

Pollinator diversity in agriculture

Biodiversity project in Baden-Württemberg (Germany)

Ecological enhancement measures prove beneficial for wild bee and butterfly biodiversity



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EDITORIAL

Dear reader,

Biodiversity is important for all of us. Everyone appreciates the aesthetic value of a diverse landscape which provides habitats for a rich variety of animal and plant species. But biodiversity means much more than this. It brings us a multitude of practical benefits, with its contribution to ecosystem services. Take pollination by insects, for example. Worldwide, almost 90 percent of flowering plant species are at least partly reliant on the transfer of pollen by insects and other animals. These plants are an essential part of ecosystems, providing food, habitats and other resources for a wide range of other species.

It is estimated that 5 - 8 percent of agricultural crop production is directly dependent on pollination by insects and other pollinators. This has an annual value of several hundred billion euros. Without insect pollination, many fruit and vegetable species would virtually cease to exist. Which brings us to the importance of species diversity; evidence shows that various crops are better pollinated and produce better yields when there is a diverse insect community providing pollination services. Unfortunately, modern agricultural landscape structures frequently no longer provide an adequate habitat for many pollinator species. The good news is that there are effective measures we can take to counter this trend – for example, by creating wildflower strips or other structures which provide food and nesting sites for pollinating wild insects.

The project described here is one of the first to experimentally test an approach to ecological enhancement – in a comparative setup over a multi-year period – at the landscape level, and to quantitatively measure results. The findings are promising. We hope to eventually broaden the scope of the measures and introduce other elements that support biodiversity – looking beyond wildflower strips, to a whole-landscape ecological enhancement strategy. In this context, it is important that the ecological enhancement measures have a large enough scale, are well managed and applied widely, to pave the way for enhanced pollinator protection and the effective promotion and maintenance of biodiversity.

Best wishes,

Dr. Christian Maus, Global Lead Scientist Bee Care

Dr. Rainer Oppermann, Institute for Agro-Ecology and Biodiversity (IFAB)

Arno Schanowski, Institute for Landscape Ecology and Nature Conservation (ILN)

“

As a research-based company with a strong focus on crop protection and with close links to agriculture, Bayer is well aware of the enormous importance of pollinators and their diversity. This is why we support the creation of habitats for pollinators in our global “Feed a Bee” program.

The long-term research project described here, that investigates the positive effects of wildflower strips and other structures on pollinator diversity in the agricultural landscape, illustrates our commitment in this area.”

Dr. Christian Maus, Bayer Bee Care Center



INTRODUCTION



STRUCTURAL CHANGES

in the agricultural landscape have led to a scarcity of foraging plants and nesting places for many pollinators.

Bayer commissioned the Institute for Agro-Ecology and Biodiversity (IFAB) in Mannheim, Germany, and the Institute for Landscape Ecology and Nature Conservation (ILN) in Bühl, Germany, to conduct a research project entitled “Ecological enhancement of farmland in the Upper Rhine Valley“. Two sites of intensively farmed arable land in the Upper Rhine Valley of southwest Germany were selected. Following a baseline survey in 2010, the project has created various wildflower areas and nesting sites for wild bees since 2011.

The project evaluates, quantitatively and qualitatively, the impact of these ecological enhancement measures on the biodiversity of wild bees and butterflies in an agricultural landscape.

AT A GLANCE

Current results of the ecological enhancement measures (2011 - 2016) show that providing a continuous supply of a combination of annual, winter-hardy and perennial wildflower mixes can make a valuable contribution to promoting wild bee and butterfly populations and enhancing species diversity of these groups.

POLLINATORS AND THEIR ROLE IN THE AGRICULTURAL LANDSCAPE

As many plant species in the world’s ecosystems rely on animal pollinators for reproduction, the stability of many ecosystems is highly dependent on a network of plants and pollinators. Plant and pollinator diversity are interdependent.

In addition to the well-known honey bee (*Apis mellifera*), there are around 2,000 wild bee species in Europe. Together with other pollinating insects, there are many thousand species involved in these pollinator networks.

