barley only (cf. chapter 3) and therefore cannot be used as a general explanation of the increase in Skylark density after conversion.

Food abundance and food availability are different things, and obviously it is the latter which is important. Providing empirical evidence of this, Odderskær ***et al.*** (1997b) found that Skylarks preferred tramlines and unsown patches to the interior of the fields, even if the latter held significantly higher densities of food items. This emphasizes the importance of the crop structure for the distribution of Skylarks (cf. Jenny 1990a,c). However, even after controlling for the effects of crop structure (by including crop biomass as a covariate in the analyses), no correlation between Skylark densities and arthropod biomass was found in the present study.

Food quality vs. food abundance is another issue. Because birds usually are incapable of digesting chitin (Bell 1990), insects with a high chitin content (e.g. carabid beetles) have a lower energy content than indicated by their dry mass. Such insects are frequently encountered in Skylark faeces (Elmegaard ***et al.*** 1994, Odderskær ***et al.*** 1997a, chapter 5 this study) and were therefore included in the group of "important Skylark food items". The generally hard-bodied Carabidae and Staphylinidae made up a much larger share of the estimated biomass of Skylark food items in the study fields before conversion than after conversion (68-70% vs. 20-33%). Therefore, the arthropod biomass values used in the analyses probably did not reflect the true energetic value of the arthropod fauna inside each plot. If this is correct, and the birds try to maximize their energy intake, it is not surprising that the attempts to model Skylark densities as a function of arthropod abundance failed. However, other reasons for this could be that the temporal scale (data averaged over 1-3 months) was not appropriate, or that food was not a limiting factor. A reduction in food abundance may only impact the population of Skylarks significantly under certain weather conditions (C.J. Topping pers. comm.).

5 Food choice of Skylarks

(Petersen, B.S. & Navntoft, S.)

Skylark food choice was studied during the period of organic farming only (2000 and 2001). Parallel with the bird observations, Skylark faeces were collected from the study fields. The faeces were analysed for arthropod fragments in the laboratory, and the Skylarks' choice of food items was compared with the available food resource as determined from the suction samples.

5.1 Methods

5.1.1 Collection of faeces

On each observation day, 18 faecal pellets (6 per plot) were collected in each study field after the finishing of the bird counts (cf. section 4.1.1). Skylarks were the only small passerines occurring in any numbers in the study fields, making confusion with faeces of other species unlikely. Furthermore, Skylark faeces (Fig. 5.1) are quite distinct from faeces of most other species, chiefly due to their cylindrical (not twisted) shape (N. Elmegaard pers. comm.). A faecal pellet was not collected if there was any doubt about its origin.

Fig. 5.1. Faecal pellet of Skylark (photo: N. Elmegaard).

Faeces were sampled while the observer was walking up and down the tramlines. No special selection of pellets was made, except that the consistency of the pellet should allow it being collected as a whole. In order to reduce the probability of sampling more than one faecal pellet from each individual Skylark per day, observers were requested to walk at least 50 m onwards before the next faecal pellet was collected. With these restrictions, the first six pellets found in each plot were sampled; this could in most cases be accomplished within 30 minutes.

The faecal pellets were put into glass tubes and cooled down in an insulated bag as soon as possible after collection. After returning to the laboratory the pellets were stored at -18˚C until further analysis. A total of 1296 faecal pellets were collected and stored.

5.1.2 Analysis of faeces

Two pellets from each glass tube were chosen for analysis. In the laboratory the pellets were treated according to a method by Elmegaard ***et al.*** (1999). The material was positioned in a 20% sodium hydroxide solution about 20 minutes thereby removing uric acid and other fragments, which could otherwise hamper a careful identification of the arthropod parts. Thereafter the samples were rinsed in demineralised water using a filter paper to collect the residues. The arthropod parts were identified in a binocular microscope (8 - 100 × magnification). Scanning electron microscope (S.E.M.) photographs of some fragments and of reference arthropods as well as photographs by Moreby (1988) supported the identification process. The residues were identified at least to order, but mostly to more specific taxa. The identified fragments of specific taxa was quantified as one individual, unless there were clear signs of higher numbers (no. of legs, heads etc.). A total of 432 faecal pellets of Skylarks were analysed.

The method used did not allow a determination of the plant contents of the pellets. Determination of plant contents would have required another processing of another set of faecal pellets which was not possible.

5.1.3 Data analysis

The aim of the analyses was to describe the composition of the faecal samples, to test for differences in composition between faecal samples and suction samples, and to test whether food choice and preferences varied with crop, year and time of the season.

The number of arthropod individuals found in faecal samples and suction samples, respectively, was summed for 29 taxonomic groups (Table 5.1). Based on these absolute frequencies the following statistical analyses were performed:

- A general comparison of the composition of the total faecal sample and the total suction sample.
- A comparison of the composition of the faecal samples from wheat and barley, including comparisons of faecal samples and suction samples from each crop.
- A comparison of the composition of the faecal samples from 2000 and 2001, including comparisons of faecal samples and suction samples from each year.
- A comparison of the composition of faecal samples from three separate time periods (roughly equivalent to May, June and July), including comparisons of faecal samples and suction samples from each period.

Comparison of compositions was performed using a G-test of independence (e.g. Sokal & Rohlf 1981). If the initial G-test showed a significant difference

($p < 0.05$), a Fisher exact test was carried out for each of the ***n*** arthropod groups to determine which proportions differed significantly between the samples. Because ***n*** tests were performed simultaneously, Bonferroni correction of the significance level was used ($\alpha = 0.05/n$). Several authors have used a similar test procedure to analyse data on animal resource use (e.g. Neu ***et al.*** 1974, Marcum & Loftsgaarden 1980, Haney & Solow 1992).

In order to describe the Skylarks' food choice, "preference", "avoidance/low use" and "proportional use" of an arthropod group were defined as follows.

Preference: frequencies in faecal sample and suction sample differed significantly and proportion of faecal sample was at least 50% higher than proportion of suction sample.

Avoidance/low use: frequencies in faecal sample and suction sample differed significantly and proportion of faecal sample was at least 50% lower than proportion of suction sample.

Proportional use: all other cases except where data were regarded too few. The latter was the case if (1) expected frequency was less than one, (2) Fisher test was non-significant (suggesting proportional use) but expected frequency was less than five, or (3) Fisher test was non-significant but frequency in faecal sample was zero.

Because the proportions sum to one, "preference" and "avoidance/low use" are used in a relative sense; preference of one food source invariable leads to avoidance/low use of another. Similarly, if an arthropod group occurs in the suction samples but is not truly available to foraging Skylarks, other groups will appear as “preferred”. Several other sources of bias exist and are discussed in section 5.3.1.

For the presentation of the results, and for the evaluation of the relative importance of the different arthropod groups as food for Skylarks, the number of individuals was converted to dry mass. The conversion was based on estimated arthropod length as described in section 3.1.2.1. Many arthropod fragments, however, could not be identified to the same detailed taxonomic levels as used for suction samples. The length estimates of arthropods collected by suction could therefore not directly be used for some higher taxonomic levels identified in the pellets, e.g Curculionidae. For these more heterogeneous groups, weighted mean lengths based on the frequency of occurrence of specific families, genera or species in the suction samples were used instead.

5.2 Results

In Table 5.1 the total numbers of the major arthropod groups identified both in Skylark faeces and in suction samples are listed. Besides the groups included in the table, a few Formicidae, Opiliones, Scarabaeidae and Silphidae were found in faeces and suction samples. Also a few Aphididae and Collembola were identified in the faecal samples whereas these groups were not counted in the suction samples (section 3.1.1).

Table 5.1. Summary of the arthropods identified in the Skylark pellets, and the corresponding catches in the field. The sampling seasons were divided into three periods, roughly corresponding to the months of May, June and July. Taxa selected as important Skylark prey are marked with an asterisk (*). Abbreviations: Img. = imagines. Juv. = juveniles.

Arthropod class/order	Arthropod group	Total no. in Skylark pellets				Total no. in suction samples			
		May	June	July	Total	May	June	July	Total
Arachnida	Araneae*	45	111	135	291	273	2936	4103	7312
Chilopoda		0	0	0	0	9	194	130	333
Diplopoda		0	0	0	0	36	127	30	193
Hemiptera	Auchenorrhyncha*	47	41	13	101	1148	626	1637	3411
	Heteroptera	1	1	1	3	9	113	621	743
Lepidoptera	Img.	3	4	1	8	11	81	247	339
	Juv.*	4	9	34	47	47	284	205	536
Diptera	Tipulidae img.	0	0	1	1	4	316	9	329
	Syrphidae img.	0	1	3	4	3	14	123	140
	Syrphidae juv.*	1	13	180	194	5	377	1743	2125
	Other Diptera	5	5	14	24	551	4845	6698	12094
Neuroptera	Chrysopidae img.	0	0	0	0	23	34	87	144
	Chrysopidae juv.*	0	16	57	73	7	297	391	695
Coleoptera	Carabidae img.*	93	163	72	328	148	1174	1994	3316
	Carabidae juv.*	0	25	17	42	32	51	101	184
	Staphylinidae img.*	119	134	66	319	705	2837	2844	6386
	Staphylinidae juv.*	6	6	10	22	61	345	137	543
	Elateridae	0	1	0	1	1	24	41	66
	Lathridiidae img.	0	0	0	0	67	70	184	321
	Cantharidae	0	0	0	0	36	768	99	903
	Nitidulidae img.*	14	11	2	27	74	193	223	490
	Cryptophagidae img.*	26	25	3	54	560	472	825	1857
	Coccinellidae img.	0	0	0	0	24	71	186	281
	Coccinellidae juv.	0	0	0	0	19	409	635	1063
	Chrysomelidae img.*	151	82	56	289	216	125	677	1018
	Chrysomelidae juv.	2	3	5	10	36	681	65	782
	Curculionidae img.*	67	54	71	192	476	326	229	1031
Hymenoptera	Symphyta juv.*	1	22	5	28	116	380	33	529
	Parasitica	3	14	38	55	620	5806	10069	16495

The composition of the total faecal sample was significantly different from the composition of the total suction sample ($p < 0.0001$). For each of the most important arthropod groups, Fig. 5.2 visualizes its proportional share of the total number of arthropods in faecal samples and suction samples, respectively. Fig. 5.3 shows the same, but measured as proportion of dry mass. The figures thus indicate which groups generally constitute the most important Skylark prey and also suggest which groups tend to be preferred or avoided by the Skylarks. However, no conclusions should be drawn from the figures without taking the different sources of sampling bias (section 5.3.1) into account. Similar reservations apply to Table 5.2, which classifies the value of the different arthropod groups as Skylark food according to the criteria listed in section 5.1.3.

