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Environmental Management on Farmland

Can short-rotation coppice strips compensate structural deficits in agrarian landscapes?

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Summary

We investigated the habitat effects of short-rotation coppice strips (SRCs) on plant, arthropod and bird communities to determine the role of SRCs in a landscape context. The habitat effects of SRCs were compared to various agrarian and semi-natural reference biotopes to analyse the added value provided by SRCs within the landscape. We compared the habitat quality of SRCs with that of agricultural land and analysed the interactions between SRCs and adjacent cultivated land to assess the potential of SRCs to improve habitat availability in agricultural landscapes. We also investigated the effects of fuel-wood strips on nature-conservation targets and their contributions to habitat connectivity and ecosystem services. We found that SRCs exhibited certain unique habitat conditions that distinguished their biotic communities from those of all other biotopes within the agrarian landscape. The crop stand architecture was highly dynamic, making the SRCs suitable for a mixture of species typical of agricultural fields or grasslands, hedgerows, ruderal plots and forests and resulting in high species richness. With increasing shading by trees, the densities of forest arthropods and bird species that require wood structures increased. Herbaceous ground vegetation developed toward the grassland or field margin vegetation, a vegetation type which is really scarce in many agricultural landscapes in Germany. We conclude that short-rotation coppice strips contribute little to traditional conservation targets, such as rare-species conservation, but they have substantial effects on habitat connectivity and ecosystem services.

Key words: Herbaceous vegetation, arthropods, birds, species richness, habitat connectivity

Introduction

One of the basic obstacles for the integration of biodiversity-conservation measures into current agricultural practice is the lack of (economic) interest from farmers. Economic compensation for conservation measures that are fully decoupled from agricultural business is not only quite expensive but also limited in success due to limited commitment of farmers to achieving the planned outcomes. Because most traditional nature-conservation targets for agricultural lands require some form of extensive land management, it is questionable whether modern agriculture in general can successfully integrate conservation goals.

Short-rotation coppice (SRC) provides dry-matter biomass yields ranging from 5 to 11 (od)t* ha^{-1}*yr^{-1} in the UK (Aylott *et al*., 2008) depending on the soil water supply, crop species and rotation period. Arable crop yields may benefit from SRC strips due to reduced wind and water erosion, decreased transpiration and increased drought resistance (Brandle *et al*., 2004). The biodiversity effects of SRCs are controversial. The lack of fertiliser and pesticide use as well as the lack of soil disturbance is generally regarded as likely to encourage wildlife (Nerlich *et al*., 2012). Recent surveys show that the ground vegetation of SRC plantings is often dominated by ruderal or weed species (Britt *et al*., 2007), and few or no rare or endangered species are likely to occur (Weih *et al*., 2003; Britt *et al*., 2007). Even bird abundance and species numbers are found to be relatively low (Gruss & Schulz, 2011) compared to semi-natural woody biotopes. In a review, Dauber *et al*. (2010) have noted that negative, neutral and positive impacts of biomass crops on biodiversity have been found at the field scale. The results depend on the crop species, the prior land use, the landscape and biogeographical context and the group of organisms considered.

Within the framework of a joint research project (ELKE - Establishing extensive land use systems as compensation measures), we investigated the potential of bioenergy cropping systems to contribute to both the sustainable use of biomass and nature-conservation targets. The major objectives of this project were to identify the biodiversity effects of SRCs within the context of a given landscape. Our field studies focused on comparing the bird, arthropod and herbaceous plant communities within SRCs to those found in a variety of regional reference biotopes. Based on this comparison, we attempted to quantify the contribution of SRCs to nature-conservation targets, such as species and biotope conservation, biotope connectivity and ecosystem services, with regard to the established regional biotope inventory.

