

Sown wildflower areas to enhance spiders in arable fields

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ABSTRACT

Sown wildflower areas (SWA) are cultivated in Switzerland to preserve and enhance farmland biodiversity. Here, the impact of SWA on spider density, diversity and species richness in winter wheat fields was studied. Edge effects and field scale effects of SWA were compared with landscape effects of perennial habitats in general. Adjoining SWA enhanced the densities of crab spiders (Thomisidae), ground spiders (Gnaphosidae), wolf spiders (Lycosidae) and young orb weavers (Araneidae) in wheat fields. In addition, numbers of wolf spiders and ground spiders increased towards field edges. Surprisingly, species richness was unaffected by SWA. Species richness, Simpson diversity, and densities of all spiders, and densities of sheetweb spiders (Linyphiidae) increased with the percentage of perennial habitats in 1.5 km radius. In conclusion, high spider diversity in wheat fields depends on perennial habitats at the landscape scale. To enhance cursorial spider families and orb weavers, SWA should be interspersed between crop fields.

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1. Introduction

Incorporating native flowering plants into agricultural landscapes has been proposed to maximize arthropod-mediated ecosystem services (Isaacs et al., 2009). Areas planted with wildflowers can provide key resources to beneficial arthropods that have become rare in modern agricultural landscapes. For example, they can serve as overwintering sites, provide alternate hosts and prey, or serve as shelter when crop fields are cultivated or receive pesticides. Sown wildflower areas (SWA) support a high diversity of beneficial arthropods, including spiders (Frank and Nentwig, 1995; Aviron et al., 2009). SWA were introduced in Switzerland as a regular agri-environment scheme in 1993 (Günter, 2000) and may enhance spiders beyond the boundaries of ecological compensation areas (Tscharnkte et al., 2007).

When testing the potential of agri-environment schemes for pest control, it is important to determine the spatial scale at which compensation areas influence the fauna (Tscharnkte et al., 2007). Some arthropods decrease in abundance within tens of meters from SWA (Frank and Nentwig, 1995; Jmhasly and Nentwig, 1995). On the other hand, spiders in arable fields have been shown to respond to landscape composition at scales up to several kilometres (Schmidt et al., 2008; Drapela et al., 2008).

Spiders were surveyed in 20 fields of winter wheat in terms of species richness, diversity and density to compare the influence of contiguous SWA vs. perennial habitats in the surrounding landscape. Higher diversity and density were expected (i) at the edge compared to the centre of fields, (ii) in fields with adjoining SWA compared to fields with grassy margins, and (iii) in landscapes with high percentages of perennial habitats compared to landscapes dominated by annual arable crops.

2. Methods

Ten landscape sectors of 1500 m radius were chosen in the study region between Solothurn and Bern, Switzerland. In each landscape sector, one winter wheat field with adjoining SWA and one winter wheat field with adjoining grassy margin were chosen. The distance between these paired fields was between 300 and 500 m. Fields received herbicides, fungicides and predominantly mineral fertilizers, but no insecticide sprays. None of them was under organic farming. The study fields were between 0.5 and 4.1 ha in size and lay between 438 and 585 m.a.s.l. SWA were sown on arable land with a certified mixture of 25 species of herbs (Günter, 2000). SWA persisted for up to six years, during which fertilizers, insecticides or fungicides were not applied. The studied SWA ranged from 0.4 to 2.3 ha in size and were at least 25 m wide. They were at least two years old, and not mown, or treated with herbicides during that time. Grassy margins were about 0.7 m wide and mown several times per year.

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Table 1
Mean, minimal and maximal percentage cover of land-use types in the ten studied landscape sectors.

Land-use type	Mean (±SD)	Min	Max
Arable land	43 ± 7	34	59
Permanent grassland	17 ± 5	11	30
Sown wildflower area	0.8 ± 0.3	0.4	1.4
Forests	12 ± 7	1	23
Water bodies	2 ± 3	0	10
Traffic routes	3 ± 1	2	5
Settlements	11 ± 5	4	22
Others	11 ± 3	7	14

Official land-use data (Swisstopo, Bundesamt für Landestopo-
graphie, Wabern, Switzerland) were used to characterize landscape
composition. They were verified and complemented in the field to
distinguish between arable land, permanent grassland, SWA,
forest, water bodies, traffic routes and settlement (Table 1).
Landscape composition was analyzed with a Geographic Informa-
tion System (ArcGIS 9.1, ESRI Geoinformatik GmbH, Hannover,
Germany). Landscape composition was calculated in a radius of
1500 m around both study fields of each landscape. The scale of
1500 m represented the upper part of the typical range in which
farmland spiders respond to landscape composition (Schmidt et al.,
2008; Drapela et al., 2008). Landscape composition was char-
acterized as the percentage of perennial habitat, because perennial
vegetation is important for spider overwintering and provides
suitable alternative habitat to the disturbed crop fields (Schmidt
and Tscharncke, 2005). Perennial habitats were all land-use types
except arable fields, water bodies, traffic routes and settlements
(Table 1). On average, 40 ± 3% of the landscape area was covered by
perennial habitats.

