SZENT ISTVÁN UNIVERSITY

Ph.D. THESIS

COMPARATIVE ANALYSES OF BIODIVERSITY ON LOWLAND ARABLE FIELDS, GRASSLANDS AND SET-ASIDE FIELDS IN THE VIEW OF CONSERVATION BIOLOGY

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1. BACKGROUND

Since the very beginning of agriculture 8000 years ago, most of Europe's area has been converted to arable fields and grasslands under cultivation (Vera 2000). The originally extensive agricultural habitats were settled by open landscape related flora and fauna elements (Sutherland 2002). However, in the second part of the 20th century, the intensification of agricultural production became higher than ever before, due to the technical investments and growing production demands (Krebs *et al.* 1999; Tilman *et al.* 2002). The amount of fertiliser and pesticide use multiplied, the landscape changed from small, mosaic parcels to monoculture systems of large fields (Robinson and Sutherland 2002; Tilman *et al.* 2002; Benton *et al.* 2003; Tscharntke *et al.* 2005), especially in the old member states of the European Union (EU) of Western and Northern Europe. As a consequence the cereal production doubled in the last 40 years (Tilman *et al.* 2002). The intensive agricultural management resulted in serious environmental problems and biodiversity decline and several once common plant and animal species became endangered (Tilman *et al.* 2002; Roschewitz *et al.* 2005).

In Central and Eastern Europe the agricultural intensification trend was similar to that in the EU member states between 1960 and 1980 (Gregory *et al.* 2005). After the collapse of the socialist regimes, however, agricultural production declined considerably (Báldi and Faragó 2007). Due to the higher proportion of extensive agricultural land, biodiversity remained higher in these regions than in the intensive Western and Northern European countries, which is well represented by the increasing populations of farmland birds in the Central and Eastern European countries. However, because of the recent admission of the post-socialist countries to the EU, farmland biodiversity there might face the same pressures from the regulations that caused considerable ecological problems and population declines in the older EU member states.

To counteract the negative effects of agriculture and consequent environmental problems, agri-environmental schemes (AESs) were introduced throughout the EU to stop biodiversity decline by reducing fertiliser and pesticide input and maintaining the remaining heterogeneous landscape structure (Kleijn and Sutherland 2003). Farmers can join voluntarily and they receive compensation through subsidies for the complying with certain restrictions, e.g. decreased use of fertilisers and pesticides. In Hungary the National AES was established by the EU accession and is now incorporated into the New Hungary Rural Development Programme (Ángyán *et al.* 2003; Haraszthy 2004). Up until now, the conservation benefits of these programs have been assessed only by a low number of studies. Although several million Euros have been invested in the AES within the EU, only a few hundred studies are available on the topic (Kleijn and Sutherland 2003; Kleijn *et al.* 2011).

In 1988/89 voluntary set-aside schemes were introduced in the EU. They became compulsory by the 1992 CAP reform, with the goal to reduce cereal overproduction. However, the resting of arable fields over few years seemed to be beneficial from soil protection and biodiversity conservation as well (van Buskirk and Willi 2004; Sotherton 1998). In 2008, compulsory set-aside management was abolished because of the increased production demands, which might cause still unknown ecological problems (Morris *et al.* 2011). In Hungary set-aside management was introduced as part of a special AES (Ángyán *et al*. 2003). The great bustard and bird habitat protection programs in some Environmental Sensitive Areas (ESA) require set-aside management of 20% of all land during the 5 year contract period, providing compensation subsidies. Arable fields are sown with a three-component seed mixture (two grasses and one leguminous species) after the last harvest and taken out of production for 1-3 years. Set-aside fields are cut once per year after 15th June, i.e. after the main breeding period of the soil-nesting farmland bird species. The lack of continuous management, compared to actively-managed arable fields, the diverse vegetation owed to the sown seed mixture, and the wild plants from the soil seed bank can provide suitable habitat for several arthropod and bird species. However, the environmental benefits of set-aside fields in Central and Eastern Europe is still largely unknown.