Materials and Methods

The field studies were carried out in southern Germany at the Scheyern Research Station, a 150-ha cloister estate located 40 km north of Munich in Bavaria. The annual precipitation is 803 mm, and the mean annual temperature 7.4°C. The predominant soils are thin (<2 m) loess-loam or loess deposits. Scheyern is situated in the tertiary hills, which represent one-third of Bavaria's agricultural region. The landscape is characterised by typical problems associated with intensive agricultural use, such as erosion, soil compaction, groundwater contamination, faunal and floral impoverishment and a lack of hedgerows and fallow strips (Schröder *et al.*, 2002).

The field studies were carried out from 2010 to 2012 and began with a detailed mapping of the biotope inventory in the study area in 2010. During this biotope mapping, the major structural parameters and dominant plant species were recorded in every biotope plot. A classification of the representative biotopes covering the major combinations of habitat conditions in the study area was used to select sites for the subsequent biotic-community surveys. The biotopes were classified using cluster analysis (TWINSPAN; Hill, 1979), correspondence analysis (CA) and canonical correspondence analysis (CCA, CANOCO 4.5; ter Braak & Smilauer, 2002). Based on the results of these analyses, we selected the following biotopes as reference systems for the SRC habitats: arable land, meadows, grass-dominated field margins, fallow land, forest edges and forests. To strengthen the comparability between the biotopes, the plots selected for subsequent surveys were limited to the area within 200 m of each SRC site (Fig. 1). By selecting sites located near each other in space, we ensured that the site conditions and local lateral impacts would be similar and that plant and arthropod species exchange could occur.

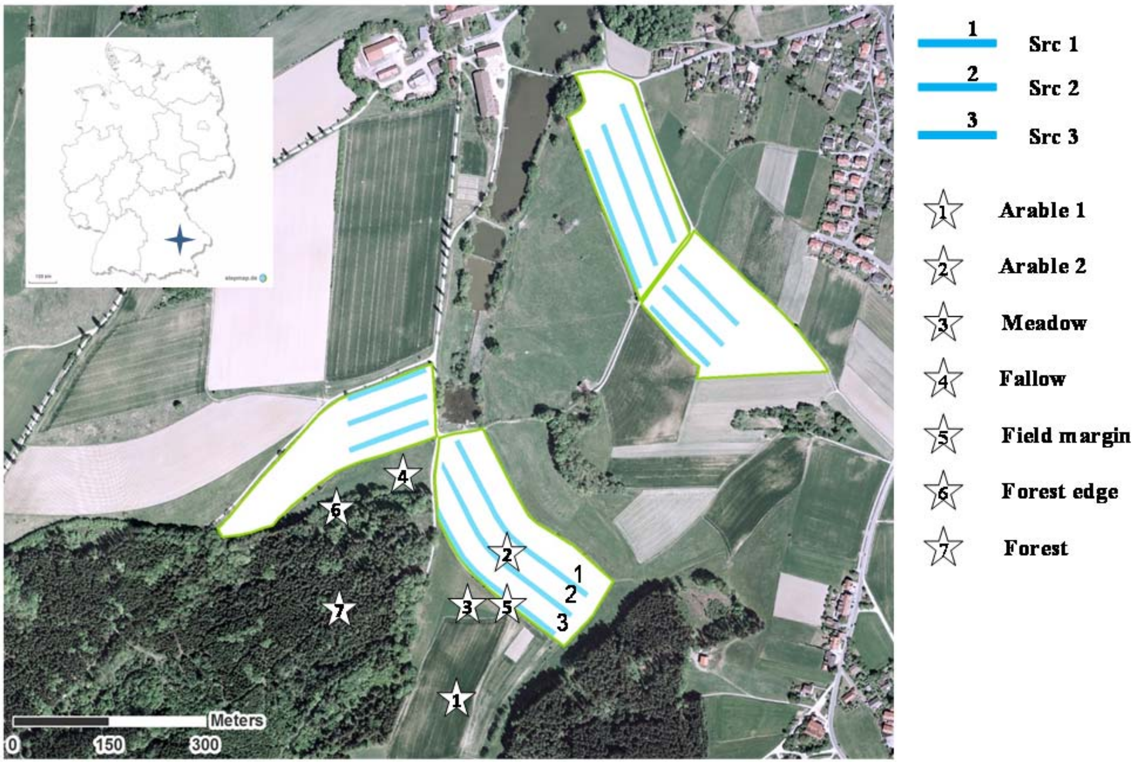

Fig. 1. Sampling design for the vegetation and arthropod surveys in SRCs and reference biotopes.