2.1. Spider sampling

Pitfall traps were set up in rows with a distance of 3 m (“edge”) and 30 m (“centre”) from the edge in each of the 20 wheat fields.
Each row consisted of five traps. Traps consisted of 0.2l cups with a
diameter of 6.5 cm. They were filled with 55 ml of a 1:3
propandiol: water mixture and an odorless detergent to break
the surface tension (Jud and Schmidt-Entling, 2008). In total, 200
traps (20 fields × 5 traps × 2 locations) were operated twice for
eight days, starting on 9–10 May 2005 and on 30–31 May 2005
respectively. Suction sampling was performed on 11–13 May 2005
in the same fields and positions as the pitfall traps. A foliage hoover
type SH 85C (Stihl, Dieburg, Germany) with a suction tube of
0.11 m diameter was lowered to just above the ground 100 times
per sample in the same areas where the traps were placed, but no
closer than 2 m to any trap. The samples were extracted during
24 h in Berlese funnels and subsequently transferred to 75%
ethanol for conservation. Adult spiders were identified to species
and juveniles to family level. The taxonomy followed Platnick
(2008). Newly hatched Araneidae and Lycosidae were analyzed
separately, because they represent a measure of reproductive
success.

2.2. Data analysis

The five pitfall traps per sample position and both sampling
periods were pooled for analysis. Raw species richness and
Simpson’s diversity of spiders were analyzed with linear mixed-
effect models with nested random effects (lme) using the library
nlme in R (R Development Core Team, 2007; Pinheiro et al., 2007).
This allowed us to use the correct degrees of freedom for the
explanatory variables within-field position (edge versus centre,

n = 40 positions), type of adjoining habitat (grassy margin versus
SWA, *n* = 20 fields) and landscape composition (percentage of
perennial habitats, *n* = 10 landscapes) within a single model.
Explanatory variables were forward selected according to Akaike’s
information criterion using the function stepAIC from the library
MASS (Venables and Ripley, 2002). Interactions between expla-
natory variables entered the model if they improved model fit
according to the AIC criterion. Simpson’s index of species diversity
was used because of its robustness with respect to sample size
(Lande, 1996). One of the ten landscapes had to be omitted from
the analysis of Simpson’s diversity in suction samples, because it
contained one position where no spider was sampled and where
the calculation of Simpson’s diversity was hence impossible.
Densities of spider families were analyzed when the catch
exceeded 20 individuals in a given sampling method. As several
families did not meet assumptions for parametric tests, exact
paired tests were performed and possible influences of landscape
composition were tested with spearman rank correlations in SPSS
13.0 for Windows.

3. Results

Overall, 9988 spider individuals were found, belonging to 65
species in 13 families (Table 2). According to pitfall traps, on
average 1.25 additional species were found at field edges
compared to the centres of fields (d.f. = 18, *t* = −2.8, *P* = 0.010).
Surprisingly, this edge effect was irrespective of the adjoining
habitat type (interaction adjoining habitat × within-field position:
n.s.). No significant edge effect on species richness was found in
suction samples, and there was no effect of within-field position on
Simpson’s diversity according to both sampling methods. Wolf
spiders (*Z* = −2.3, *P* = 0.019) and ground spiders (*Z* = −2.4,
P = 0.021) had higher densities at the edge than in the centre of
the wheat fields according to pitfall traps (Fig. 1A). Sheetweb
spiders had higher densities in the field centres than at the edges
according to both sampling methods (pitfall traps: *Z* = −2.4,
P = 0.017, suction sampling: *Z* = −2.6, *P* = 0.008, Fig. 1). Suction
sampling revealed higher densities of orb weaver nestlings
(*Z* = −2.0, *P* = 0.049) and long-jawed spiders (Tetragnathidae,
Z = −2.6, *P* = 0.008, Fig. 1B) near the field edge compared to the
centre.