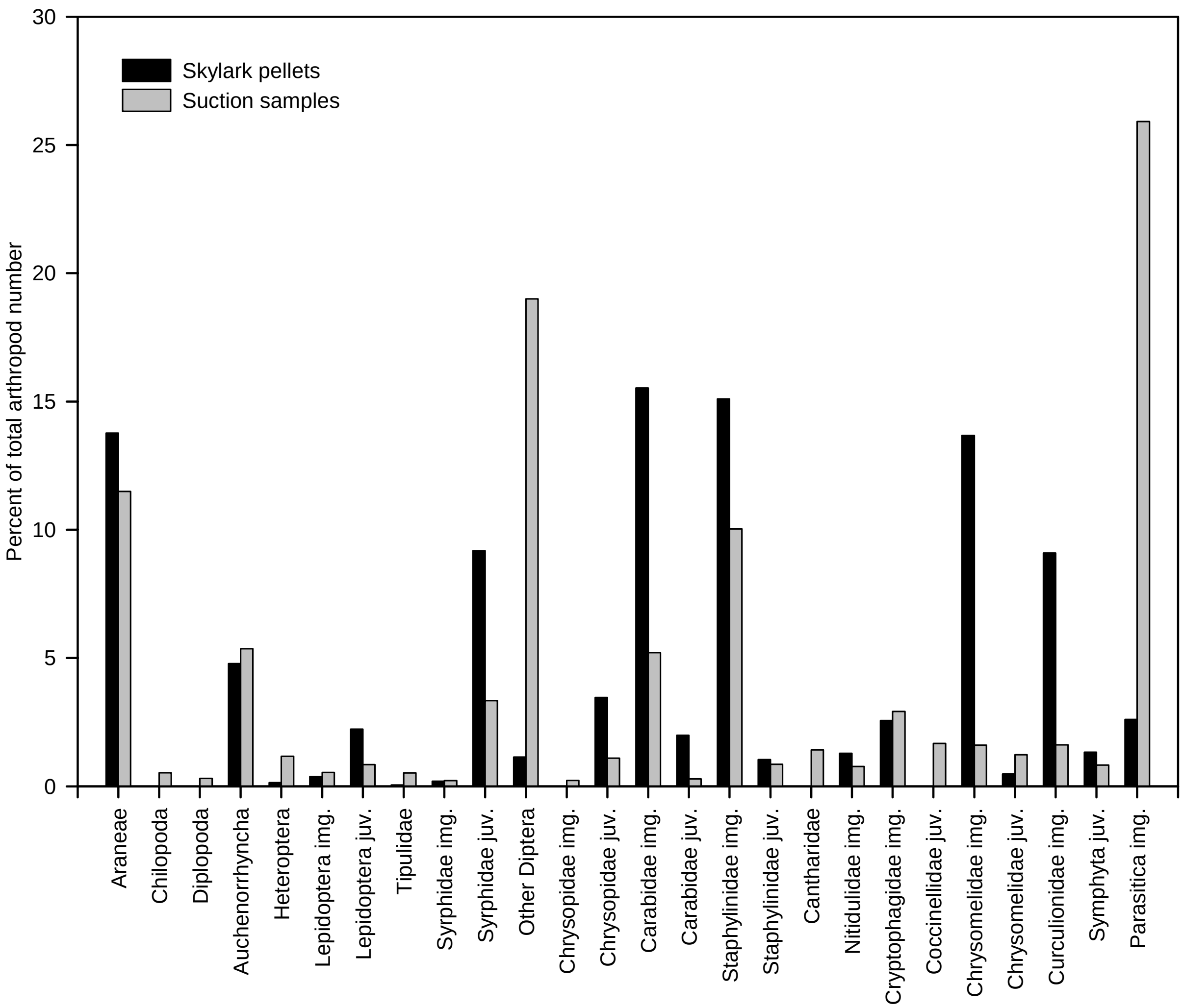

Fig. 5.2. Proportions, **by number**, of selected arthropod groups in faecal pellets and suction samples.

The composition of faecal samples from wheat and barley (Fig. 5.4) differed significantly ($p < 0.0001$). When tested separately, only the relative frequencies of Chrysomelidae imagines and Cryptophagidae differed significantly between crops. Both groups were more frequent in faecal pellets from barley fields than in pellets from wheat fields and were also found more frequently in suction samples from barley.

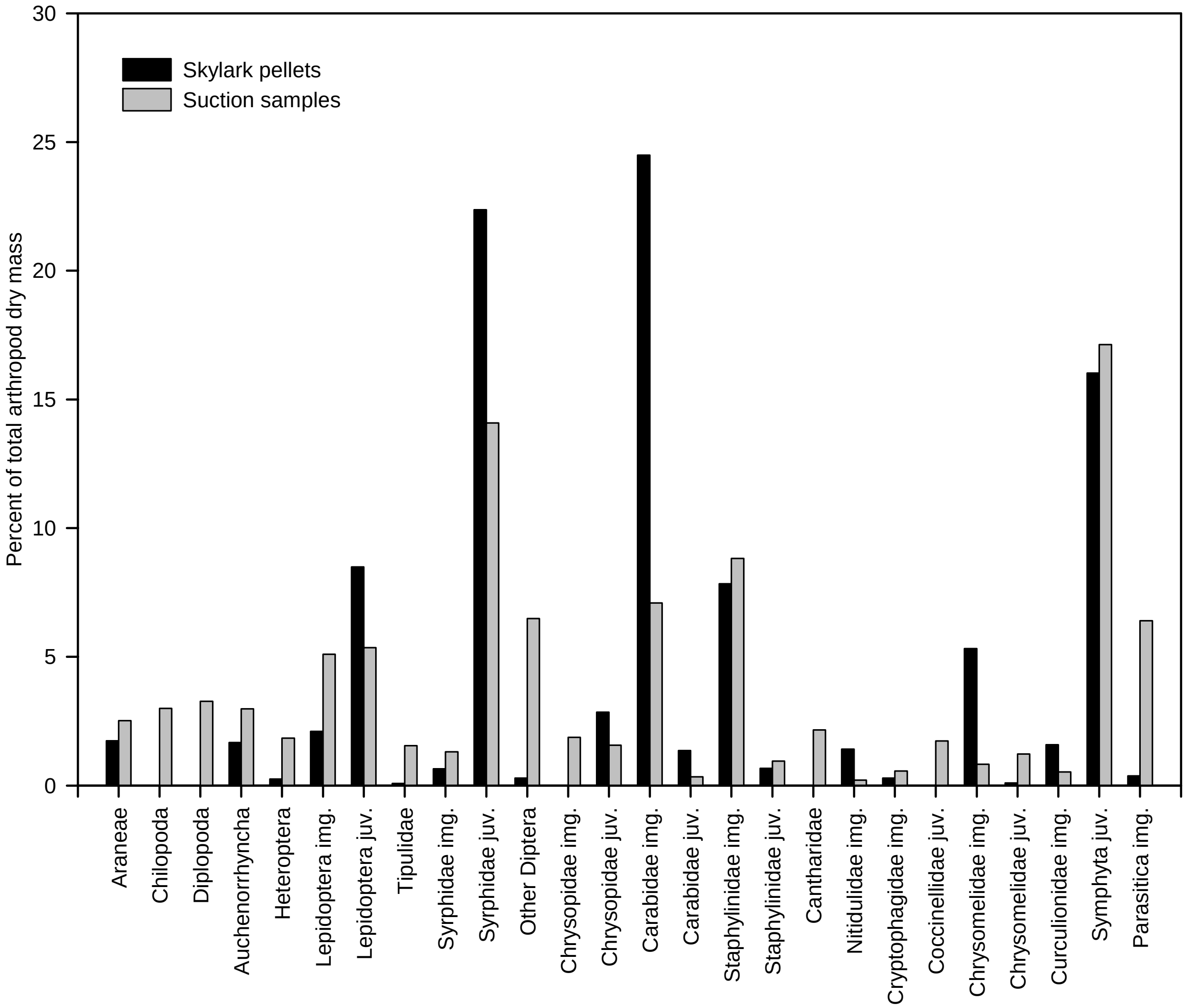

Fig. 5.3. Proportions of estimated **dry mass** made up by selected arthropod groups in faecal pellets and suction samples.

Table 5.2. Classification of 29 arthropod groups as Skylark food based on a comparison of the occurrence of each group in Skylark faeces and field suction samples. The classification criteria are explained in section 5.1.3.

Preferred	Proportional use	Avoided/low use	Too few data
Lepidoptera juv.	Araneae	Chilopoda	Diplopoda
Syrphidae juv.	Auchenorrhyncha	Heteroptera	Syrphidae img.
Chrysopidae juv.	Lepidoptera img.	Tipulidae img.	Chrysopidae img.
Carabidae img.	Staphylinidae juv.	Other Diptera	Elateridae
Carabidae juv.	Nitidulidae img.	Lathridiidae img.	
Staphylinidae img.	Cryptophagidae img.	Cantharidae	
Chrysomelidae img.	Symphyta juv.	Coccinellidae img.	
Curculionidae img.		Coccinellidae juv.	
		Chrysomelidae juv.	
		Parasitica	

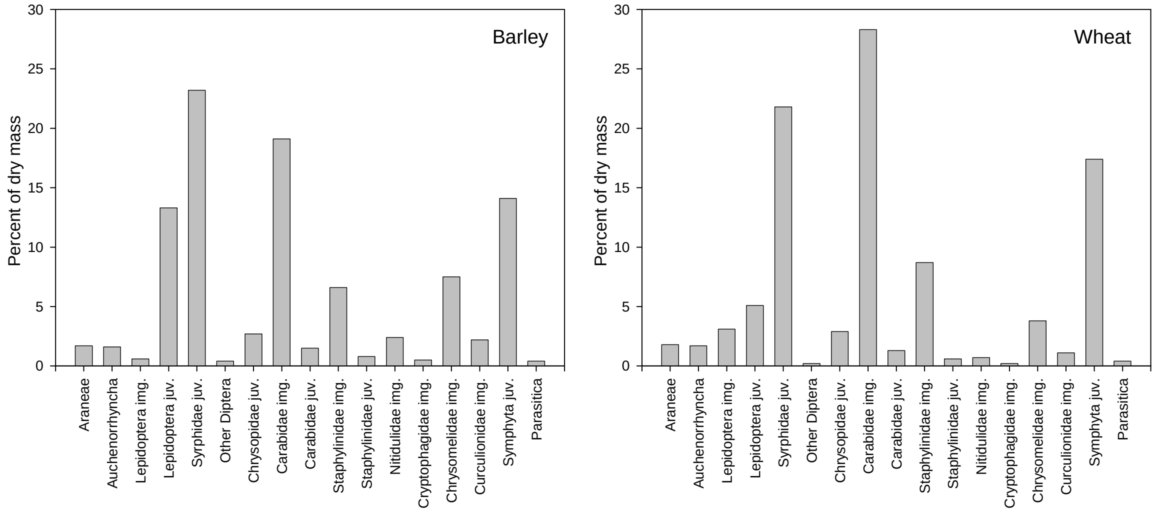

Fig. 5.4. Proportions of estimated dry mass of Skylark prey made up by selected arthropod groups in faecal samples from barley and wheat.

The composition of the faecal samples also differed significantly between years ($p < 0.0001$). The relative frequencies of Auchenorrhyncha, Cryptophagidae and Nitidulidae were significantly higher in 2000 than in 2001 while the opposite was true for juvenile Syrphidae (Fig. 5.5). These differences mirrored similar differences in the composition of the suction samples.

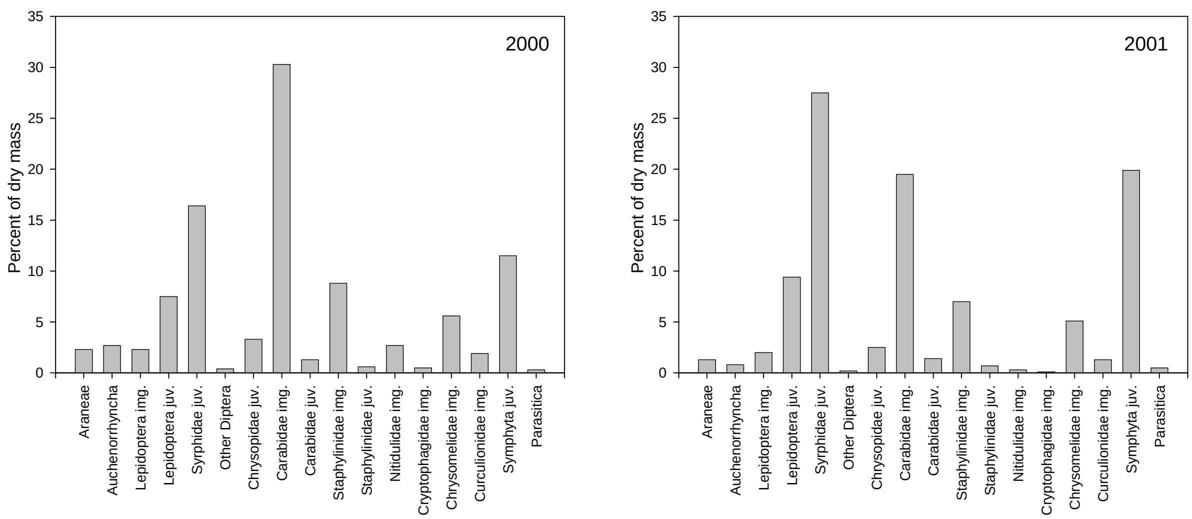

Fig. 5.5. Proportions of estimated dry mass of Skylark prey made up by selected arthropod groups in faecal samples from 2000 and 2001.

There were also significant changes in the composition of the faecal samples during the season ($p < 0.0001$). When tested separately, 13 groups showed significant, seasonal changes in relative frequency (Fig. 5.6). In some groups these changes in proportion of diet reflected similar changes in their occurrence in the fields (Fig. 5.7), but in most groups the data suggested a shift in the Skylarks' dietary preferences during the season.