Short-rotation coppice strips

The SRC strips were planted in April 2009. Each strip consisted of three double rows spaced 1.5 m apart, with an overall width of 8.25 m. The planted tree species changed every 30 m within each strip to evaluate the yield potential of different tree crops for the given site conditions. The following species were planted within the strips along four arable fields: four poplar varieties ("Max3", "Muhle Larson", "Angroscoggin" and "M"), robinia, willow ("Inger"), black alder and a mixture of regionally common hedge trees. Ground vegetation was manually cut three times during the first year after planting to avoid seedling losses due to weed competition. After planting, no fertilisers or pesticides were applied. The regional hedge-tree mixture showed substantial tree loss for a variety of reasons. The black alder segments also suffered substantial losses in 2009/2010 due to fungal infestation. The black alders were re-planted in 2010.

Vegetation survey

We surveyed the vegetation in four replicate plots within each biotope using 5 m × 5 m fixed plots, except in the forest biotope, where 100 m × 100 m plots were used. The surveys were carried out three times per year in 2011 and 2012 to detect the seasonal differences in vegetation aspects and to obtain a realistic picture of the total regional species inventory. In addition to compiling a species list, we characterised the abundance of each species separately in all vegetation layers. Species abundance was measured based on ground coverage according the Braun-Blanquet scale. Some additional structural parameters were recorded, including the average layer height and the proportions of woody species, herbs and grasses, lichens, plant litter and bare ground.

Arthropod survey

Epigeal spiders were caught in 10 plots (see Fig. 1) using pitfall traps (Barber, 1931), which were arranged in a straight line with an inter-trap distance of 5 m. Five pitfall traps were established in each plot during the vegetation period. The traps were changed every two weeks, and the trapped spiders were sorted in the laboratory and preserved in 70 % ethanol for subsequent species-level determination.

Bird survey

The bird community was surveyed five times per year in 2011 and 2012, starting at the beginning of March and ending in the middle of July. The entire study area was surveyed. Bird species occurrence was assessed according to the territory-mapping method of Südbeck *et al*. (2005). All bird surveys were undertaken in the early morning hours. All observed species and individuals were recorded and classified as breeding, feeding or migrating birds. Individual territories were delineated by interpreting bird behaviour and migration. Nests were not sought directly but were recorded when they were discovered by chance. The results of this survey can be interpreted only in terms of the number and density of individual territories for each bird species, supporting conclusions related to habitat use or habitat suitability rather than reproductive success.

Data analysis

The similarity of the plant and arthropod species composition in the SRCs to that of the reference biotopes was analysed by canonical correspondence analysis (CCA) using the software package CANOCO. To ensure the validity of the analysis, only species with an overall frequency greater than 10% were included in the analysis. We used generalised linear models (GLM; SPSS 16.0) with the nonlinear Poisson-log linear link function and the WALD coefficient to quantify the differences among biotopes with regard to the annual and spatial variance among the replicates of the plant and arthropod surveys. We interpreted the marginal means based on their residuals. The GLM provided the following additional outputs: i) estimates of the eta parameter, which expresses the partial variance due to individual factors or interactions; ii) contrast tests, providing significance levels for each factor level according a predefined baseline and iii) *post-hoc* tests for the marginal means using the Bonferroni correction for the fixed factors. The bird data were mapped onto the biotope inventory using GIS to visually demonstrate the spatial habitat use of seven selected bird species with different habitat requirements. One of these species was a typical forest bird (common blackbird), three were typical shrub and hedgerow users (common whitethroat, garden warbler, yellowhammer) and three were typical of open habitats (skylark, grey partridge, meadow pipit). The habitat-use analysis differentiated between breeding/fixed territories and feeding/singing perch sites. Breeding/fixed territories were classified only when they could be unambiguously identified; any ambiguous observation was classified as feeding habitat use.