On the field scale, neither species richness nor Simpson’s
diversity was significantly influenced by the adjoining habitat
type. However, densities of several spider families were signifi-
cantly enhanced by adjoining SWA. In pitfall traps, crab spiders
(*Z* = −2.6, *P* = 0.008), ground spiders (*Z* = −2.2, *P* = 0.036) and wolf
spiders (*Z* = −2.1, *P* = 0.039, Fig. 2A) showed significantly higher
densities in wheat fields beside SWA than beside grassy margins.
Twenty times more orb weaver nestlings (*Z* = −3.2, *P* = 0.001,
Fig. 2B) were found in wheat fields with adjoining SWA than with
adjoining grassy margins by suction sampling.

According to pitfall traps, species richness increased with the
percentage of perennial habitats in the surrounding landscape, but
only in the centre of the fields and not at the field edges (Fig. 3A,
interaction landscape composition × within-field position:
d.f. = 18, *t* = 2.45, *P* = 0.025). Suction sampling revealed a positive
correlation of species richness with the percentage of perennial
habitats irrespective of within-field position (Fig. 3B, d.f. = 9,
t = 3.9, *P* = 0.004). Simpson’s diversity increased with the per-
centage of perennial habitats in both sampling methods (Fig. 3C and D,
pitfall traps: d.f. = 9, *t* = 3.4, *P* = 0.008, suction sampling: d.f. = 8,
t = 3.4, *P* = 0.009). The densities of sheetweb spiders correlated
positively with the percentage of perennial habitat in the
surrounding landscape in both pitfall traps (*r*_s = 0.65, *P* = 0.043)
and suction samples (*r*_s = 0.79, *P* = 0.011). Densities of other spider
families showed no significant relation to landscape composition.

Table 2

Catches of adult spiders by method and adjoining habitat type (field edges and centres combined; GM = field with adjoining grassy margin; SWA = field with adjoining sown wildflower area).

Family	Species	Suction sampling		Pitfall traps	
		GM	SWA	GM	SWA
Agelenidae	<i>Histopona torpida</i>			2	
	<i>Tegenaria silvestris</i>			1	
Araneidae	<i>Araneus diadematus</i>			1	
	<i>Araniella opistographa</i>	1			
	<i>Larinioides cornutus</i>	2	2		
	<i>Mangora acalypha</i>	7	5	1	
Clubionidae	<i>Clubiona reclusa</i>		6		4
Corinnidae	<i>Phrurolithus festinus</i>			1	
Gnaphosidae	<i>Drassyllus pusillus</i>			2	14
	<i>Micaria pulicaria</i>		1	4	5
Hahniidae	<i>Hahnina nava</i>			1	2
Linyphiidae	<i>Araeoncus humilis</i>	9	9	27	17
	<i>Bathypantes gracilis</i>		2	2	4
	<i>Centromerita bicolor</i>				1
	<i>Collinsia inerrans</i>			1	
	<i>Diplocephalus cristatus</i>			1	
	<i>Diplocephalus latifrons</i>			1	
	<i>Diplocephalus picinus</i>		1	2	
	<i>Diplostyla concolor</i>			12	14
	<i>Erigone atra</i>	4	3	4	5
	<i>Erigone dentipalpis</i>	6	14	199	125
	<i>Meioneta rurestris</i>	14	41	340	267
	<i>Mermessus trilobatus</i>	20	14	36	12
	<i>Microlinyphia pusilla</i>				1
	<i>Monocephalus fuscipes</i>			1	
	<i>Oedothorax apicatus</i>	27	37	556	732
	<i>Oedothorax fuscus</i>	1	2	23	23
	<i>Oedothorax retusus</i>			16	23
	<i>Pelecopis parallela</i>	3	3	21	14
	<i>Porrhomma microphthalamum</i>	10	3	7	2
	<i>Porrhomma oblitum</i>	15	7	5	2
	<i>Silometopus reussi</i>	2		2	
	<i>Tenuiphantes tenuis</i>	7	5	5	4
	<i>Tiso vagans</i>			2	7
	<i>Troxochrus nasutus</i>		1		
	<i>Walckenaeria nudipalpis</i>			1	
	<i>Walckenaeria unicornis</i>			1	
	<i>Walckenaeria vigilax</i>	1	1	8	7
Liocranidae	<i>Apostenus fuscus</i>			1	
	<i>Liocranoeca striata</i>			1	
Lycosidae	<i>Alopecosa cuneata</i>			3	1
	<i>Alopecosa pulverulenta</i>		1	5	15
	<i>Arctosa leopardus</i>	1		16	38
	<i>Pardosa agrestis</i>	8	16	1108	1788
	<i>Pardosa amentata</i>		5	63	143
	<i>Pardosa hortensis</i>			7	2
	<i>Pardosa palustris</i>	6	11	484	544
	<i>Pardosa pullata</i>				7
	<i>Pardosa saltans</i>				1
	<i>Pirata latitans</i>			1	3
	<i>Pirata uliginosus</i>				1
	<i>Trochosa ruricola</i>	2	2	170	257
	<i>Trochosa terricola</i>			1	1
Pisauridae	<i>Pisaura mirabilis</i>				6
Tetragnathidae	<i>Pachygnatha clercki</i>	3	3	42	50
	<i>Pachygnatha degeeri</i>	1	7	36	26
	<i>Tetragnatha extensa</i>		1		
Theridiidae	<i>Achaearanea riparia</i>			1	
	<i>Enoplognatha thoracica</i>			1	1
	<i>Robertus neglectus</i>	6	8	2	2
	<i>Steatoda phalerata</i>			1	
	<i>Theridion varians</i>		1		
Thomisidae	<i>Diaea dorsata</i>	1			
	<i>Xysticus cristatus</i>	1			
	<i>Xysticus kochi</i>		3	4	28