In recent decades, structural changes, especially in the agricultural landscape, have resulted in a scarcity of forage plants and a shortage of suitable nesting sites for many wild bee species. The decline in the diversity of wildflowers in agricultural habitats has significantly reduced the availability of forage plants for many pollinators, leading to seasonal shortages in the food supply, even for honey bees.

Wildflower strips and areas can be sown on farmland to compensate for this shortage of flowers. Critical factors for the effective performance of strips include the composition of wildflower mixes, the size and number of wildflower areas and, specifically, how strips are interconnected to create corridors. A broad diversity of flowering plants adapted to the site and a season-long supply of flowers are other factors that will have a positive effect.

In some European countries, the creation of wildflower strips on farmland is funded by state government-run agro-environmental programs. In some countries, there is a choice between annual and perennial seed mixes.



WILDFLOWER STRIPS

The living conditions of insects such as wild bees and butterflies can be improved using ecological enhancement measures such as the creation of wildflower strips in the agricultural landscape.



PROJECT DESCRIPTION

PROJECT SITES



Location of the two farms in Baden-Württemberg (Germany)



Maize cultivation in the Dettenheim project area



Wheat cultivation in the Rheinmünster project area



“Oberrhein überjährig” [Upper Rhine winter-hardy] flower mix in June 2015

This project is being conducted at two sites in the Upper Rhine Valley of Baden-Württemberg (southwestern Germany), on agricultural land belonging to **Bolzhof farm in Dettenheim** and **Birkenhof farm in Rheinmünster**. There are two 50-hectare study areas at each site. One establishes the ecological enhancement measures and the other is a control area with no modifications.

The project sites are located in an intensively farmed agricultural landscape comprising 95 percent arable land and very little grassland. Over the course of the project, the landscape in the study areas has been dominated by maize and cereal crops (2016: 78 and 98 percent respectively of the arable land in the ecological enhancement area and 95 and 100 percent respectively in the control areas). Changes in landscape structure over the years have been minimal. In Rheinmünster, the proportion of maize has increased, while in Dettenheim other crops were cultivated at a marginal scale in addition to maize and cereals (linseed and alfalfa).

ECOLOGICAL ENHANCEMENT MEASURES

Two types of ecological enhancement measures were introduced since 2011 on 10 percent (5 ha) of each ecological enhancement area:

- sowing of wildflower mixes
- creation of bee banks (nest sites for ground-nesting wild bees)

An important factor in the project's concept is how wildflower areas are distributed to ensure that they are linked in the landscape and that foraging distances for pollinators are kept to a minimum.

No measures were introduced in the control areas.

DEVELOPMENT OF ECOLOGICAL ENHANCEMENT MEASURES 2011 - 2016

Annual wildflower mixes

In the first year, four different annual mixes were sown in the spring (early May).

Winter-hardy wildflower mixes

From the second year, winter-hardy mixes were sown in the fall (September/October) in addition to the spring sowings. Based on the positive initial experiences, the decision was made in 2013 to increase the number of fall sowings for the remainder of the project. The areas sown in the fall provide food supply for insects from as early as March/April. Based on the experiences from previous years, a winter-hardy wildflower mix developed specifically for the sites was sown from fall 2014 (“Oberrhein überjährig”, see photo left).

Perennial wildflower mixes

From fall 2012, perennial wildflower mixes were sown in addition to the annual and winter-hardy mixes.

Due to plowing of the study plots, all wildflower areas in the Rheinmünster project area had to be reseeded in spring 2016. In Dettenheim, only eight of the 13 wildflower areas, in total, had to be reseeded. Two different perennial wildflower mixes and one annual wildflower mix were used.

Bee banks

As an additional measure, 10 - 20 m long earth banks were created in the ecological enhancement areas of both sites to provide nest sites for ground-nesting wild bee species (bee banks). These oppositely plowed earth walls dry out and warm up more quickly than the surrounding soil. Patchy vegetation is important because it makes it easier for ground-nesting wild bees to dig, providing a more suitable nesting site. Because the initially established 30 - 50 cm high banks eroded rapidly, their height was increased to 80 - 100 cm in 2013. As these earth banks are also quickly covered by plants the seeds of which are already present in the topsoil, they have to be cleared of overgrowing vegetation on a regular basis. In Rheinmünster, the relocation of the wildflower areas required the creation of a new bee bank in 2016.