Results

Vegetation

In 2012, we found 189 plant species across all plots. As shown in Fig. 2, the SRC strips contained by far the greatest species richness during both years of the study. The total species numbers in the SRCs were approximately 2–3 times higher than those in cultivated fields, 50–100% higher than those in grass-dominated biotopes (meadows, fallows, field margins) and 25–60% higher than those in the forest site. The species numbers in the SRC strips decreased slightly from 2011 to 2012 in the poplar and robinia segments, where shading by trees was strongest.

The species composition in the SRC strips was characterised by a mixture of arable, grassland and ruderal species. The canonical correspondence analysis (Fig. 3) revealed that the ground-level vegetation in the SRC strips was highly similar to that of the meadows and field margins. These plant communities were clearly distinguished from those of the forest and forest edge, where mostly different species occurred. The vegetation of the SRC strips differed from that of the arable land independent of the crop type and also differed from that of the fallow land. Although most of the vegetative cover consisted of grassland and ruderal species, we recorded two red-list species (typical of arable land) and an increasing proportion of woodland-associated herbaceous perennials and shrubland-associated species. In contrast, we found almost no species typical of dry-grassland communities in the SRCs.

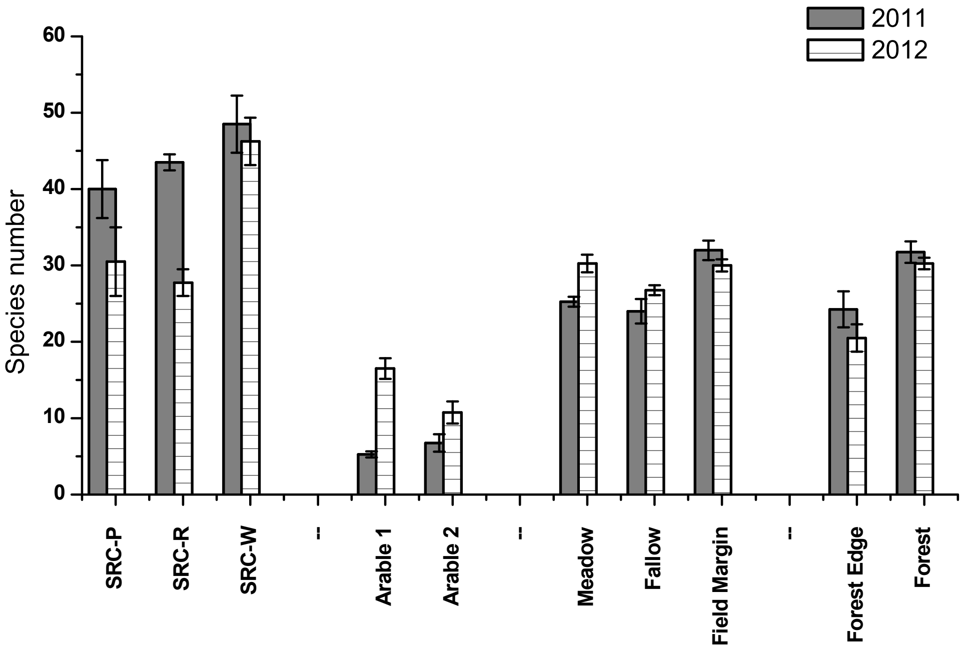

Fig. 2. Comparison of the total plant species number in the SRCs and reference biotopes in 2011 and 2012 (sum of four replicates, surveyed three times per year; SRC-P – poplar; SRC-R – robinia; SRC-W – willow; arable 1 – wheat/summer barley; arable 2 – potatoes/wheat).