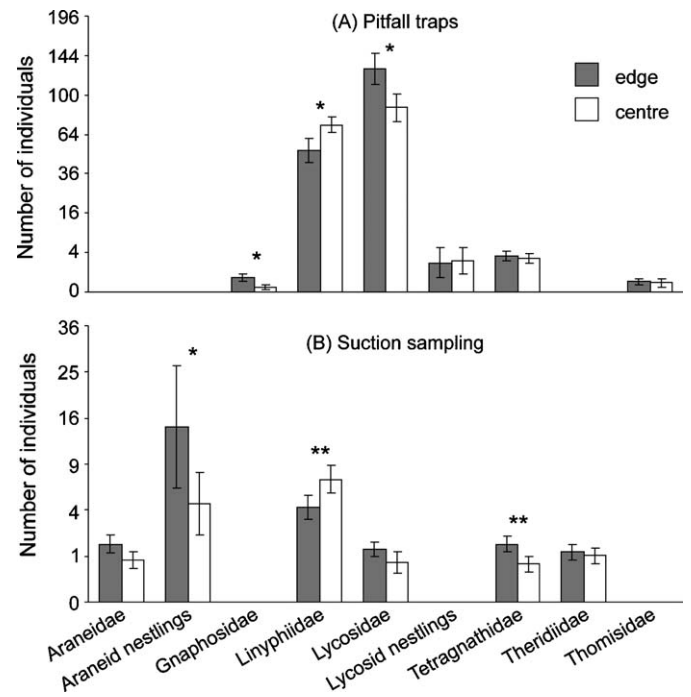


Fig. 1. Influence of the position within wheat fields on average densities (\pm S.E.) of spiders based on (A) pitfall traps, (B) suction sampling ($n = 40$). * $P < 0.05$, ** $P < 0.01$.

4. Discussion

Cursorial spiders (Gnaphosidae, Lycosidae, Thomisidae) and young orb weavers showed higher densities in fields with adjoining SWA than in fields with grassy margins, and partly towards field edges. The increase towards field edges is in accordance with the overwintering of these families outside of

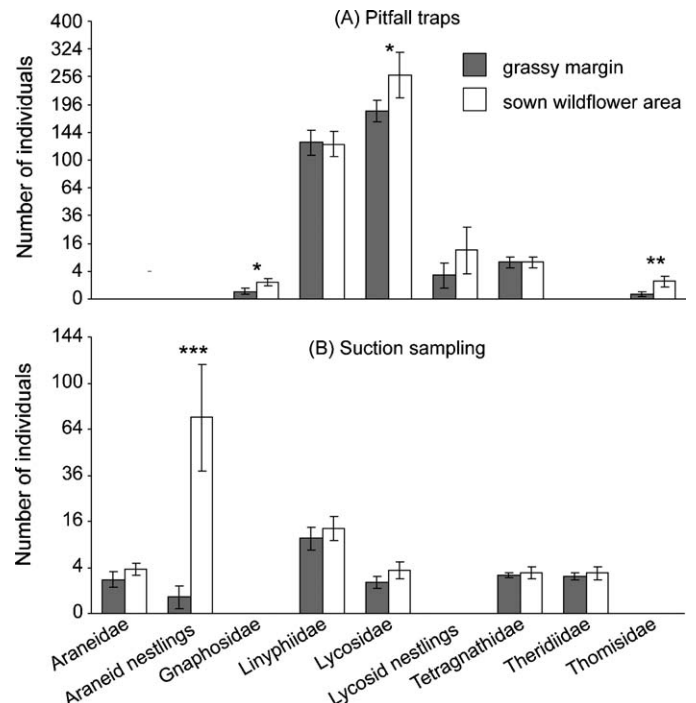


Fig. 2. Influence of adjoining habitat type on average densities (\pm S.E.) of spiders in wheat fields based on (A) pitfall traps, (B) suction sampling ($n = 20$). * $P < 0.05$, ** $P < 0.01$, *** $P < 0.001$.