2. AIMS AND SCOPE

Due to the historical context and management strategies, Hungary's biodiversity is much higher than that of the Western European countries. However, its accession to the EU and consequent changes in agricultural practices might cause serious environmental problems. There are some studies about the agricultural and environmental national situation (Mandzáros *et al.* 1984), but even so, our knowledge about the potential consequences of agriculture intensification is still limited (pl. Báldi *et al.* 2005; Nagy *et al*. 2009).

This thesis investigates two main questions of the national agroecology. First it concentrates on the biodiversity of cereal fields, managed by different intensity. We studied the effects of local management intensity (fertiliser and pesticide use) and landscape structure on the weeds, arthropods and breeding and/or foraging bird species in cereal fields in the Kiskunság region. Our main hypotheses were:

(1) The local management practices, i.e. inorganic fertiliser and pesticide use, decrease the species richness and abundance of weeds, arthropods and birds.

(2) These taxa show different species richness and abundance in the edge and in the interior of the cereal fields.

(3) Landscape heterogeneity, measured by the percentage of semi-natural habitats (e.g. grasslands), within a 500 m radius, increases the diversity and abundance of weeds, arthropods and birds.

(4) In case of weeds, species requiring higher soil nitrogen content will be dominant in the intensive fields, while species with low or medium soil nitrogen tolerance will have lower cover or might even disappear.

(5) The species composition and structure of vegetation has an effect on the arthropods and birds species composition.

In the second part of this thesis, I analyze the vegetation, arthropod and bird fauna in one-, two- and three-year-old set-aside fields as a function of the elapsed time since the beginning of set-aside management and compered with winter cereal fields and semi-natural grasslands in the Heves ESA. Our main hypotheses were:

(1) The extensive management of set-aside fields, the lack of arable crop, and the annual cutting of vegetation promotes the growth of several plant species from the soil seed bank, resulting in diverse, heterogeneous vegetation.

(2) The diverse vegetation results in higher species richness and abundance and different species composition of arthropods and birds in the set-aside fields than in the cereal fields.

(3) The increasing age of set-aside fields results in changing biodiversity, which might become similar to that in the semi-natural grasslands.

3. MATERIALS AND METHODS

3.1. *I. Study: the effects of cereal field management intensity in the Kiskunság*

The study sites were located in and around the Kiskunság National Park. According to our questionnaire, five land-owners were chosen with a total of 18 cereal fields. We differentiated seven management intensity levels based on inorganic fertiliser use, represented usually by 3-3 cereal fields. Herbicides were used in six, insecticides were used in two cases from the seven.

The botanical survey was conducted in two parallel transects per field: one in the edge, in the first cereal rows and another one in the interior of the fields, 50 m from the edge. We surveyed the weed species and their cover, assessed the average vegetation cover, weed cover, vegetation height and the cover of bare soil. According to the time of their presence in our flora we distinguished native, archaeophyton and neophyton species (Botta-Dukát *et al.* 2004); we distinguished weed species with low-medium and high nitrogen preference based on the Borhidi nitrogen preference scale (Borhidi 1993).

Spiders (Araneae) and carabid beetles (Carabidae) were sampled by two funnel pitfall traps per transect during four two-week long period in May and June. In each transect, we placed one yellow pan trap for bee sampling, filled with water. Pantraps were emptied weekly in May and June. Species were categorized by body size, divided into small and large (Bombus spp.) wild bees (O'Toole and Raw 1991).

We assessed the relative abundance of birds using the point count method (Szép and Nagy 2002), in 12-15 100 m radius circle per intensity level in April and May. During the data analyses we considered only those bird species (in total 28), which use cereal fields as breeding and/or foraging habitat. Apart from the total species richness, abundance of skylark (*Alauda arvensis* L.) and yellow wagtail (*Motacilla flava* L.) were analyzed separately.