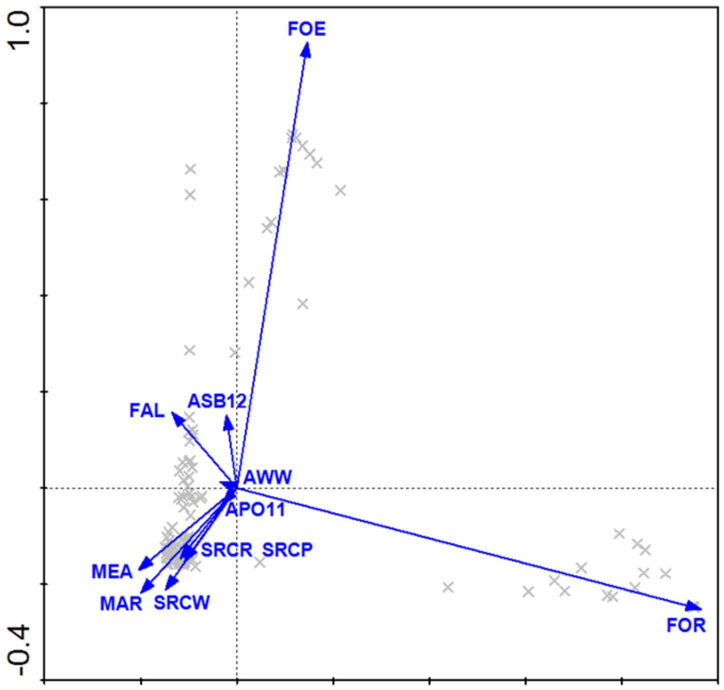

Fig. 3. Species composition of the SRC strips compared to that of the reference biotopes (canonical correspondence analysis; AWW – arable winter wheat; ASB12 – arable summer barley, 2012; APO11 – arable potatoes, 2011; SRC-P – poplar; SRC-R – robinia; SRC-W – willow; FOE – forest edge; FOR – forest, MEA – meadow; MAR – field margin; FAL – fallow).

Epigeal spiders

The regional species pool of epigeal spiders included 127 species in 2011 and 126 species in 2012. The differences in species numbers between the surveyed biotopes were small and not significant. The largest species numbers were found in the forest edges and field margins, while the lowest species numbers were found in the arable fields. An intermediate number of species occurred in the SRC strips. We calculated three indices with different foci to characterise the diversity of the spider communities in the SRCs (Table 1). The Shannon index indicates that spiders were more evenly distributed in the SRCs than in the cultivated fields or meadow. The SRC strips tended to have more species with only one individual (as shown by the Alpha index) and an intermediate number of highly dominant species (as shown by the Simpson index) compared to the arable fields and meadow. Both indices had lower values in the SRCs than in the forests and forest edges, which generally had the highest values of these indices.

Table 1. *Diversity of spider communities in SRC strips compared to reference biotopes (annual species occurrences based on 2011 and 2012 field surveys; SRC-1, SRC-2, SRC-3 – short-rotation coppices; Ara1, Ara2 – arable fields; MEA – hay meadow; FAL – fallow; MAR – field margin; FOE – forest edge; FOR – forest)*

Index	SRC-1	SRC-2	SRC-3	Ara1	Ara2	MEA	FAL	MAR	FOE	FOR
Species number, 2011	38	36	37	28	23	34	45	46	53	32
Species number, 2012	35	41	34	31	31	44	36	57	54	37
Simpson index, 2011	6.90	3.09	5.16	2.25	3.58	1.93	5.88	2.43	8.92	8.54
Simpson index, 2012	6.62	8.93	4.97	7.67	4.47	2.26	4.85	6.14	12.37	10.00
Alpha index, 2011	10.18	7.68	8.39	6.33	5.05	6.04	9.14	12.8	15.57	10.02
Alpha index, 2012	11.73	11.65	8.51	7.07	7.02	9.91	8.39	13.65	16.84	12.82
Shannon index, 2011	2.5	1.77	2.08	1.59	1.77	1.18	2.16	4.84	2.89	2.67
Shannon index, 2012	2.52	2.72	2.19	2.43	2.06	1.56	2.24	2.44	3.05	2.73