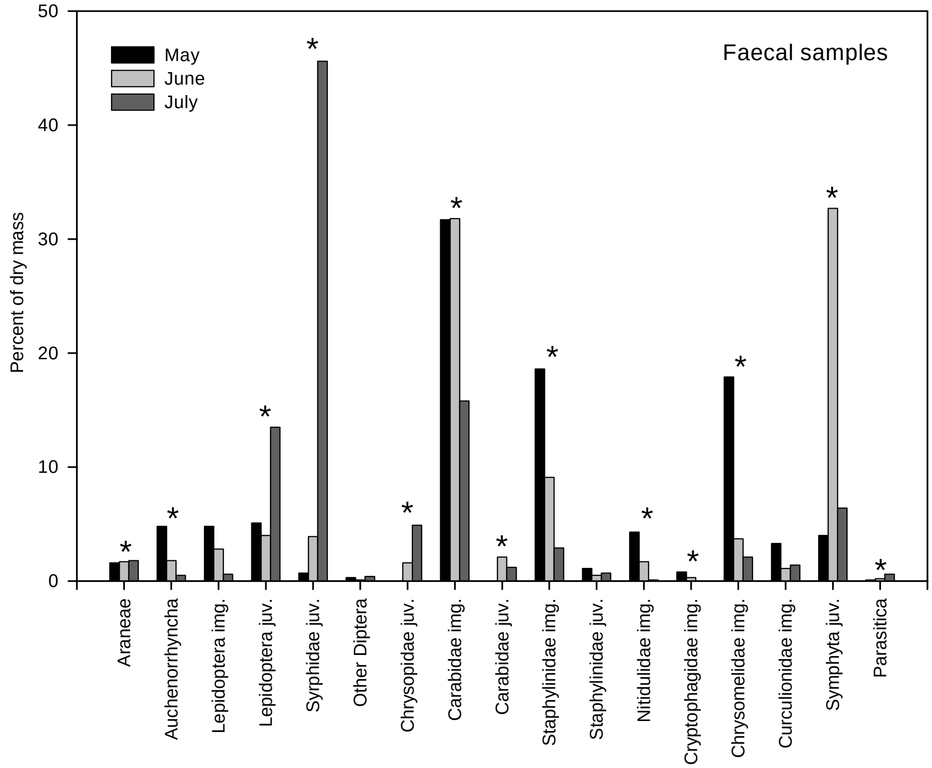

Fig. 5.6. Proportion of estimated dry mass made up by selected arthropod groups in Skylark faecal samples from May, June and July. Groups with significant seasonal changes in relative frequency are marked with an asterisk (*).

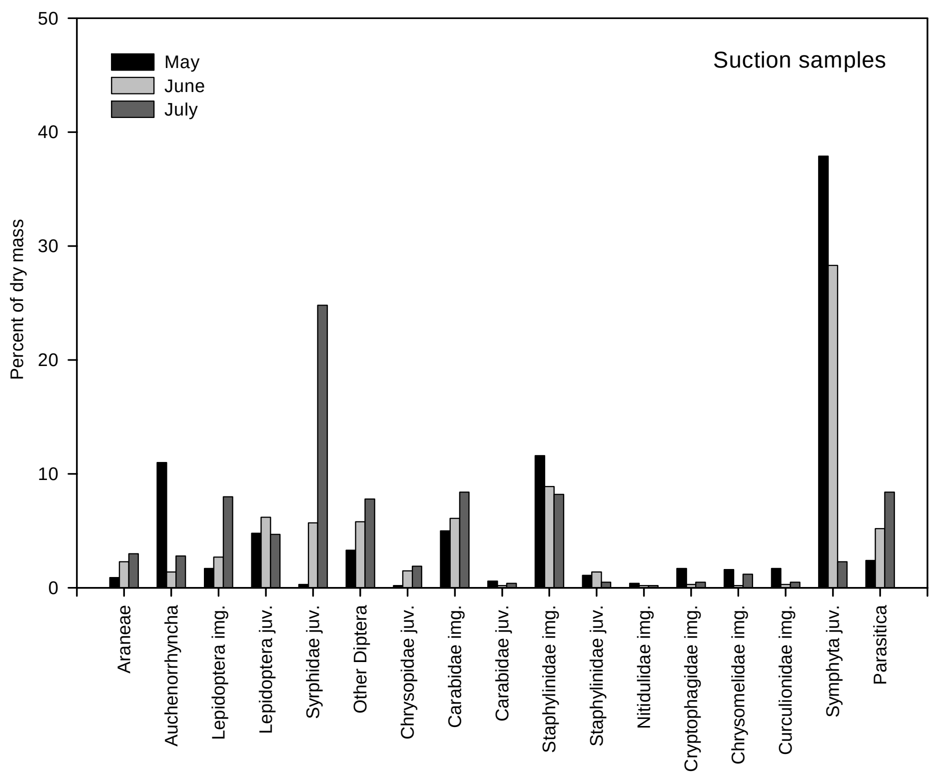

Fig. 5.7. Proportion of estimated dry mass made up by selected arthropod groups in field suction samples from May, June and July.

5.3 Discussion

5.3.1 Sources of bias

The strength of this experiment is that the measuring of abundance of different food taxa and the diet composition studies based on bird faeces were carried out at the same time and within the same fields. Without a measure of food abundance, it is impossible to know whether the diet composition revealed by the faecal samples simply mirrors the relative availability of different food taxa or whether birds actively select or avoid different potential food items. However, different methods of sampling of prey and diet data create several biases in the measurement of overall diet composition and evaluation of food preferences (Wilson ***et al***. 1999).

Faecal analysis tends to underestimate the presence of soft-bodied invertebrates (Eybert & Constant 1992). Moreby (1988) found that Collembola, Diptera, very small Coleoptera, nymphal-stage Hemiptera and small Hymenoptera may be underestimated. Moreover, remains from some taxa pose identification problems, with the consequence that the level of detail available differs greatly across data. This should be seen in combination with the fact that little information is available on identification of arthropod larvae at detailed taxonomic levels (Wilson ***et al***. 1999). Therefore identification of arthropod fragments in this study was limited to distinguishable major groups.

Suction sampling introduces a bias towards smaller species in the abundance measurements. Efficiency has been found to vary with species within size groups and in relation to vertical stratification and daily activity. Vegetation density and humidity also influences sampling efficiency (Sunderland ***et al***. 1995). Among the arthropod groups included in this study especially larger Carabidae adults inevitably are underestimated in suction samples relative to their abundance in the field. This is due to their concealed location on and within the ground and their predominantly nocturnal activity. Juvenile Carabidae and Staphylinidae are underestimated too, because of their ground dwelling activity. Also Lepidoptera and Symphyta are difficult to sample efficiently by suction. For adults densities are probably underestimated due to their ability to escape during sampling, a general problem with flying stages. The larvae are able to cling to the plants and this ability increases with size, probably causing underestimation of the number of large larvae. This problem may also occur for other larvae and pupae with a clinging ability, e.g. Chrysomelidae larvae. Furthermore, in late season when the crop is high, a number of insects found in the crop canopy are sampled although they are not available to the Skylarks, which exclusively forage on the ground. An accurate description of food density is difficult to make and precise estimates of food availability are hardly obtainable (Elmegaard ***et al.*** 1999).

The most pronounced bias in a preference study may occur when a certain arthropod group is overestimated by faecal analyses and underestimated by suction sampling or vice versa. This may be the case especially for Carabidae, of which fragments are easily identified in faecal pellets but densities are underestimated by suction sampling in the field, resulting in a considerable overrating of the degree of preference. Seasonal changes of bias may occur, especially in some juvenile groups. In May, the larvae are small and easy to sample but difficult to identify in the faeces. Later in the season, the large larvae are more easily identified in faeces while suction sampling is hampered by their ability to stick to the plants. As a result, the degree of preference may be underrated in early season but overrated in late season.

Another kind of bias is created when the number of individuals is converted to dry mass based on length estimates. Naturally, the method overestimates dry masses of long and slender specimens, e.g. Symphyta larvae, compared to short and broad specimens, e.g. Chrysomelidae adults. Furthermore, some estimates of mean length are questionable because they are based on suction samples, a method which tends to favor sampling of small individuals. For instance the length estimate of the subgroup "Other Carabidae", of which individuals were only identified to family level in the faecal pellets, was probably to low. Another problem occurred because of seasonal changes. For practical reasons it was decided to use only one length estimate of juvenile stages, despite the size development during their life cycle (e.g. Symphyta larvae grow from a few mm to 4 cm). This decision caused dry masses of juveniles early in the season to be overestimated while dry masses of juveniles later in the season were underestimated.

All statistical tests, and thus the determination of "preferred" and "avoided/low use" groups, were based on the raw data, i.e. on the number of individuals. The conversion to dry mass and the associated biases caused some displacement of preference/avoidance patterns, as can be seen from a comparison of Figs. 5.2 and 5.3. For instance, the proportion of Staphylinidae individuals was higher in the Skylark pellets than in the suction samples, whereas the opposite was true when estimated dry masses were considered.

In Table 5.3 the combined effect of the different sources of bias mentioned above is assessed for each of the taxonomic groups included in the study.

5.3.2 Skylark food preferences

Judged from the faecal samples, and averaged over the whole sampling period, adult Carabidae together with juvenile Syrphidae and Symphyta made up more than 60 percent of the dry mass of the animal part of the Skylark diet in the study fields. Also juvenile Lepidoptera and adult Staphylinidae and Chrysomelidae constituted more than five percent of the dry mass. Araneae and adult Curculionidae were eaten in large numbers too, but due to their generally small body size both groups made up less than two percent of the total dry mass. The vegetable part of the diet was not measured in the present study but may constitute more than 50 percent of the total dry mass (Cramp 1988, Christensen ***et al.*** 1996).

Adult Carabidae, Staphylinidae, Chrysomelidae and Curculionidae beetles were all found in Skylark faeces in higher numbers than predicted by their frequency in the suction samples, indicating that they were preferred by the Skylarks. For the large, ground-dwelling beetles, however, the degree of preference may well be overestimated (cf. section 5.3.1). Juvenile Syrphidae, Lepidoptera and Chrysopidae were preferred whereas Symphyta larvae were utilized in accordance with their frequency of occurrence. Other taxa occurring in approximately equal proportions in faecal samples and suction samples were Araneae, Auchenorrhyncha and adult Lepidoptera, but these groups constituted only a few percent of the total dry mass.

Table 5.3. Summary of the assumed bias of the assessment of the Skylarks' degree of preference for each arthropod group. Abbreviations: Img. = imagines. Juv. = juveniles.

Arthropod class/order	Arthropod group	Preference bias		
		Over-estimation	Neutral	Under-estimation
Arachnida	Araneae			√
Chilopoda			√	
Diplopoda			√	
Hemiptera	Auchenorrhyncha		√	
	Heteroptera		√	
Lepidoptera	Img.		√	
	Juv.		√	
Diptera	Tipulidae img.			√
	Syrphidae img.		√	
	Syrphidae juv.		√	
	Other Diptera			√
Neuroptera	Chrysopidae img.		√	
	Chrysopidae juv.		√	
Coleoptera	Carabidae img.	√		
	Carabidae juv.	√		
	Staphylinidae img.		√	
	Staphylinidae juv.	√		
	Elateridae		√	
	Lathridiidae img.		√	
	Cantharidae		√	
	Nitidulidae img.		√	
	Cryptophagidae img.	√		
	Coccinellidae img.		√	
	Coccinellidae juv.		√	
	Chrysomelidae img.		√	
	Chrysomelidae juv.		√	
	Curculionidae img.		√	
Hymenoptera	Symphyta juv.		√	
	Parasitica		√	

Elmegaard ***et al.*** (1994) found that Coleoptera predominated, by numbers, in Skylark faeces from a range of different localities, crops and cropping systems. The coleopterous families most frequently found were Curculionidae, Chrysomelidae, Carabidae and Staphylinidae. These groups also occurred frequently in the pellets in the present study. Elmegaard ***et al.*** also found that Araneae, Tipulidae and Symphyta were frequent in Skylark faeces from Danish arable land. Of those groups, however, only Araneae constituted more than 5 percent (by number) in the faeces in the present study. This difference may well be a result of differences in the occurrence of the groups in the fields studied. Furthermore, Syrphidae occurred frequently in the faecal pellets from this study whereas the group was not dealt with separately by Elmegaard ***et al***. When Elmegaard ***et al.*** (1994) compared faecal samples and D-vac samples from cereal fields, the Skylarks seemed to prefer large Araneae, Curculionidae, Chrysomelidae, Symphyta, Lepidoptera, and Tipulidae. Of these groups only juvenile Lepidoptera, adult Chrysomelidae and Curculionidae were found to be preferred in the present study.

In sugar beet fields during spring, Green (1980) found that insect remains in Skylark faeces were almost entirely from adult Coleoptera. Fifty-six percent were from Elateridae, 22 percent from Curculionidae, 13 percent from Scarabaeidae and 9 percent from Carabidae. In the present study, Elateridae made up less than 0.1 percent. The different results are probably due to very different field conditions; the almost bare beet fields in spring hardly offer any host plants for herbivorous insects.