To test the effects of land-use on the biodiversity of arable fields, we calculated the percentage of semi-natural habitats within a 500 m radius around the sampling points, which describes the percentage of grasslands, forests and marshy habitats (Clough *et al.* 2007). The effects of management and landscape structure on the species richness and abundance of weeds, arthropods and birds and their functional groups were analysed using the linear mixed effect models. The explanatory variables were: the percentage of semi-natural habitats, the nitrogen content of fertilisers (kg/ha/year), the transect position in case of weeds and arthropods (edge *vs.* interior), and the number of insecticide applications in case of arthropods. The lack of spatial independence among samples from the same study sites was taken into account by random factors. In the case of arthropods and birds, we tested the effects of weed species richness, vegetation height and bare soil surface in separated models.

3.2. *II. Study: Set-aside management in the Heves ESA*

We compared the biodiversity of one-, two- and three-year-old agri-environmental set-aside fields to each other and to winter cereal fields and semi-natural grasslands. We chose 6-6 set-aside fields from each age category, one cereal field next to each set-aside field and six semi-natural grasslands.

The species richness of weeds, the vegetation height, and the bare soil surface were surveyed in ten 2X2 m botanical quadrates per field. Carabid beetles were sampled by five funnel pitfall traps per field, three times during May and June. We sampled orthopterans and butterflies by transect sampling in 10, 20 or 30 minutes depending on the field size. Orthopterans were sampled once in August by visual and acoustic counting. Butterflies were sampled four times between April and August. We placed one white, yellow, blue and green pan trap per field to sample bees in May and June. The relative abundance assessment of birds was carried out by point count method, two times in April and May. Species were grouped according to their feeding guilds (insectivores, granivores, predators) and European species protection status (species listed and not listed in the Species of European Conservation Concern (SPEC) list).

We tested the effects of habitat type (cereal field, one-. two- and three-year-old set-aside field, semi-natural grassland), using linear mixed effect models. We compared the following parameters: in the case of arthropods the species richness of weeds, and in the case of arthropods and birds the weed species richness, vegetation height, bare soil surface, variability of vegetation height and bare soil surface. The lack of spatial independence among samples from the same location was taken into account by random factors. We used Tukey-HSD post hoc test for pairwise comparison among the habitat types. We studied the effects of habitat type and weed species richness on the species composition of arthropods and birds by partial redundancy analyses (RDA).

4. RESULTS

4.1. *I. Study: the effects of cereal field management intensity in the Kiskunság*

- Weeds: the fertiliser nitrogen had a significant negative effect on the species richness of archaeophytons and weeds with low-medium nitrogen preference and on the cover of native weeds. The interaction between transect position and percentage of semi-natural habitats was marginally significant in the case of total species richness and significant in the case of archeopthytons and weeds with low-medium nitrogen preference. This means the difference in the species richness of weeds between the edge and the interior of cereal fields is higher in homogenous than in heterogeneous landscape.
- Spiders and carabid beetles: the species richness and abundance of spiders and carabids was significant higher at the edge of cereal fields than in the interior. We found that semi-natural habitats, fertiliser and insecticide use had no effect. The species richness of weeds had significant positive effect on the species richness of spiders.
- Bees: the fertiliser nitrogen content had a negative effect on the total abundance of bees and on the abundance of small bees, but did not affect the large bee species. Insecticide use had a significant, negative effect on the total species richness, the species richness of small bees and the abundance of large bees, but only a marginal negative effect on the total abundance. In fields with more intensive fertilisation, there was lower difference in total abundance between the edge and interior of fields. The percentage of semi-natural habitats, the species richness and cover of insect-pollinated plants had no effect on the species richness and abundance of bees.
- Birds: we found less bird species and fewer individual birds, in areas with vegetation cover higher than 85%. There were more birds in the larger fields. The abundance of skylark increased where there were a higher percentage of semi-natural habitats, but it was lower in fields larger than 100 hectare. The vegetation cover and the species richness of weeds had positive effect on the abundance of skylark, which was highest in case of ca. 21 weed species. The percentage of semi-natural habitats had negative effect on the abundance of yellow wagtail, the field size had positive effect on their abundance. It was lower in case of the highest fertiliser nitrogen amounts.

4.2. *II. Study: Set-aside management in the Heves ESA*

- Weeds: the species richness of weeds was much higher in the set-aside fields and semi-natural grasslands than in the cereal fields. With the increasing age of set-aside fields, the height of vegetation decreased and the percentage of bare soil surface increased. The variability of vegetation height and bare soil surface was far beyond the cereal fields.