The role of SRC strips in promoting forest species and in providing biotope connectivity can be evaluated most effectively by examining the occurrence of forest-associated species within the SRCs (Fig. 4). The number of individuals of forest-associated species increased significantly from 2011 to 2012, 4 years after the establishment of the SRC strips. In 2012, more individuals of these species were recorded in the SRCs than in any other biotope except forests and forest edges.

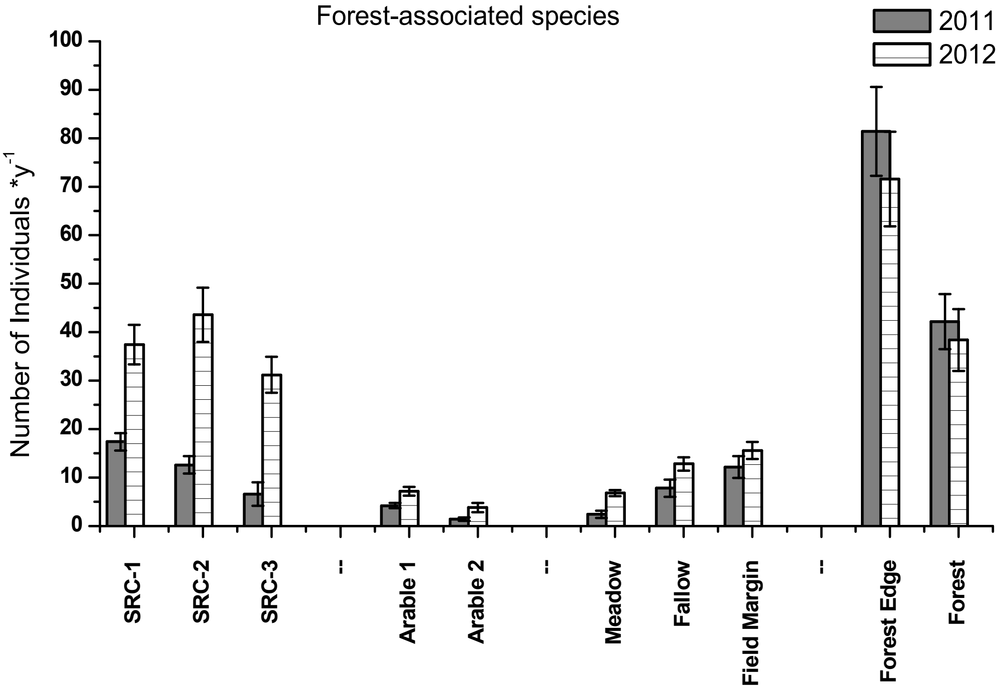

Fig. 4. Occurrence of forest-associated epigeal spiders within SRC strips compared to reference biotopes (sum of five replicates, SRC-1,2,3 – short-rotation coppices; arable 1- wheat/summer barley; arable 2 – potatoes/wheat).

Birds

In 2012, 55 bird species were recorded within the boundary of the study area. Another 11 species were recorded near the boundary and apparently occurred at least temporarily within the study area.