A few Aphididae were identified in the faecal pellets but aphid numbers were not estimated in the suction samples. Due to the energy cost for the Skylarks of collecting such small insects, they are considered unimportant as food items (N. Elmegaard pers. comm.). Feeding experiments with Aphididae have revealed that shares higher than 7 percent of the diet inhibited growth and feather development of Partridge chicks (Borg & Toft 2000).

”Other Diptera” and Parasitica were frequent in the suction samples but were rarely found in the faeces. In general, it is probably difficult (and not energetically profitable) for Skylarks to feed on small, fast-flying insects. Among the other groups avoided or little used were Chilopoda, Diplopoda, Heteroptera, Cantharidae, adult and larval Coccinellidae and larval Chrysomelidae. Some of these taxa are known to contain ill-tasting or toxic compounds.

There were few significant differences in Skylark faecal contents between wheat and barley fields. Chrysomelidae adults were more frequent in faecal samples from barley than in faeces from wheat, reflecting their higher abundance in barley fields. Contrary to the adults, larval Chrysomelidae turned out to be avoided. However, avoidance was only clear in barley fields where the larvae were most abundant. Particularly ***Oulema*** larvae may be unsuitable as Skylark food because they use their excrements as a protective cover. In general the arthropod fauna was more diverse in barley than in wheat, and this was partly mirrored in the composition of the faeces. Adult Carabidae were more frequently eaten in wheat, and Staphylinidae and Nitidulidae were among the preferred food items here, while this was not the case in barley where more alternative food items were available.

Significant differences in faecal composition between years were few and generally mirrored similar differences in the suction samples, e.g. larval Syrphidae were more frequently found in 2001 than in 2000. Juvenile Lepidoptera and Staphylinidae were utilized proportional to their occurrence in 2000 (when they were relatively frequent), but were classified as preferred food items in 2001 (when they were rare). The avoidance/low use of Chrysomelidae larvae was only significant in 2001 when they occurred most frequently in the fields.

The composition of the Skylark diet changed significantly during the season. In May adult beetles (mainly Carabidae, Chrysomelidae, and Staphylinidae) dominated. Later in the season, juvenile stages of Symphyta, Syrphidae and Lepidoptera comprised a major part of the diet. In general the composition of the diet mirrored the availability of the different arthropod groups in the fields. Thus, besides the groups mentioned above, frequencies of Auchenorrhyncha, Nitidulidae and Curculionidae in the diet declined during the season while juvenile Chrysopidae increased in numbers.

Throughout the breeding season, the pattern of preference and avoidance/low use remained fairly constant, although the Skylarks' preference for adult beetles seemed to decline as arthropod diversity increased and more soft-bodied food items became available. The apparent low use of juvenile Symphyta in May was probably largely an artifact, cf. section 5.3.1.

The faecal samples did not include food brought to nestlings. Generally, the diet of Skylark nestlings consists almost entirely of insects, with very little plant material (Cramp 1988). Based on 550 nestling faeces from Danish barley fields, Odderskær ***et al.*** (1997a) found that nestling diet was dominated by Carabidae (42% of total dry weight), with Lepidoptera and Heteroptera contributing 19% and 7%, respectively. In a Swiss study from mixed farmland, ligature (neck ring) samples indicated that adult and larval Diptera dominated the diet of nestlings together with Orthoptera and Lepidoptera (Jenny 1990a). It is difficult to judge to what extent differences in methodology and differences in location contributed to the different outcome of the two studies. When the adults are feeding nestlings their own diet may be slightly changed, because some food items rich in protein and poor in chitin may be reserved for the young.

5.3.3 Effects of conversion to organic farming

Odderskær ***et al.*** (1997a) compared the diet of Skylark nestlings in sprayed and unsprayed spring barley fields. They found that Araneae, Carabidae and Staphylinidae made up a greater part of the diet in sprayed fields than in unsprayed fields whereas the opposite was true for several other groups, e.g. Lepidoptera, Chrysomelidae and Symphyta. The composition of the D-vac samples from their study fields is not described in their report, but it must be assumed that the differences in nestling diet largely reflected similar differences in the arthropod communities in the fields.

In the present study, most arthropod groups preferred by Skylarks increased in abundance after conversion to organic farming, i.e. larval Lepidoptera, Syrphidae and Chrysopidae, and adult Chrysomelidae and Curculionidae. Some important groups utilized proportional to their frequency of occurrence also increased, i.e. Araneae (only in barley), Auchenorrhyncha and Symphyta. General arthropod diversity increased as well.

On the contrary, Carabidae and Staphylinidae decreased in abundance after conversion. Taken together, these two groups made up between 20 and 50 percent of the animal part of the diet during the breeding season. Although these figures may be too high (section 5.3.1), especially Carabidae clearly qualified as preferred food items. They thus constituted a very important exception to the general result that Skylark food resources were improved by the conversion.

Although often large and energy-rich, Carabidae and Staphylinidae may not be ideal Skylark food. Perhaps their main asset is that they are fairly easily caught. Odderskær ***et al.*** (1997a) found that nestling survival reached a minimum in the year when the frequency of Carabidae in their diet was the highest (76% of dry weight). Due to a high content of indigestible chitin, the energetic value of Carabidae and other hard-bodied beetles is somewhat lower than indicated by their dry weight. Furthermore, a diet dominated by one particular group of organisms may reduce the probability of survival. Kluyver (1933) and Tinbergen (1981) found that the mortality of Starling nestlings increased if they were fed on an unbalanced diet consisting almost exclusively of ***Tipula*** larvae. Diversity in the food intake may thus be a quality in itself (Elmegaard ***et al.*** 1999), and this is more easily obtained in organically grown fields.

6 General discussion and conclusions (Esbjerg, P., Petersen, B.S., Navntoft, S., Jensen, A.-M.M. & Johnsen, I.)

6.1 Summary of results

The overall aim of the present project was to quantify changes in flora and fauna biodiversity during conversion from conventional to organic farming. The study was designed to reveal possible changes at each of the three main trophic levels as well as the interaction between these levels. The project took place at one farm over two seasons with organic practice immediately following previous conventional practice. The study crops were spring barley and winter wheat.

Flora:

- In wheat, the density of weeds increased to a level significantly higher (more than 100%) than during the preceding conventional period with normal pesticide dosage, however, it was not different from the density found at reduced dosages in the conventional period. In spring barley, no difference between periods was found.

- Carry-over effects were absent. The weed density in the organic period did not reflect the difference in dosages as was the case during the conventional period.

- The density of Cruciferae increased significantly in both crops after conversion.

- As to the number of weed species, the overall picture was parallel to that of density, since species number was strongly correlated to weed density.

- The flora composition did not change with conversion.

- Flowering improved from 30% in the conventional period to 70% in the organic period, the improvement was most pronounced in wheat.

- Bird available seeds on the soil surface increased from an average of 0.026 g/m^2 in the conventional phase to 0.95 g/m^2 after the conversion, however the seed mass showed very high variation between years.

- During the organic period the weed biomass accounted for 2% of crop + catch crop + weed biomass in barley but only for 0.2% in wheat.

Arthropods:

- There was no significant period effect across crops. The total insect dry mass was higher in barley after conversion to organic farming but in wheat the dry mass was lower after conversion.

- In the organic period the insect fauna showed no significant response to the dosages of the previous conventional period.

- Skylark prey in barley increased significantly in the organic phase while it decreased significantly in wheat.

- In barley all analyzed herbivorous groups (e.g. Auchenorrhyncha, Crysomelidae adults, Curculionidae adults and larvae of Lepidoptera (Fig. 3.3)) increased in the organic phase. In wheat only larvae of Symphyta increased.

- In organic barley a significant increase took place of all the specific aphid predators while this was only the case for larvae of Syrphidae in wheat.

- The proportion and density of polyphagous predators, mainly Carabidae and Staphylinidae, dropped considerably in wheat during the organic phase.

- There was a clear relation between density of flowering plants and abundance of adult Lepidoptera, relevant for both barley and wheat.

Birds:

- Skylark abundance was influenced by the conversion of agricultural practice: averaged over the breeding season, Skylark numbers were 55% higher after conversion than before.

- The number of Skylarks in early May was not different from the numbers in the preceding conventional period but soon increased and stayed high until the end of July.

- Skylark abundance during the organic period was inversely related to crop biomass while no correlation between Skylark prey and Skylark abundance was found.

- The composition of arthropod remnants in faecal pellets from Skylarks differed significantly from the composition in suction samples.

- The composition of arthropod remains in Skylark faecal pellets changed significantly during the breeding season. There was statistical difference between contents from wheat and barley and also between years.

Yield:

- The crop yield decreased with 42 and 41% in winter wheat and spring barley, respectively.

6.2 Discussion

Interestingly the apparent benefit, in terms of density and species number of weeds, of conversion is not more than the flora improvement of reducing the herbicide dosages with 75%. In spring barley, such flora improvement was not found, therefore the mechanical weeding associated with organic practice appears as immediately rather effective in killing/controlling weed plants. However, the biologically attractive, more than doubled proportion of flowering plants in the organic period with its total absence of herbicides underlines the difference between the two agricultural methods. Mechanical weeding has an immediate lethal effect as opposed to the sustained sublethal effect of herbicide application, which resulted in a delayed development of the surviving weed plants. This is underlined by the 36-fold increase in bird available weed seeds, which constitutes a potential support to bird survival during winter but also may be a subject of agricultural concern. Of importance for biodiversity is the improved flowering and the probably related increased occurrence of butterflies and moths. The improved flowering, however, also indicates a higher mean biomass per specimen and results in a more complex spatial vegetation structure, which may imply a better food quality for herbivorous insects (Kjær & Elmegaard 1996) and stabilise the microclima, respectively.

Given the lack of carry-over effects on the weed flora from previous dosage levels, the lack of reflectance of these dosage levels in the distribution and densities of insects is not surprising. Many of the species included have life stages with high mobility, as e.g. adult butterflies and beetles with wings, and these will from season to season redistribute depending upon a whole array of factors including the crop. Even many of the non-flying beetles, as e.g. some of the large Carabidae, have a fairly high mobility (***Pterostichus melanarius*** 9 m/h (Frampton ***et al***. 1995), ***P. cupreus*** range over an area of 6-29 ha in a season (Bommarco 1997)).

Most remarkable among the insect results is the clear increase of dry mass and more specifically Skylark prey in barley, an increase that did not take place in wheat. This may seem surprising as the weed density increased in wheat during the organic period. Despite this increase, however, the weed biomass in organic barley was 10 times higher than the weed biomass in organic wheat. This may point at the relieved insecticide pressure as the determining factor, and possibly with the highest effect in barley, which has a more open structure than wheat. Interestingly all the herbivores (e.g. larvae of Lepidoptera and adults of Chrysomelidae and Curculionidae) in barley did increase, and so did also aphid predators such as larvae of Chrysopidae, Syrphidae and Cocinellidae. For the latter the possible effect of large amounts of aphids in the 2000 season (Table 3.5) cannot be neglected. However, both the positive effect on these aphid predators of reducing insecticide dosages in the preceding conventional period (Navntoft & Esbjerg 2000) and their high sensitivity to most insecticides (Hassan ***et al.*** 1987) suggest that some of the increase can be ascribed to the omission of insecticides. Expressed in another way: aphids are a prerequisite for a good amount of the larvae of these specific predators but with the exception of Pirimicarb even a limited insecticide dosage would presumably have removed a considerable proportion. How much the influence of a non-insecticide situation means is further underlined by the strongly increased amount of Symphyta larvae in wheat during the organic period. The absolute majority of these belong to the genus ***Dolerus***, which live high in the crop and potentially is strongly exposed to insecticide treatment.

Among the results on arthropods the significant decrease in the organic wheat of the surface dwelling polyphagous predators Araneae, Carabidae and Staphylinidae is surprising. A similar decrease did not take place in barley where the weed biomass as mentioned earlier was 10 times higher, and in wheat the real decrease occurred in 2001 (cf. Fig. 3.7). A possible reason could be the effect of wheat with both a low level of weeds and mechanical weeding repeated in two successive years. The effect may become especially strong if e.g. the genus ***Trechus***, accounting for nearly 80% of the sampled Carabids, in some way is sensitive to this situation. Taking into account the potential lack of weed plants as shelter and the soil surface condition just after mechanical weeding it might be relevant to pay some future attention to possible side effects of intensive mechanical weeding.