- Carabids, orthopterans, butterflies and bees: the species richness and abundance of carabids, orthopterans and butterflies was the lowest in the cereal fields. The species richness of carabids was the highest on the two-and three-year-old set-aside fields, but their abundance did not differ among the habitat types. The species richness of orthopterans showed a linear, increasing trend with the age of set-aside fields and it was the highest in the grasslands. The abundance of orthopterans was the highest in the two- and three-years old set-aside fields. The species richness of butterflies was higher even in the one-year-old set-aside fields than in the cereal fields and similar to that on the older set-asides and grasslands. The abundance of butterflies was higher in the grasslands than in the set-aside fields. The species richness and abundance of bees showed no difference among the habitat types. The weed species richness had significant positive effect on the species richness of carabids, orthopterans and butterflies, and on the abundance of orthopterans and butterflies. The vegetation height had significant positive, the percentage of bare soil surface had negative effect on the species richness of orthopterans.
- Birds: the most abundant species were the skylark, the yellow wagtail and the corn bunting (*Miliaria calandra* L.). The species richness and abundance of farmland birds was significant higher in the set-aside fields than in their cereal field pair. The effectiveness of set-aside management increased in regard to species richness as a function of set-aside age. Species richness was higher in the three-year-old set-aside fields than in the younger ones. Both the insectivores and granivores bird species showed the lowest species richness and abundance in the cereal fields and the one-year-old set-asides, but increased on the two-and three-year-old fields. The species richness and abundance was similar on the three-year-old set-asides and grasslands. We found similar patterns in case of the SPEC and non-SPEC species. The species richness of weeds had a positive effect on the species richness and abundance of birds, with the exception of the species richness of granivores. The species richness and abundance of insectivores and the species richness of non-SPEC species decreased with the increasing vegetation height. The percentage of bare soil surface had a positive effect on the granivores and PSEC species. The variability of bare soil surface increased the species richness and abundance of birds. The variability of vegetation height had a positive effect on the species richness and abundance of insectivores, and on the abundance of non-SPEC species.
- Species composition analyses: the redundancy analyses (RDA) showed the significant effect of habitat type on the species composition of carabids, orthopterans, butterflies and birds.

The weed species richness had significant effect on the species composition of orthopteran and bird assemblages.

4.3. New scientific results

4.3.1. *I. Study: the effects of cereal field management intensity in the Kiskunság*

(1) Inorganic fertiliser application decreases the species richness and weed cover, especially those of native species and those with low-medium nitrogen preference, and has a negative effect on the arthropods and bird species, being strongly connected to cereal fields. The insecticide use decreases the species richness and abundance of arthropods with low distribution, for example those of small bees.

(2) The edge of cereal fields (first cereal rows) is richer in weeds and arthropods than the interior of the fields, which difference is higher in case of intensive management.

(3) Considering the landscape scale effects, a higher percentage of semi-natural habitats in 500 m radius around the fields increases the number of native weed species and the abundance of some bird species, for example skylarks in the cereal fields.

(4) The weed species richness has a positive effect on the species richness of arthropods and on the abundance of some bird species. The species richness and abundance of birds in cereal fields is highest in case of medium vegetation cover.

4.3.2. *II. Study: Set-aside management in the Heves ESA*

(1) The extensive management of set-aside fields, the lack of arable crop and the annual cut promotes the growing of several weed species from the soil seed bank, developing diverse and structurally heterogeneous vegetation.

(2) The species richness and abundance of arthropods and birds is higher in set-aside fields than in cereal fields, and the species composition differs as well, which is partly due to the high weed species richness on the set-aside fields in the case of orthopteran and bird assemblages.

(3) During the three years of set-aside management, the weed species richness and the percentage of bare soil surface increase, the vegetation height decrease. The species richness and abundance of some arthropod groups and farmland birds show increases with increasing set-aside age, however, set-aside fields are I general richer in biodiversity compared to cereal fields. The set-aside fields are richer in weed species than the semi-natural grasslands. Arthropods and birds are found in similar numbers in the two habitat types.