We selected seven common species to clarify the impact of SRCs on bird abundance (Fig. 5). Species typically found in cultivated land, such as skylark, partridge and meadow pipit, were generally uncommon in the study area but were found in the neighbourhood of the SRCs (see upper-right corner), though not inside the SRCs. All of the selected shrubland species (common whitethroat, garden warbler and yellowhammer) benefitted from the SRCs. The magnitude of this effect likely depends strongly on the surrounding landscape features. The SRCs located in the upper-right corner were disturbed by the neighbouring human dwellings and had low connectivity to existing habitat patches, while the SRCs in the lower-right corner showed a much stronger effect. Some woodland- or forest-associated species (e.g., common blackbird) were observed to use the SRCs as breeding habitat. We found no rare or endangered bird species using the SRCs as habitat. Most of the recorded species were common, widespread and broadly adapted. The SRC strips substantially extended the habitat availability for shrubland species by the fourth year after planting. The habitat structure provided by the SRCs was accepted by the shrubland birds and proved suitable for their breeding.

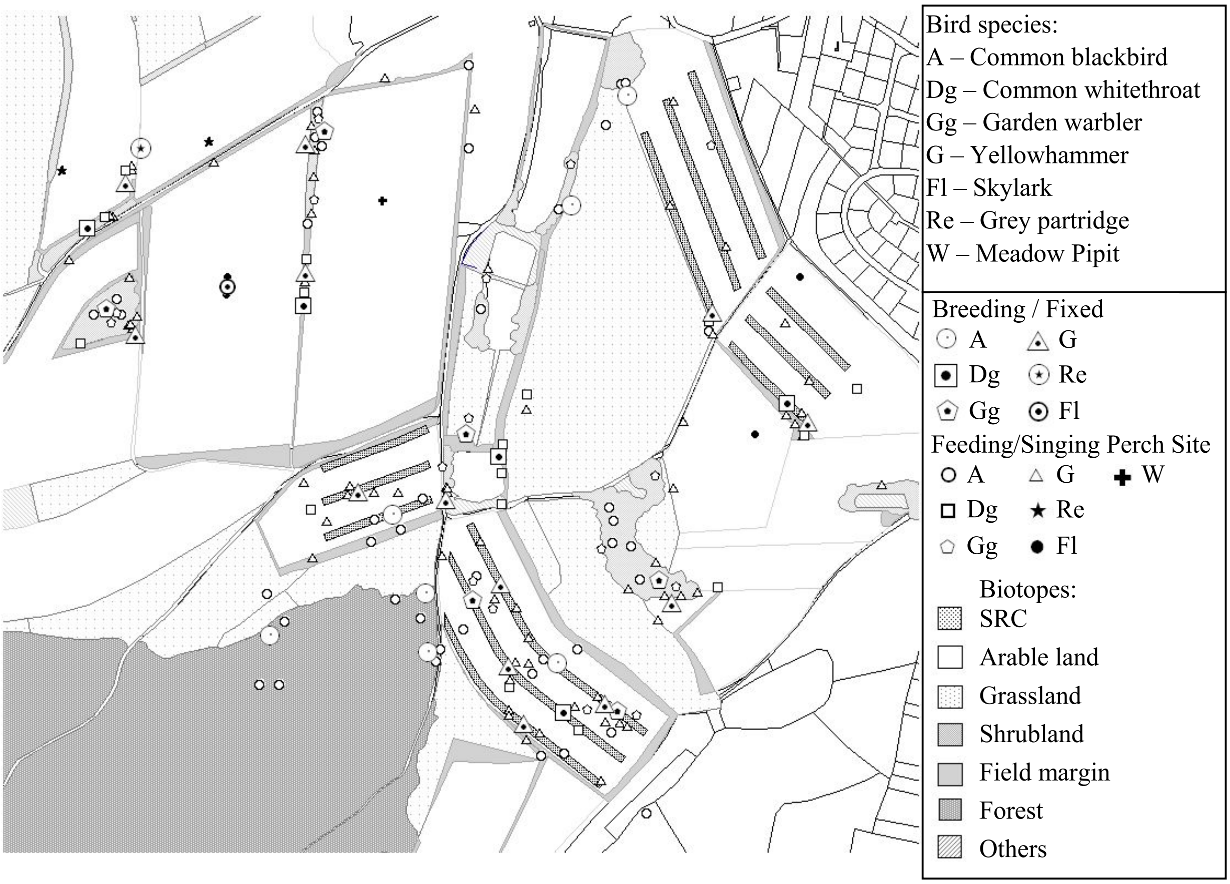

Fig. 5. Contribution of SRC strips to the habitat use of birds in the landscape (Scheyern Research Station, 2012, differentiating between habitat use for breeding/fixed territories and feeding/singing perch sites; territory-mapping method).