The result of the Skylark counts, an increase from 8.6 individuals per 6 ha in the conventional period to 13.3 per 6 ha in the organic period automatically calls for attention on the food situation, but no general correlation between Skylark numbers and prey biomass could be established. However, the relative increase of soft-bodied larvae, easy to catch and digest, belonging to Lepidoptera and Chrysopidae in barley and Tenthredionidae and Syrphidae in wheat is suggestive. Only the variation in crop biomass appeared as a significant predictor of Skylark densities, highlighting the importance of an open crop structure for the Skylarks' feeding possibilities. Hence it is not possible to obtain a coherent tri-trophic-level explanation with Skylark as the top. On the other hand the improvement of food availability should on a longer time scale be a possible support to breeding success and survival, which could lead to increasing populations of Skylark if such "organic fields" are available within a reasonable distance. However, the relative importance of productivity and survival in determining population densities of Skylarks is not well understood and probably varies. Available data indicate that yearly mortality of adult Skylarks may vary between 11 and 71 percent (Schläpfer 1988, Jenny 1990c).

The average decrease in crop yield of 41-42% was in this case higher than the average biomass decrease of 25%, which was found in a comparison of old organic and conventional cereal fields (Hald 1999) and just outside the range of 21-37% yield decrease expected in cereals by converting to organic dairy farming in Denmark (Halberg & Kristensen 1997).

The strong yield decrease is difficult to explain. The level of available nitrogen in the soil might be a limiting factor for the cereal production. The weed density did not increase so much that competition may be the cause and the wheat varieties grown in the organic period were not less competitive than the varieties grown in the conventional period (P.K. Hansen pers. comm.). Only one of the fields had one year a high aphid population, thus the omission of insecticides cannot explain the yield decrease either. In the organic period the cereals were sown in double rows, this may result in a higher intra-specific competition and may explain some but not all of the yield decrease. No fungicides were used in the organic period, which may decrease the yield, if fungi are present.

6.3 Conclusions

While the effect of differences in pesticide dosage were clear at all trophic levels studied in the conventional period (Esbjerg & Petersen 2002) no carry-over effect of the three different dosage levels to the organic period could be stated neither for plants nor for arthropods and Skylarks.

On the plant side, diversity of species and the density of weeds increased after conversion to organic practice, however the highest density found was at the same level as obtained by reducing herbicide dosages with 75%. Flowering and seed production increased strongly with the organic practice, and using flowering as an indicator of mean biomass per specimen, it should be safe to conclude that the average dry mass per plant increased and thus also biodiversity including a biomass parameter.

The insect life reacted more markedly in several ways. E.g. the diversity within the experimental area increased as a result of more flowers, particularly attractive to Lepidoptera. Also dry mass and relative abundance of many taxonomic groups and accordingly biodiversity improved.

An interesting conclusion is that increased performance of weeds and the improvement of insect life, which can mainly be ascribed to absence of pesticides, could hardly have been reached through an agriculturally acceptable dosage reduction. Apart from its own value this forms a potentially high value resource of bird food.

Despite this food aspect it cannot be concluded that the strong increase of Skylark numbers in the organic phase is due to improved food resources. It can only be confirmed that the immediate presence of this bird depends much on vegetation structure as evidenced by the strong negative correlation with crop biomass. However, adequate food amounts are a prerequisite for the beneficial effects of changes in crop structure.

In total the biodiversity has been changed by conversion to organic practice but with the mixed picture it has little meaning to express this in biodiversity indexes. However, it can be stated that with the exception of epigaeic polyphagous predators conversion improved biodiversity. The exception calls for attention on the possible effect of mechanical weeding under some conditions.

6.4 Perspectives

As an outcome of the studies from the conventional period it could be suggested to use 75% reduction of pesticide dosages as a route to improving clearly and safely the “nature content” of arable fields. This would create some agricultural problems which can most likely be solved in the near future.

The conversion to organic practice is slightly more delicate to evaluate. First the change in flora which is obvious at a certain age (Hald & Reddersen 1990) can of course not be obtained if conversion is used only as a short-sighted environmental tool. However, the improvement of flowering is a most desirable change to the better automatically including improvements of insect life in response to flowers (nectar feeders) and to a better plant biomass/quality (herbivores). From that perspective it is recommendable to select single fields in some mosaic way and use organic practice, or at least some key elements of organic practice, for a season. As this is also an agricultural weed challenge because of a strongly increased seed production it has to be dealt with very carefully and certainly it will be recommendable not to include “weed hot spots” in such an environmental short term action.

On the insect side the results are clear enough to recommend untreated fields as a support to nature. The decision not to use insecticides could in the larger picture be dropped in case of a very unusual threat, e.g. extreme aphid attacks with a prospect of 10% losses or more. The results, however, also tell that one of the better investments for nature would be a generally increased effort to avoid insecticide treatments which are not absolutely necessary, also including fields which are not part of a particular environmental effort.

In order to increase the number of Skylarks using a field the importance of the crop structure is beyond dispute but in this light the food aspect should not be forgotten. For the Skylark population there is little doubt that a network of fields with improved food availability will be of importance. Parallel with this and leaning on analyses of long term effects of agricultural practice on farmland birds in England and Wales (Chamberlain ***et al.*** 1999) and Scotland (Benton ***et al.*** 2002) there is hardly any doubt about the environmental value of using both the reduced dosages elucidated in the conventional period (Esbjerg & Petersen 2002) and a strategy of short organic or zero-pesticide periods at single field level. This can ensure a network of nature-improved fields in the somewhat poor agricultural landscape.

7 References

Albrecht, H. & Mattheis, A. (1998): The effects of organic and integrated farming on rare arable weeds on the Forschungsverbund Agrarokosysteme Munchen (FAM) research station in southern Bavaria. ***Biological Conservation*** 86: 347-356.

Altieri, M.A. & Whitcomb, W.A. (1979): The potential use of weeds in manipulation of beneficial insects. ***Hortiscience*** 14: 12-18.

Beijerinck, W. (1947): ***Zadenatlas der nederlandsche flora, ten behoeve van de botanie, palaeontologie, bodemcultuur en warekennis. Omvattende, naast de inheemsche flora, onze belangrijkste cultuurgewassen en verschillende adventiefsoorten.*** H. Veenman & Zonen, Wageningen.

Bell, G.P. (1990): Birds and mammals on insect diet: a primer on diet composition analysis in relation to ecological energetics. ***Studies in Avian Biology*** 13: 416-422.

Benton, T.G., Bryant, D.M., Cole, L. & Crick, H.Q.P. (2002): Linking agricultural practice to insect and bird populations: a historical study over three decades. ***Journal of Applied Ecology*** 39: 673-687.

Berthelsen, J.P., Rasmussen, K. & Kjellsson, G. (1997): Fouragerende fugles udnyttelse af ukrudtsfrøpuljen. Metodeudvikling og vurdering af fødemuligheder i relation til pesticidpåvirkning. ***Bekæmpelsesmiddel-forskning fra Miljøstyrelsen*** 28. Miljø- og Energisministeriet, Miljøstyrelsen

Bommarco, R. (1997): Feeding, reproduction and dispersal of a generalist predator, ***Pterostichus cupreus*** L. (Coleoptera, Carabidae) related to agricultural landscape composition. ***Agraria*** 59. Swedish University of Agricultural Sciences

Borg, C. & Toft, S. (2000): Importance of insect prey quality for grey partridge chicks ***Perdix perdix***: a self-selection experiment. ***Journal of Applied Ecology*** 37: 557-563.

Breland, T.A. (1996): Green manuring with clover and ryegrass catch crops undersown in small grains: Crop development and yields. ***Acta Agriculturae Scandinavica Section B*** 46, 30-40.

Braae, L., Nøhr, H. & Petersen, B.S. (1988): Fuglefaunaen på konventionelle og økologiske landbrug. ***Miljøprojekt*** 102. Miljøstyrelsen.

Burn, A.J. (1989): Long-term effects of pesticides on natural enemies of cereal crop pests. In: Jepson, P.C. (ed.). ***Pesticides and non-target invertebrates***. Intercept Ltd, Dorset, UK, pp. 177-193.

Chamberlain, D.E., Fuller, R.J., Bunce, R.G.H., Duckworth, J.C. & Shrubb, M. (2000): Changes in the abundance of farmland birds in relation to the timing of agricultural intensification in England and Wales. ***Journal of Applied Ecology*** 37: 771-788.

Chamberlain, D.E., Wilson, A.M., Browne, S.J. & Vickery, J.A. (1999): Effects of habitat type and management on the abundance of skylarks in the breeding season. ***Journal of Applied Ecology*** 36: 856-870.

Christensen, K.D., Falk, K. & Petersen, B.S. (1996): Feeding Biology of Danish Farmland Birds. ***Arbejdsrapport fra Miljøstyrelsen*** 12/1996. Danish Environmental Protection Agency.

Clapham, A.R., Tutin, T.G. & Warburg, E.F. (1959): ***Excursion Flora of the British Isles.*** Cambridge University Press.

Cramp, S. (ed.) (1988): ***The Birds of the Westerm Palearctic, Vol. V.*** Oxford University Press, Oxford.

Danielsen, J. (1992): Registreringsmetode for bladlus i vårbyg. ***Nordisk Planteværnskonference***, Roskilde.

Davies, D.H.K, Christal, A., Talbot, M., Lawson, H.M. & Wright, G. McN. (1997): Changes in weed populations in the conversion of two arable farms to organic farming. ***Brighton Crop Protection Conference, Weeds***: 973-978.

Diaz, M. (1990): Interspecific patterns of seed selection among granivorous passerines: Effects of seed size, seed nutritive value and bird morphology. ***Ibis*** 132: 467-476.

Donald, P.F. & Vickery, J.A. (2000): The importance of cereal fields to breeding and wintering Skylarks ***Alauda arvensis*** in the UK. In: Aebischer, N.J., Evans, A.D., Grice, P.V. & Vickery, J.A. (eds.): ***Ecology and Conservation of Lowland Farmland Birds***: 140-150. British Ornithologists' Union, Tring.

Donald, P.F., Buckingham, D.L., Moorcroft, D., Muirhead, L.B., Evans, A.D. & Kirby, W.B. (2001): Habitat use and diet of skylarks ***Alauda arvensis*** wintering on lowland farmland in southern Britain. ***Journal of Applied Ecology*** 38: 536-547.

Elmegaard, N., Rasmussen, P.N. & Poulsen, J.G. (1994): Arthropod food items of the Skylark (Alauda arvensis) in Danish fields. ***Arbejdsrapport fra Miljøstyrelsen*** 46/1994. Miljøstyrelsen.

Elmegaard, N.E., Andersen, P.N., Odderskær, P. & Prang, A. (1999): Food supply and breeding activity of Skylarks in fields with different pesticide treatment. In: Adams, N.J. & Slotow, R.H. (eds.) ***Proc. 22 Int. Ornithol. Congr., Durban***: 1058-1069. Birdlife South Africa, Johannesburg.

Elsen, T. van (2000): Organic farming as a challenge for the integration of agriculture and nature development. In: Stolton, S., Geier, B. & McNeely, J.A. (eds.): ***The relationship between nature conservation, biodiversity and organic agriculture***: 76-85. Proceedings of an international Workshop held in Vignola, Italy 1999.

Esbjerg, P. & Petersen, B.S. (eds.) (2002): Effects of reduced pesticide use on flora and fauna in agricultural fields. ***Pesticides Research*** 58. Danish Environmental Protection Agency. Danish Ministry of the Environment.

Evans, J., Wilson, J.D. & Browne, S.J. (1995): Habitat selection and breeding success of Skylarks ***Alauda arvensis*** on organic and conventional farmland. The Effect of Organic Farming Regimes on Breeding and Winter Bird Populations. Part III. ***BTO Research Report*** 154. British Trust for Ornithology, Thetford, & Ministry of Agriculture, Fisheries and Food.

Eybert, M.C. & Constant, P. (1992): Validité de l'analyse des sacs fécaux pour l'étude du régime alimentaire des jeunes au nid de la linotte mélodieuse (***Carduelis cannabina***). ***Canadian Journal of Zoology*** 70: 2171-2177.

Fadl, A., Purvis, G. & Towey, K. (1996): The effect of soil cultivation on the incidence of ***Pterostichus melanarius*** (Illig.) (Coleoptera: Carabidae) in arable land in Ireland. ***Annales Zoologici Fennici*** 33: 207-214.

Frampton, C.A., Cilgi, T., Fry, G.L.A. & Wratten, S.D. (1995): Effects of grassy banks on the dispersal of some carabid beetles (Coleoptera: Carabidae) on farmland. ***Biological Conservation*** 70: 347-355.

Green, R.E. (1980): Food selection by Skylarks and grazing damage to sugar beet seedlings. ***Journal of Applied Ecology*** 17: 613-630.

Gross, K.L. (1990): A comparison of methods for estimating seed numbers in the soil. ***Journal of Ecology*** 78: 1079-1093.