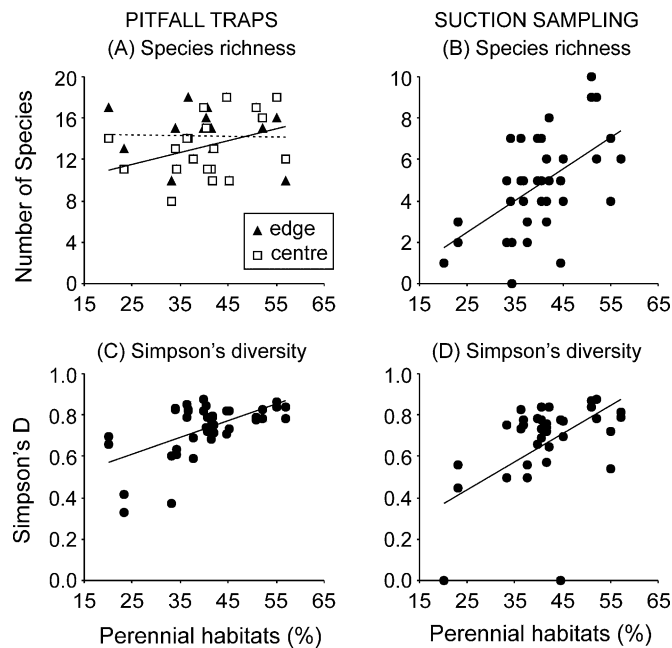


Fig. 3. Influence of landscape composition on (A and B) species richness and (C and D) Simpson's diversity of spiders in wheat fields according to (A and C) pitfall traps and (B and D) suction sampling.

arable fields (Schmidt and Tscharrntke, 2005), and with their lower recolonisation power compared to most sheetweb spiders (Bell et al., 2005; Oberg and Ekbom, 2006). Compared to grassy margins, SWA combine several advantages for spiders. First, mowing results in mortality or emigration of most spiders (Thorbek and Bilde, 2004). The studied SWA were free of such disturbance since several years. Due to the absence of disturbance, SWA develop a richly structured vegetation and litter layer that persists throughout the year. Abundant litter favours spider overwintering. In particular, cursorial families such as ground spiders and crab spiders are favoured by litter, and aerial web builders such as orb weavers benefit from richly structured standing vegetation (Bell et al., 2001). Finally, the abundance of flowers in SWA may attract additional prey and thereby increase spider fitness. Spider diversity and density of the dominant sheetweb spiders (Linyphiidae) increased with the percentage of perennial habitats at the landscape scale. This response of sheetweb spiders at the largest spatial scale in the current study is in accordance with their far-ranging dispersal and previous studies (Bell et al., 2005; Oberg and Ekbom, 2006; Schmidt et al., 2008). Sheetweb spiders need perennial habitats for overwintering and as refuge during times when crop fields are disturbed (Thorbek and Bilde, 2004; Schmidt and Tscharrntke, 2005).

The increase of cursorial spiders and orb weavers near SWA can affect agriculture in two ways. First, biological control may be improved through higher functional diversity of hunting spiders with a broad prey spectrum (Nyffeler, 1999) that can be particularly effective in suppressing herbivores (Schmitz, 2008). Young orb weavers (Araneidae) showed the strongest positive response to nearby SWA. While their direct benefit to agriculture is not known, orb weavers can suppress densities of homopterans and grasshoppers (Sanders et al., 2008). The decrease of cereal aphids towards SWA in the studied fields may be attributable to this improved biological control (Flückiger and Schmidt, 2006). Second, cursorial spiders may disrupt biological control (Straub et al., 2008) by preying more frequently on other spiders (Nyffeler, 1999; Denno et al., 2004; M.H. Schmidt-Entling, pers. obs.).

In the present study, pitfall traps generally produced similar patterns for spider density and diversity as suction sampling,

despite the relatively low numbers of spiders recorded with suction sampling. As adult spiders in suction samples were mostly sheetweb spiders, the pattern of species richness largely corresponds to sheetweb spider abundance. Pitfall traps caught considerable numbers of cursorial species, whose densities did not respond to large-scale landscape composition. Remarkably, the highest similarity between pitfall trap and suction sampling results concerned Simpson's diversity, which underlines its robustness against sampling intensity (Lande, 1996).

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