Discussion

There are several issues of concern regarding the potential effects of SRCs on wildlife in open areas. The choice of the reference system appears to strongly affect the final conclusions of many recent publications. The bird communities in SRCs have been found to be “principally poor” in species and individual numbers compared to those of natural old-growth willow shrublands (Gruss & Schulz, 2011); similarly, the plant diversity of SRCs has been found to be low compared to that of old-growth mixed-deciduous forests (Weih *et al*., 2003). Compared to arable land and coniferous forests, which dominate most landscapes in the study region,

SRCs have been reported to support substantially higher bird species numbers and densities (Schulz *et al*., 2009). SRC plantings were richer in plant species than arable land, coniferous forest or German mixed forest (Baum *et al*., 2012). The ground-beetle diversity in SRCs has been found to be lower (Schulz *et al*., 2009) or not significantly different (Allegro & Sciaky, 2003) compared to arable land. According to Mast *et al*. (2012), SRC strips tend to increase carabid-beetle species richness in neighbouring cultivated fields. Most studies have found that SRCs do not contribute to the occurrence of endangered species (Baum *et al*., 2012). Because many papers (e.g. Dauber *et al*., 2010) have stressed the importance of the surrounding landscape for the nature and magnitude of the biodiversity effects of SRCs, we attempted to investigate these effects in a clearly delineated landscape context and within a sampling design that allowed species to migrate between the study plots. Therefore, the species pool was similar for all biotopes investigated.

Our results suggest that SRC strips provide habitats with high plant diversity, especially compared to the arable land that they replace. This high species richness is mainly caused by the highly dynamic vegetation of the system, which remains in early secondary succession due to the mixing of species from arable land, grassland and disturbed areas (Baum *et al*., 2012). The plant species composition of SRCs is highly similar to that of grass-dominated field margins and old meadows. SRC strips can apparently offset the structural habitat deficit of cultivated land for plants associated with field margins, natural grasslands or forests and for shrubland-associated herbaceous perennials.

In agreement with the findings of Mast *et al*. (2012) for carabids, we found no significant effects of SRCs on the species richness of epigeal spiders. The spider community was more evenly distributed in SRCs than on arable land or meadows but was less evenly distributed in SRCs than in natural habitats, such as forest edges and forests. SRC strips provide alternative habitats for forest-associated species and may help to improve habitat connectivity for forest-associated arthropods. To assess the specific contribution of SRCs to arthropod communities, Allegro & Sciaky (2003) have suggested the use of a forest-affinity index.

Our bird survey underpins the role of woody habitats in promoting the presence of birds in agricultural landscapes. Species that prefer woody open range habitats, such as yellowhammer, garden warbler, common whitethroat and common blackbird, already showed intensive use of the SRCs in the fourth year after planting. In general, SRCs increase the density of bird territories and provide foraging habitat during both summer and winter (Sage *et al*., 2006). We did not detect any trend in the densities of species that regularly use arable land, such as skylark and partridge, due to their rarity in the study area. Sage *et al*. (2010) has found that SRCs support high skylark densities comparable to those found in wheat crops.

We conclude that SRCs have their own particular habitat qualities resulting from a novel combination of habitat conditions found in existing biotopes (Baum *et al*., 2012). The plant communities of SRCs are somewhat similar to those of field margins, meadows and forest-related shrublands. Among the arthropod community, forest-associated species are positively impacted by SRCs. Among bird species, those associated with structured woody habitats in open areas appear to benefit most from SRCs.

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