Grøntved, J. & Sørensen, T. (1941) ***Nøgle til bestemmelse af danske græsser i blomsterløs tilstand***. Munksgaard, København.

Haas, H. & Laursen, F. (1994): ***Ukrudtskimplanter. Frøukrudt på bekæmpelsesstadiet***, 5th edn. Jordbrugsforlaget, København.

Halberg, N. & Kristensen, I.S. (1997): Expected crop yield loss when converting to organic dairy farming in Denmark. ***Biological Agriculture & Horticulture*** 14: 25-41.

Hald, A.B. & Reddersen, J. (1990): Fuglefføde i kornmarker - insekter og vilde planter. ***Miljøprojekt*** 125. Miljøstyrelsen.

Hald, A.B. (1999): Weed vegetation (wild flora) of long established organic versus conventional cereal fields in Denmark. ***Annals of Applied Biology*** 134: 307-314.

Haney, J.C. & Solow, A.R. (1992): Testing for resource use and selection by marine birds. ***Journal of Field Ornithology*** 63: 43-52.

Hanf, M. (1990): ***Ackerunkräuter Europas mit ihren Kimlingen und Samen***, 3rd edn. BLV Verlagsgesellschaft, München.

Hansen, K. (ed.) (1981): ***Dansk feltflora***. Gyldendal, København.

Hartl, W. (1989): Influence of Undersown Clovers on Weeds and on the Yield of Winter Wheat in Organic Farming. ***Agriculture, Ecosystems and Environment*** 27: 389-396.

Hassan, S.A., Albert, R., Bigler, F., Blaisinger, P., Bogenschütz, H., Boller, E., Brun, J., Chiverton, P., Edwards, P., W.D., Englert, W.D., Huang, P., Ingles, C., Naton, E., Oomen, P.A., Overmeer, W.P.J., Rieckmann, W, Samsøe-Petersen, L., Stäubli, A., Tuset, J.J., Viggiani, G., and Vanwetswinkel, G. (1987): Results of the third joint pesticide testing programme by the IOBC/WPRS-Working Group "Pesticides and Beneficial Organisms". ***Journal of Applied Entomology*** 103: 92-107.

Herrmann, Von G., Hamplund, U. & Bachthaler, G. (1986): Unkrautbesatz und Unkrautentwicklung, Ergebnisvergleich von Regulierungsmassnahmen bei ökologischer und konventioneller Wirtschaftsweise in Winterweizen, Futterrüben, Kartoffeln und Mais. ***Bayerisches Landwirtschaftliches Jahrbuch*** 63: 795-805.

Holm, S., Tersbøl, M. & Kristensen, H. (sine anno): ***Optimal ressourceudnyttelse i økologiske sædskifter – registrering, diagnosticering og varsling af skadegørere.*** Unpublished report. Danmarks JordbrugsForskning.

Holm-Nielsen, C. (1998): ***Frø fra det dyrkede land***. Danmarks Jordbrugsforskning, Forskningscenter Flakkebjerg.

Jenny, M. (1990a): Nahrungsökologie der Feldlerche ***Alauda arvensis*** in einer intensiv genutzten Agrarlandschaft des schweizerischen Mittellandes. ***Der Ornithologische Beobachter*** 87: 31-53.

Jenny, M. (1990b): Populationsdynamik der Feldlerche ***Alauda arvensis*** in einer intensiv genutzten Agrarlandschaft des schweizerischen Mittellandes. ***Der Ornithologische Beobachter*** 87: 153-163.

Jenny, M. (1990c): Territorialität und Brutbiologie der Feldlerche ***Alauda arvensis*** in einer intensiv genutzten Agrarlandschaft. ***Journal für Ornithologie*** 131: 241-265.

Jensen, A.-M.M. & Johnsen, I. (2002): Wild flora. Chapter 2 in: Esbjerg, P. & Petersen, B.S. (eds.) Effects of reduced pesticide use on flora and fauna in the agricultural fields. ***Pesticides Research*** 58. Danish Environmental Protection Agency.

Jensen, A.-M.M. (2001): ***Effects of reduced pesticide use on weed populations***. Ph.D. thesis, Botanical Institute, Faculty of Science, University of Copenhagen.

Kauppila, R. (1990) Conventional and organic cropping systems at Suitia - IV: Weeds. ***Journal of Agricultural Science in Finland*** 62, 331-337.

Kjær, C. & Elmegaard, N. (1996): Effect of herbicide treatment on host plant quality for a leaf-eating beetle. ***Pesticide Science*** 47: 319-325.

Kluyver, H.N. (1933): ***Bijdrage tot de biologie en de ecologie van de Spreeuw (Sturnus vulgaris vulgaris L.) gedurende zijn voortplantingstijd.*** Pub. Plantenziektenk. Dienst. Wageningen.

Korsmo, E. (1926): ***Ogräs. Ogräsarternas Liv och Kampen mot dem i Nutidens Jordbruk***. Albert Bonniers Förlag, Stockholm.

Kroos, S. & Schaefer, M. (1998): The effect of different farming systems on epigaeic arthropods: a five-year study on the rove beetle fauna (Coleoptera: Staphylinidae) of winter wheat. ***Agriculture, Ecosystems and Environment*** 69: 121-133.

Landbrugets Rådgivningscenter (1997): ***Vejledning i planteværn***. Danmarks Jordbrugsforskning, Landskontoret for planteavl.

Liebman, M. & Dyck, E. (1993): Crop rotation and intercropping strategies for weed management. ***Ecological Applications*** 3, 92-122.

Lorenz, E. (1994): ***Mechanische Unkrautbekämpfungsmassnahmen in Zuckerrübenkulturen und ihre Nebenwirkungen auf Laufkäfer (Coleoptera, Carabidae) und andere epigäische Arthropoden.*** Cuvillier, Göttingen.

Marcum, C.L. & Loftsgaarden, D.O. (1980): A nonmapping technique for studying habitat preferences. ***Journal of Wildlife Management*** 44: 963-968.

Marshall, E.J.P. (1989): Distribution patterns of plants associated with arable field edges. ***Journal of Applied Ecology*** 26: 247-258.

McCune, B. & Mefford, M.J. (1997): ***Multivariate Analysis of Ecological Data, Version 3.20.*** MjM Software, Gleneden Beach, Oregon, USA.

Melander, B. (1998): Beskrivelse af ukrudtsarterne. ***Ukrudtsbekæmpelse i landbruget***: 41-189. 3. udgave. Statens Planteavlsforsøg, Flakkebjerg.

Mikkelsen, V.M. (1989): Cultivated fields. ***Opera Botanica*** 96: 73-80.

Moreby, S.J. (1988): An aid to the identification of arthropod fragments in the faeces of gamebird chicks (Galliformes). ***Ibis*** 130: 519-526.

Moreby, S.J., Aebischer, N.J., Southway, S.E. & Sotherton, N.W. (1994): A comparison of the flora and arthropod fauna of organically and conventionally grown winter wheat in southern England. ***Annals of Applied Biology*** 125: 13-27.

Moreby, S.J. & Sotherton, N.W. (1997): A comparison of some important chick-food insect groups found in organic and conventionally-grown winter wheat fields in Southern England. ***Biological Agriculture and Horticulture*** 15: 51-60.

Navntoft, S. & Esbjerg, P. (2002): Arthropods. In: Esbjerg, P. & Petersen, B.S. (eds.). Effects of Reduced Pesticide Use on Flora and Fauna in Agricultural Fields. ***Pesticides Research*** 58: 67-92. Danish Environmental Protection Agency. Danish Ministry of the Environment.

Neu, C.W., Byers, C.R., Peek, J.M. & Boy, V. (1974): A technique for analysis of utilization-availability data. ***Journal of Wildlife Management*** 38: 541-545.

Odderskær, P., Prang, A., Elmegaard, N. & Andersen, P.N. (1997a): Skylark Reproduction in Pesticide Treated and Untreated Fields. ***Pesticides Research*** 32. Miljøstyrelsen.

Odderskær, P., Prang, A., Poulsen, J.G., Andersen, P.N. & Elmegaard, N. (1997b): Skylark ***(Alauda arvensis)*** utilisation of micro-habitats in spring barley fields. ***Agriculture, Ecosystems & Environment*** 62: 21-29.

Petersen, B.S. (1994): Interactions between birds and agriculture in Denmark: from simple counts to detailed studies of breeding success and foraging behaviour. In: Hagemeijer, E.J.M. & Verstrael, T.J. (eds.): ***Bird Numbers 1992. Distribution, monitoring and ecological aspects. Proceedings of the 12th International Conference of IBCC and EOAC, Noordwijkerhout, The Netherlands***: 49-56. Statistics Netherlands, Voorburg/Heerlen & SOVON, Beek-Ubbergen.

Roberts, H.A. & Ricketts, M.E. (1979): Quantitative relationships between the weed flora after cultivation and the seed population in the soil. ***Weed Research*** 19: 269-271.

Rogers, L.E., Hinds, W.T. & Buschbom, R.L. (1977): A general weight vs. length relationship for insects. ***Annals of Entomological Society of America*** 69: 387-389.

Rydberg,N.T. & Milberg, P. (2000): A survey of weeds in organic farming in Sweden. ***Biological Agriculture & Horticulture*** 18: 175-185.

Salisbury, E.J. (1942): ***The Reproduction Capacity of Plants. Studies in Quantitative Biology***. G. Bell and Sons, LTD, London.

Salonen, J. (1993): Weed infestation and factors affecting weed incidence in spring cereals in Finland - a multivariate approach. ***Agricultural Science of Finland*** 2: 525-535.

Salonen, J., Hyvönen, T. & Jalli, H. (2001): Weed flora in organically grown spring cereals in Finland. ***Agricultural and Food Science in Finland*** 10: 231-242

SAS Institute (1990a): ***SAS Procedures Guide. Version 6, Third Edition.*** SAS Institute Inc., Cary, NC.

SAS Institute (1990b): ***SAS/STAT User's Guide. Version 6, Fourth Edition.*** SAS Institute Inc., Cary, NC.

SAS Institute (1996): ***SAS/STAT Software: Changes and Enhancements for Release 6.12***. SAS Institute Inc., Cary, NC.

Schläpfer, A. (1988): Populationsökologie der Feldlerche ***Alauda arvensis*** in der intensiv genutzten Agrarlandschaft. ***Der Ornithologische Beobachter*** 85: 309-371.

Sjursen, H., Bayley, M. & Holmstrup, M. (2001): Enhanced drought tolerance of a soil-dwelling springtail by pre-acclimation to a mild drought stress. ***Journal of Insect Physiology*** 47: 1021-1027.

Sokal, R.R & Rohlf, F.J. (1981): ***Biometry.*** W.H. Freeman and Company, New York.

Sotherton, N.W. (1990): The effects of six insecticides used in the UK cereal fields on sawfly larvae (Hymenoptera: Tenthredinidae). ***Brighton Crop Protection Conference: Pests and Diseases***: 999-1004.

Steenfeldt, S., Rasmussen, P.N. & Jensen, T.S. (1991): Food selection in a population of Partridge ***Perdix perdix*** in Danish arable farmland. ***Dansk Ornitologisk Forenings Tidsskrift*** 85: 67-76.

Stoltze, M. & Pihl, S. (eds.) (1998): ***Rødliste 1997 over planter og dyr i Danmark***. Miljø- og Energiministeriet, Danmarks Miljøundersøgelser og Skov- og Naturstyrelsen, København.

Stryhn, H. (1996): ***Longitudinale data: Simple univariate analysemetoder***. Institute of Mathematics and Statistics. Royal Veterinary and Agricultural University, Copenhagen.

Sunderland, K.D. (1975): The diet of some predatory arthropods in cereal crops. ***Journal of Applied Ecology*** 12: 507-515.

Sunderland, K.D., De Snoo, G.R., Dinter, A., Hance, T., Helenius, J., Jepson, P., Kromp, B., Lys, J.-A., Samu, F., Sotherton, N.W., Toft, S. & Ulber, B. (1995): Density estimation for invertebrate predators in agroecosystems. In: Toft, S., Riedel, W. (eds.), ***Arthropod Natural Enemies in Arable Land*** 1. Acta Jutlandica LXX: 2. Natural Science Series 9: 133-162. Aarhus University Press.

Thiele, H.-U. (1977): ***Carabid Beetles in their Environments***. Springer-Verlag, Berlin.

Thompson, K., Bakker, J.P. & Bekker, R.M. (1997): ***The soil seed banks of North West Europe: methodology, density and longevity***. Cambridge University Press.

Tinbergen, J.M. (1981): Foraging decisions in Starlings ***Sturnus vulgaris*** L. ***Ardea*** 69: 1-67.