5. CONCLUSIONS AND RECOMMENDATIONS

5.1. *I. Study: the effects of cereal field management intensity in the Kiskunság*

From a conservation biology point of view, the extensive agricultural management at the local and landscape scale promotes the distribution of native and archaeophyton weed species, while it negatively affects the neophyton weed species, which often spread invasively in the intensive sites (Botta-Dukát *et al.* 2004; Šilc and Čarni 2005). However, depending on the management of the cereal fields, the positive effect of the surrounding semi-natural habitats at the landscape scale appears only in the edge of the cereal fields. The propagulums cannot develop in the interior part of the cereal fields in case of intensive management with their dense and tall crop. Therefore the extensive management and the decreased amount of fertiliser at the scale of the field might have considerable importance in the conservation of arable weeds. AESs in Central Hungary might be able to keep the diverse arable weed vegetation, especially native and archaephyton weeds this way.

The diverse vegetation composition and structure enhance the arthropod and bird assemblages, which play an important role in crucial ecosystem services, such as pollination and biocontrol (Bianchi *et al.* 2006; Ebeling *et al.* 2008). Bees are responsible for the pollination of many crop and wild plant species; their decline, due to intensive agricultural practices. The decreased pollination efficiency might have serious ecological and economic consequences (Biesmeijer *et al.* 2006; Klein *et al.* 2007). In Hungary 80% of plant species, including some arable crops, are pollinated by bees (Pinke *et al.* 2008). In order to conserve our still rich bee fauna, extensive agricultural management is required. The decreased use of inorganic fertilisers might be beneficial, particularly in regards to the small bees, since they are more sensitive to the local site conditions because of their more limited distribution distance. Less inorganic fertiliser results in richer weed assemblages, higher number of insect-pollinated plants, and more foraging resources for bees. The reduced application of insecticides has a positive effect on both small and large bees. Extensive management at the landscape scale, the remaining of semi-natural habitats is especially important for the large bee species, and foraging even over large distances from their nest.

This study failed to detect strong direct effects of agricultural intensity on species richness and abundance of farmland birds, possibly due to the limited number of study sites. However, we suggest that the further intensification of cereal fields and the loss of surrounding semi-natural habitats might have serious negative effects on the most abundant farmland bird species, e.g. skylark and yellow wagtail. We emphasize therefore the reduced application of inorganic fertilisers (max 100 kg nitrogen/ha/year) and the conservation of semi-natural habitats as a strategy to keep the diverse farmland bird assemblages.

5.2. *II. Study: Set-aside management in the Heves ESA*

The set-aside management on arable fields had a considerable positive effect on the species richness and abundance of the studied weeds, arthropods and birds, due to the lack of continuous management and arable crop. In the case of arthropods and birds, this is linked to the compositionally and structurally diverse vegetation, developed from the soil seed bank. Reduced disturbance, i.e. the annual cut of vegetation, helps maintain this diverse vegetation during several years, which promotes the conservation of arthropods and birds in the set-aside fields (Siemann 1999; Goulson et al. 2008). In contrast, the continuous and more intensive management of cereal fields has often negative effects on farmland biodiversity.

Although we found almost no difference in the species richness and abundance of arthropods among the different aged set-aside fields, there were considerable changes on community level (Steffan-Dewenter and Tscharntke 1997). Previous studies suggest the increasing dominance of important pollinators and pest control agents over the years of set-aside management too (Corbet 1995). However, our study showed the importance of one-year-old set-aside fields as well, where more butterflies were found compared to the cereal fields. Further studies would be necessary to investigate the assemblages of flora and fauna of set-aside fields over the three years. According to our results, set-aside fields are suitable habitats for both arable field and grassland related plant and arthropod species, providing a special opportunity to conserve farmland biodiversity. Furthermore they can provide habitats for important pollinator and biocontrol agents, enhancing these ecosystem services on the adjacent crop fields as well. These ecological processes would be worth of further research.

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7. PUBLICATIONS

1. Journal articles

1.1. In English in international journals with IF

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