Toepfer, S. & Stubbe, M. (2001): Territory density of the Skylark ***(Alauda arvensis)*** in relation to field vegetation in central Germany. ***Journal für Ornithologie*** 142: 184-194.

Tutin, T.G., Heywood, V.H., Burges, N.A., Valentine, D.H., Walters, S.M. & Webb, D.A. (eds). (1964-1980): ***Flora Europaea*** (1-5). University Press, Cambridge.

Wilson, J.D., Evans, J., Browne, S.J. & King, J.R. (1997): Territory distribution and breeding success of skylarks ***Alauda arvensis*** on organic and intensive farmland in southern England. ***Journal of Applied Ecology*** 34: 1462-1478.

Wilson, J.D., Morris, J.A., Arroyo, B.E., Clark, S.C. & Bradbury, R.B. (1999): A review of the abundance and diversity of invertebrate and plant foods of granivorous birds in northern Europe in relation to agricultural change. ***Agriculture, Ecosystems and Environment*** 75: 13-30.

Appendix A
Herbicide and insecticide applications 1997-1999

Appendix A.1. Herbicides and insecticides used in the growing season 1996/1997, trade name, normal dosage per hectare, active ingredient(s) and treatment intensity index. Normal dosage is not equal to recommended dosage, see section 1.3 for a definition of normal dosage. A treatment intensity index on 1.00 for a particular product is given for application of the recommended dosage in a certain crop according to the list of recommended dosages (Landbrugets Rådgivningscenter 1997). All herbicides and insecticides have been sprayed at reduced dosages in the plots destined for reduced dosages.

Year	Crop	Date	Trade name	Normal dosage/ha		Active ingredient(s)			Treatment intensity index
					Herbicides				
1997	Barley	15 May	Express	0.10	tb*	Tribenuron-methyl	500	g a.i./kg	0.05
		30 May	Express	0.50	tb*	Tribenuron-methyl	500	g a.i./kg	0.25
			Metaxon	1.50	l	MCPA	750	g a.i./l	0.75
			Starane 180	0.25	l	Fluroxypyr	180	g a.i./l	0.36
	Wheat	23 Oct	Flexidor	0.05	l	Isoxaben	500	g a.i./l	0.20
			Mylone Power	0.50	l	Ioxynil	160	g a.i./l	0.25
						Mechlorprop	480	g a.i./l	
			Tolkan	1.50	l	Isoproturon	500	g a.i./l	0.60
		15 May	Express	1.00	tb*	Tribenuron-methyl	500	g a.i./kg	0.50
			Starane 180	0.30	l	Fluroxypyr	180	g a.i./l	0.38
	Beets	8 May	Ethosan	0.15	l	Ethofumesat	500	g a.i./l	0.19
			Goltix	1.00	kg	Metamitron	700	g a.i./kg	0.22
			Herbasan	1.25	l	Phenmedipham	160	g a.i./l	0.21
			Matrigon	0.30	l	Clopyralid	100	g a.i./l	0.25
		16 May	Ethosan	0.15	l	Ethofumesat	500	g a.i./l	0.19
			Goltix	1.00	kg	Metamitron	700	g a.i./kg	0.22
			Herbasan	1.25	l	Phenmedipham	160	g a.i./l	0.21
			Matrigon	0.30	l	Clopyralid	100	g a.i./l	0.25
		2 June	Ethosan	0.15	l	Ethofumesat	500	g a.i./l	0.19
			Goltix	0.50	kg	Metamitron	700	g a.i./kg	0.11
			Herbasan	1.25	l	Phenmedipham	160	g a.i./l	0.21
					Insecticides				
	Barley	23 June	Karate	0.15	l	Lambda-cyhalothrin	25	g a.i./l	0.50
	Wheat	7 July	Pirimor	0.10	kg	Pirimicarb	500	g a.i./kg	0.40
	Beets	8 May	Karate	0.15	l	Lambda-cyhalothrin	25	g a.i./l	0.50
		9 July	Perfektion EC20	1.00	l	Dimethoate	200	g a.i./l	Field edge

* One tablet (tb) weights 7.5 gram

Appendix A.2. Herbicides and insecticides used in the growing season 1997/1998, trade name, normal dosage per hectare, active ingredient(s) and treatment intensity index. All herbicides and insecticides have been sprayed at reduced dosages in the plots destined for reduced dosages.

					Herbicides				
1998	Barley	15 May	Express	1.50	tb*	Tribenuron-methyl	500	g a.i./kg	0.75
			Starane 180	0.40	l	Fluroxypyr	180	g a.i./l	0.57
		17 Sept	Touchdown	3.00	l	Glyphosate-trimesium	480	g a.i./l	1.20
	Wheat	10 Nov.	Stomp SC	1.00	l	Pendimethalin	400	g a.i./l	0.25
			Tolkan	1.00	l	Isoproturon	500	g a.i./l	0.40
		9 May	Express	1.00	tb*	Tribenuron-methyl	500	g a.i./kg	0.50
			Starane 180	0.40	l	Fluroxypyr	180	g a.i./l	0.50
		13 Oct.	Touchdown	3.00	l	Glyphosate-trimesium	480	g a.i./l	1.20
	Beets	10 May	Betasana Flow	1.30	l	Phenmedipham	160	g a.i./l	0.22
			Ethuron	0.10	l	Ethofumesat	500	g a.i./l	0.13
			Goltix	1.00	kg	Metamitron	700	g a.i./kg	0.22
		18 May	Betasana Flow	1.50	l	Phenmedipham	160	g a.i./l	0.25
			Ethuron	0.15	l	Ethofumesat	500	g a.i./l	0.19
			Goltix	1.00	kg	Metamitron	700	g a.i./kg	0.22
		28 May	Betasana Flow	1.00	l	Phenmedipham	160	g a.i./l	0.17
			Ethuron	0.20	l	Ethofumesat	500	g a.i./l	0.25
			Goltix	0.75	kg	Metamitron	700	g a.i./kg	0.17
			Safari	20	g	Triflusulfuron-methyl	1000	g a.i./kg	0.22
					Insecticides				
	Barley	16 June	Pirimor	0.05	kg	Pirimicarb	500	g a.i./kg	0.20
			Mavrik 2F	0.05	l	Tau-fluvalinat	240	g a.i./l	0.25
	Wheat	23 June	Mavrik 2F	0.10	l	Tau-fluvalinat	240	g a.i./l	0.50
	Beets	22 July	Pirimor	0.30	kg	Pirimicarb	500	g a.i./kg	1.00

* One tablet (tb) weights 7.5 gram

Appendix A.3. Herbicides and insecticides used in the growing season 1998/1999, trade name, normal dosage per hectare, active ingredient(s) and treatment intensity index. All herbicides and insecticides have been sprayed at reduced dosages in the plots destined for reduced dosages.

					Herbicides				
1999	Barley	10 May	Express	1.00	tb*	Tribenuron-methyl	500	g a.i./kg	0.50
			Oxitril	0.30	l	Ioxynil	200	g a.i./l	0.30
						Bromoxynil	200	g a.i./l	
		7 June	Metaxon	1.00	l	MCPA	750	g a.i./l	0.50
	Wheat	2 Nov	Boxer	0.80	l	Prosulfocarb	800	g a.i./l	0.20
			Stomp SC	0.80	l	Pendimethalin	400	g a.i./l	0.20
			Tolkan	0.50	l	Isoproturon	500	g a.i./l	0.20
		10 May	Express	1.00	tb*	Tribenuron-methyl	500	g a.i./kg	0.50
			Starane 180	0.30	l	Fluroxypyr	180	g a.i./l	0.38
	Beets	4 May	Ethosan	0.12	l	Ethofumesat	500	g a.i./l	0.15
			Goltix	1.00	kg	Metamitron	700	g a.i./kg	0.22
			Herbasan	1.50	l	Phenmedipham	160	g a.i./l	0.25
		17 May	Ethosan	0.12	l	Ethofumesat	500	g a.i./l	0.15
			Goltix	1.00	kg	Metamitron	700	g a.i./kg	0.22
			Herbasan	1.50	l	Phenmedipham	160	g a.i./l	0.25
		31 May	Ethuron	0.15	l	Ethofumesat	500	g a.i./l	0.19
			Herbasan	1.50	l	Phenmedipham	160	g a.i./l	0.25
			Safari	25	g	Triflusulfuron-methyl	1000	g a.i./kg	0.28
					Insecticides				
	Barley	15 June	Mavrik 2F	0.10	l	Tau-fluvalinat	240	g a.i./l	0.50
	Wheat	15 June	Mavrik 2F	0.10	l	Tau-fluvalinat	240	g a.i./l	0.50
	Beets	-	-	0.00	-	-	-	-	0.00

* One tablet (tb) weights 7.5 gram

Appendix A.4. Herbicides used in winter wheat in the growing season 1999/2000 (autumn application before conversion), trade name, dosage per hectare, active ingredient(s) and treatment intensity index. The herbicides were sprayed at the same dosage in all three plots.

					Herbicides				
1999	Wheat	8 Nov	Stomp SC	1.00	l	Pendimethalin	400	g a.i./l	0.25
			Tolkan	1.00	l	Isoproturon	500	g a.i./l	0.40

Appendix B
Basic field treatments

Appendix B.1. Basic field treatments in the conventional period.

		Field 1		Field 2		Field 3	
		Size: 31 ha. Soil type: JB no. 6		Size: 30 ha. Soil type: JB no. 6		Size: 36 ha. Soil type: JB no. 6	
Oremandsgård	1996		Sugar beets		White clover		Winter wheat
		15.11	Ploughing	23.09	Ploughing/sowing wheat (Lynx, 157 kg/ha)	04.11	Ploughing
	1997	20.03	Fertilizer (NPK 18-5-10+S, 560 kg/ha)	10.03	Fertilizer (NPK 18-5-10+S, 400 kg/ha)	12.03	Hoeing
		31.03	Sowing barley (Optic, 176 kg/ha)	23.04	Fertilizer (NPK 24-0-0+S, 300 kg/ha)	13.03	Hoeing
		15.05	Fungicide	15.05	Fungicide	21.03	Fertilizer (NPK 14-4-12+Na, 850 kg/ha)
		30.05	Fungicide	20.06	Fungicide	10.04	Hoeing
		05.06	Fertilizer (Manganesesulphate, 3 kg/ha)	21.08	Harvest (74 hkg/ha)	12.04	Sowing beets
		23.06	Fungicide			11.06	Fertilizer (Manganesesulphate, 3 kg/ha)
		10.08	Harvest (65 hkg/ha)			03.06	Weed hoeing (1/2, 1/4)
						12.06	Weed hoeing (1/2, 1/4)
						26.06	Weed hoeing (1/1, 1/2, 1/4)
						Oct.	Harvest
		18.09	Ploughing / sowing wheat (Versailles, 173 kg/ha)	01.11	Ploughing	01.12	Ploughing
	1998	27.03	Fertilizer (NPK 18-5-10+S, 530 kg/ha)	01.04	Hoeing / fertilizer (NPK 0-6-21+Mg,S,Na, 800 g/ha)	30.03	Hoeing
		14.04	Fertilizer (Calciumammo., 300 kg/ha)	14.04	Hoeing	31.03	Fertilizer (NPK 18-5-10+S, 525 kg/ha)
		02.06	Fungicide	10.06	Weed hoeing (1/2, 1/4)	18.04	Sowing barley (Optic, 170 kg/ha)
		22.06	Fungicide	14.04	Hoeing	15.05	Fungicide
		Aug.	Harvest (96 hkg/ha)	17.04	Fertilizer (Ammonia liquid, 140 kg/ha)	16.06	Fungicide
				23.04	Sowing beets	23.08	Harvest (61 hkg/ha)
				11.05	Weed hoeing (1/2, 1/4)		
				19.05	Weed hoeing (1/2, 1/4)		
				10.06	Weed hoeing (1/2, 1/4)		
				18.06	Weed hoeing (1/1)		
				25.06	Weed hoeing (1/2, 1/4)		
				22.07	Fungicide		
				23.11	Harvest		
		05.11	Ploughing	25.11	Ploughing	7.10	Ploughing / sowing wheat (Pentium, 240 kg/ha)
	1999	04.04	Hoeing	01.04	Fertilizer / hoeing (NPK 18-5-10+Mg, S, B, 600 kg/ha)	26.03	Fertilizer (NPK 18-5-10+Mg, S, B, 495 kg/ha)
		05.04	Fertilizer (NPK 0-5-17, 885 kg/ha)	03.04	Sowing barley (Optic, 155 kg/ha)	14.04	Fertilizer (Calciumammo. 386 kg/ha)
		07.04	Hoeing / fertilizer (Ammonia liquid, 145.1 kg/ha)	07.05	Rolling	26.05	Fungicide
		18.04	Hoeing	08.06	Fertilizer (Manganesesulphate, 3.5 kg/ha)	17.06	Fungicide
		19.04	Sowing beets	15.06	Fungicide	25.08	Harvest (89 hkg/ha)
		20.05	Weed hoeing (1/2, 1/4)	18.06	Harvest (59 hkg/ha)		
		25.05	Weed hoeing (1/2, 1/4)				
		08.06	Fertilizer (Manganesesulphate, 3 kg/ha)				
		16.06	Weed hoeing (1/2, 1/4)	30.08	Stubble hoeing		
		28.06	Weed hoeing (1/1, 1/2, 1/4)	20.09	Ploughing	10.09	Stubble hoeing
		Nov.	Harvest	22.09	Sowing wheat (Bill, 217 kg/ha)	08.10	Ploughing / Sowing wheat (Pentium, 217 kg/ha)

Appendix B.2. Basic field treatments in the organic period. Field 3 was not part of the experiment in 2000 and field 1 was not included in 2001 (for field location see Fig. 1.1)

		Field 1		Field 2		Field 3	
		Size: 31 ha. Soil type: JB no. 6		Size: 30 ha. Soil type: JB no. 6		Size: 36 ha. Soil type: JB no. 6	
Oremandsgård	2000	29.03	Hoeing	30.03	Slurry (18 t/ha) (66.6 kg N/ha)	30.03	Slurry (17 t/ha) (62.9 kg N/ha)
		06.04	Slurry (14 t/ha) (51.8 kg N/ha)	17.04	Slurry (8 t/ha) (29.6 kg N/ha)	21.04	Slurry (9 t/ha) (33.3 kg N/ha)
		12.04	Sowing barley (Ferment, 180 kg/ha) / rye grass (Tetramax, 10 kg/ha)	27.04	Weed hoeing (spike-tooth harrow)	27.04	Weed hoeing (spike-tooth harrow)
		27.04	Rolling	27.08	Harvest (56 hkg/ha)	26.08	Harvest (50 hkg/ha)
		02.05	Weed hoeing (spike-tooth harrow)				
		08.05	Weed hoeing (spike-tooth harrow)	04.09	Stubble hoeing	27.08	Stubble hoeing
		05.06	Sowing / white clover (Milo, 4 kg/ha) Weed hoeing (spike-tooth harrow)	26.09	Ploughing	28.08	Stubble hoeing
		14.06	Weed hoeing) (inter-row cultivation)	27.09	Hoeing		
		22.08	Harvest (29 hkg/ha)	28.09	Hoeing / sowing wheat (Terra, 200 kg/ha)		
				29.09	Rolling	01.12	Ploughing
				23.10	Weed hoeing (spike-tooth harrow)		
	2001			09.04	Slurry (32 t/ha) (118.4 kg N/ha)	11.04	Hoeing
				25.04	Weed hoeing (spike-tooth harrow)	13.04	Slurry (26 t/ha) (96.2 kg N/ha)
				03.05	Weed hoeing (spike-tooth harrow)	15.04	Hoeing
				08.05	Sowing rye grass (Tetramax, 8 kg/ha) / white clover (Milo, 2 kg/ha)	17.04	Sowing Barley (Otira, 183 kg/ha)
				09.05	Weed hoeing (spike-tooth harrow)	01.05	Weed hoeing (Blind) (spike-tooth harrow)
						15.05	Weed hoeing (spike-tooth harrow)
				20.08	Harvest (44 hkg/ha)	25.05	Weed hoeing) (inter-row cultivation)
						28.05	Sowing rye grass (Tetramax, 16 kg/ha) / white clover (Milo, 4 kg/ha) Weed hoeing (spike-tooth harrow)
						15.08	Harvest (42 hkg/ha)

Appendix C
Names of organisms studied

Appendix C.1. Plant species present in the vegetation – Scientific name, English name (Clapham *et al.* 1959), Danish name, present as vegetative, flowering, seed setting or in the seed mass.

Scientific name	English name	Danish name	Vegeta-tive	Flower-ing	Seed setting	Bird available seeds
Acer pseudoplatanus L.	Great Maple	Ahorn	*			*
Aethusa cynapium L.	Fool's Parsley	Hundepersille	*	*		*
Anagallis arvensis L.	Scarlet Pimpernel	Rød Arve	*	*		*
Aphanes arvensis L.	Parslet Piert	Alm. Dværgløvefod	*	*		*
Arenaria serpyllifolia L.	Thyme-leaved Sandwort	Alm. Markarve	*	*		
Atriplex patula L.	Common Orache	Svine-Mælde	*	*		
Beta vulgaris (L.) ssp. *vulgaris*	Beet	Roe	*			
Betula sp.	Birch	Birk				*
Bilderdykia convolvulus (L.) Dumort.	Black Bindweed	Snerle-Pileurt	*	*	*	*
Brassica napus L. ssp. *napus*	Rape	Raps	*	*	*	*
Capsella bursa-pastoris (L.) Medicus	Shepherd's Purse	Hyrdetaske	*	*	*	*
Chaenorrhinum minus (L.) Lange	Small Toadflax	Liden Torskemund	*			
Chamomilla suaveolens (Pursh) Rydb.	Rayless Mayweed	Skive-Kamille	*	*	*	*
Chenopodium album L.	Fat Hen	Hvidmelet Gåsefod	*	*	*	*
Cirsium arvense (L.) Scop.	Creeping Thistle	Ager-Tidsel	*	*		*
Elymus repens (L.) Gould	Couch-grass	Alm. Kvik	*	*	*	
Epilobium sp.	Willow-herb	Dueurt	*			*
Equisetum arvense L.	Common Horsetail	Ager-Padderok	*			
Euphorbia exigua L.	Dwarf Spurge	Liden Vortemælk	*	*	*	*
Euphorbia helioscopia L.	Sun Spurge	Skærm-Vortemælk	*	*	*	*
Euphorbia peplus L.	Petty Spurge	Gaffel-Vortemælk	*	*	*	*
Festuca rubra L.	Red Fescue	Rød Svingel	*			
Fumaria officinalis L.	Common Fumitory	Læge-Jordrøg	*	*		*
Galeopsis tetrahit L.	Common Hemp-nettle	Alm. Hanekro	*	*	*	*
Galium aparine L.	Cleavers	Burre-Snerre	*	*	*	*
Geranium pusillum L.	Small-flowered Cranesbill	Liden Storkenæb	*			
Hordeum vulgare L.	Barley	Byg	-	-	-	*
Kickxia elatine (L.) Dumort.	Fluellen	Spydbladet Torskemund	*	*		*

Continues

Appendix C.1 continued

Scientific name	English name	Danish name	Vegeta-tive	Flower-ing	Seed setting	Bird available seeds
Lamium amplexicaule L.	Henbit	Liden Tvetand	*	*	*	
Lamium hybridum Vill.	Cut-leaved Dead-nettle	Fliget Tvetand	*	*	*	*
Lamium purpureum L.	Red Dead-nettle	Rød Tvetand	*	*	*	
Lapsana communis L.	Nipplewort	Haremad	*	*		
Lolium perenne L.	Rye-grass	Alm. Rajgræs	*			
Matricaria perforata Merat	Scentless Mayweed	Lugtløs Kamille	*	*	*	*
Myosotis arvensis (L.) Hill	Common Forget-me-not	Mark-Forglemmigej	*	*	*	*
Papaver rhoeas L.	Field Poppy	Korn-Valmue	*	*	*	*
Plantago major L.	Rat-tail Plantain	Glat Vejbred	*	*		
Poa annua L.	Annual Poa	Enårig Rapgræs	*	*	*	*
Poa trivialis L. ssp. *trivialis*/ *Poa pratensis* L.	Rough-stalked/Smooth-stalked Meadow-grass	Alm./Eng-Rapgræs	*			
Polygonum aviculare L.	Knotgrass	Vej-Pileurt	*	*	*	*
Polygonum lapathifolium L.	Pale Persicaria	Bleg Pileurt	*	*		*
Polygonum persicaria L.	Persicaria	Fersken-Pileurt	*	*	*	
Ranunculus repens L.	Creeping Buttercup	Lav Ranunkel	*			
Rumex crispus L.	Curled Dock	Kruset Skræppe				*
Sambucus nigra L.	Elder	Alm. Hyld	*			
Senecio vulgaris L.	Groundsel	Alm. Brandbæger	*	*		
Silene noctiflora L.	Night-flowering Campion	Nat-Limurt	*	*	*	*
Sinapis arvensis L.	Wild Mustard	Ager-Sennep	*	*	*	*
Solanum nigrum L. ssp. *nigrum*	Black Nightshade	Sort Natskygge	*			
Sonchus asper (L.) Hill	Spiny Milk-Thistle	Ru Svinemælk	*	*	*	*
Sonchus oleraceus L.	Milk-Thistle	Alm. Svinemælk	*	*	*	*
Stachys arvensis L.	Field Woundwort	Ager-Galtetand	*			
Stellaria media (L.) Vill.	Chickweed	Fuglegræs	*	*	*	*
Taraxacum sp. L.	Dandelion	Mælkebøtte	*			
Trifolium repens L.	White Clover	Hvid-Kløver	*			*
Triticum aestivum L.	Wheat	Alm. Hvede	-	-	-	*
Urtica urens L.	Small Nettle	Liden Nælde	*			
Veronica agrestis L.	Field Speedwell	Flerfarvet Ærenpris	*	*	*	*
Veronica persica Poiret	Large Field Speedwell	Storkronet Ærenpris	*	*	*	
Veronica arvensis L.	Wall Speedwell	Mark-Ærenpris	*			*
Veronica hederifolia L.	Ivy-leaved Speedwell	Vedbend-Ærenpris	*	*	*	
Viola arvensis Murray	Field Pansy	Ager-Stedmoderblomst	*	*	*	*

Appendix C.2. Names of the common arthropods in the study fields.

Arthropod class/order Scientific name	Lower taxonomic level Scientific name	English name	Danish name
Araneae		Spiders	Edderkopper
Opiliones		Harvestmen	Mejere
Chilopoda		Centripedes	Skolopendre
Diplopoda		Millipeds	Tusindben
Collembola		Springtails	Springhaler
Hemiptera			Næbmundede
	Auchenorrhyncha	Cicada	Cikader
	Aphididae	Aphids	Bladlus
	Rhopalosiphum padi	Bird-cherry oat aphid	Havrebladlus
	Sitobion avenae	English grain aphid	Kornbladlus
	Heteroptera	Bugs	Tæger
Lepidoptera		Butterflies and moths	Sommerfugle
Diptera		Flies	Tovinger
	Tipulidae	Crane flies	Stankelben
	Syrphidae	Hover flies	Svirrefluer
Neuroptera		Lacewings	Netvinger
	Chrysopidae	Green lacewing	Guldøjer
Coleoptera		Beetles	Biller
	Carabidae	Ground beetles / Carabids	Løbebiller
	Bembidion	Brassy ground beetles	Glansløbere
	Pterostichus cupreus	Strawberry ground beetles	Bred metaljordløbere
	Pterostichus melanarius	Strawberry ground beetles	Markjordløbere
	Trechus	A ground beetle genus	Grotteløbere
	Staphylinidae	Rove beetles	Rovbiller
	Silphidae	Carrion beetles	Ådselsbiller
	Scarabaeidae	Chafers and dung beetles	Gødningsbiller (torbister)
	Elateridae	Click beetles	Smældere
	Lathridiidae	Lathridiids	
	Cantharidae	Soldier beetles	Blødvinger
	Nitidulidae	Blossom beetles	Glansbiller
	Cryptophagidae	Mould beetles	
	Coccinellidae	Ladybirds	Mariehøns
	Chrysomelidae	Leaf beetles	Bladbiller
	Gastrophysa polygoni	Knotgrass beetles	Pileurtbladbiller
	Oulema	A leaf beetle genus (e.g. Cereal leaf beetles)	Bladbilleslægt (bl.a. Alm. kornbladbiller)
	Curculionidae	Weevils	Snudebiller
	Ceutorhynchus	A weevil genus	En snudebilleslægt
Hymenoptera			Årevingede
	Symphyta		Savhvepse (bl.a. bladhvepse)
	Tenthredinidae	Common sawflies	Egentlige bladhvepse
	Parasitica	Parasitic wasps	Snylte- og galhvepse

Appendix C.3. Names of the common birds in the study fields.

Scientific name	English name	Danish name
Alauda arvensis	Skylark	Sanglærke