SURVEYING POLLINATOR POPULATIONS

A baseline survey was done in the study areas in 2010. It determined the current status of the landscape and the populations of wild bees and butterflies before the enhancement measures were introduced. Subsequent surveys were done every year, in spring/summer during site visits via observation and collection of insect specimens with sweep nets.

In 2011, different wildflower mixtures were tested. As the resulting flowering patches could not be fully surveyed, consistent figures are only available from 2012.

To account for differences in daily activity patterns of different species, the wild bee surveys were done by visiting each sampling area for 30 minutes in the morning and in the afternoon. Bee banks were searched for wild bee nests. Two types of nesting aids for wild bees were installed to investigate the establishment of brood cells. The butterfly surveys recorded butterflies at a maximum distance of five meters from marked observation points along pre-defined straight lines (transect sampling).

VEGETATION SURVEYS IN WILDFLOWER AREAS

Once a year, a vegetation survey was done in each wildflower area, where all the plant species present on 50 m-long transects were recorded, along with their flowering status and frequency.



Bee bank in Dettenheim after clearing with the brushcutter in July 2015



Two types of nesting aid for wild bees were installed on the experimental areas: with removable front panel; and with different-sized holes in a wood matrix



Wild bees and butterflies being surveyed in a wildflower area

PROJECT FINDINGS TO DATE



Development of a perennial wildflower mix ("Oberrhein überjährig" [Upper Rhine winter-hardy]) in the first year. Cornflowers and poppies are the dominant flowering species on the site in June.



In year 2 or 3, some wildflower areas showed a high degree of structural diversity, providing additional habitats for animals.



A perennial wildflower area in the first year ("Oberrhein überjährig" [Upper Rhine winter-hardy]), before (right) and after (above) a dry period at the end of June/beginning of July.

Results of the ecological enhancement measures between 2011 and 2016 show that providing a continuous supply of combined annual, winter-hardy and perennial wildflower mixes make a valuable contribution to supporting wild bee and butterfly populations and their species diversity.

In the experimental plots where enhancement measures were tested, noticeable increases were observed in the number of species and individuals per species – particularly among wild bees and to a lesser extent for butterflies. It should be noted that the numbers of species, and especially the numbers of individuals, can be subject to considerable natural fluctuations from one year to another. These variations can be caused by phenomena such as different weather conditions.

The bee banks were less successful than wildflower areas. They were only used as nest sites when the vegetation was regularly cleared.

Main findings:

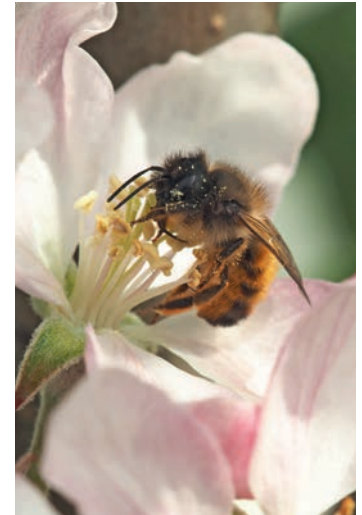
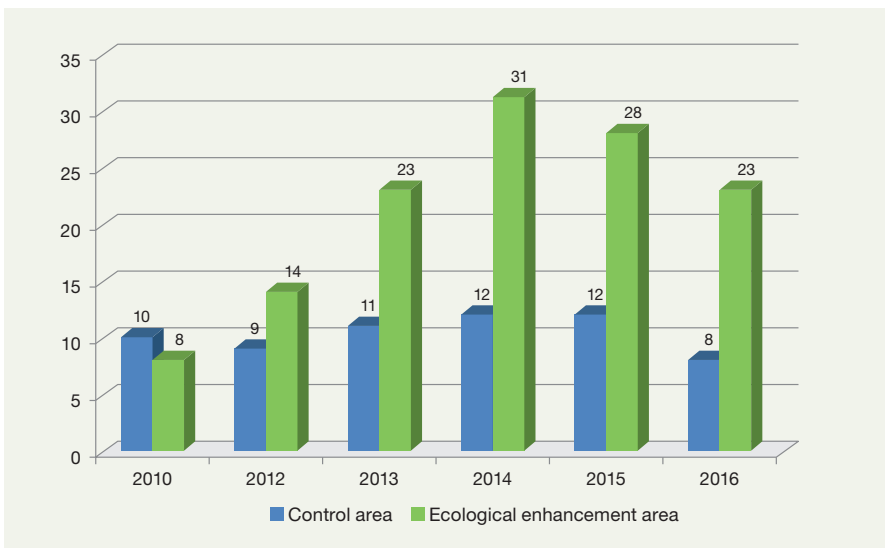
- The creation of wildflower areas on 10 percent of the arable land in the ecological enhancement areas resulted in a considerable and sustained increase in the number of species and of individual wild bees and butterflies.
- Patches of perennial and winter-hardy flowers are particularly important to provide an early supply of flowers for foraging, along with the creation of a variety of different types of wildflower areas.
- Wildflower areas should be renewed in sections as individual plant species can become dominant over the years.
- A wildflower area management strategy helps provide and control the optimum supply of foraging plants and keeps unwanted vegetation in check.
- It is also helpful if wildflower areas are supplemented with a mosaic of lightly covered arable areas (i.e. sown at a lower seed rate and less densely covered). This practice is especially effective for supporting birds such as partridges, skylarks and mammals such as hares.



CHANGES IN THE NUMBERS OF WILD BEE SPECIES

In **Rheinmünster**, the number of wild bee species per sampling area in the ecological enhancement area increased from an average of 8 in 2010 to a peak of 31 in 2014. In 2016, the average was 23 species. Initially, the average number of species in the control area was 11 per sampling area, a number which remained stable over the years (with an average of 8 species in 2016).

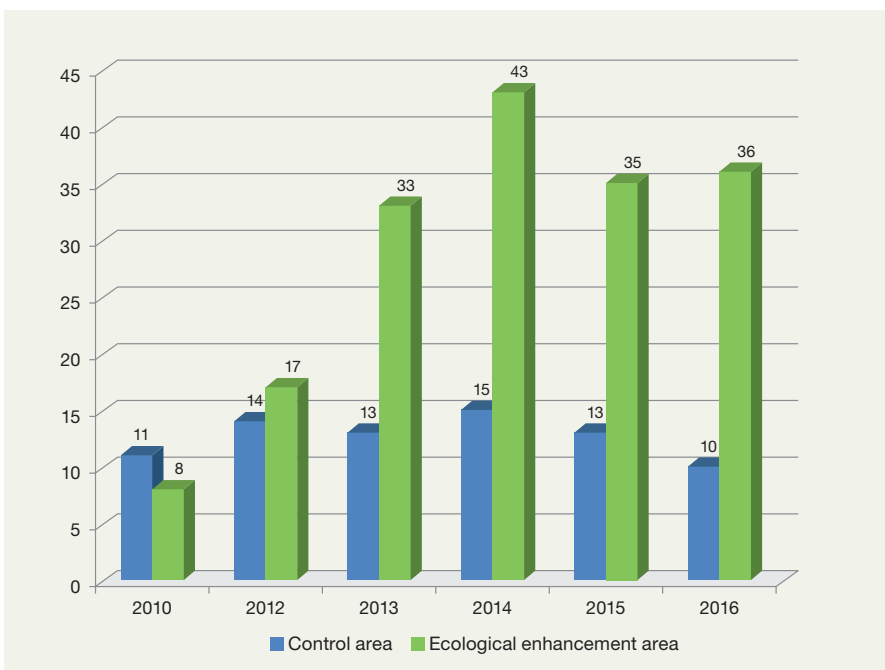
Average number of wild bee species per sampling area in Rheinmünster



Red mason bee
(*Osmia bicornis*)

The graph below shows the development in the numbers of wild bee species in **Dettenheim**.

Average number of wild bee species per sampling area in Dettenheim



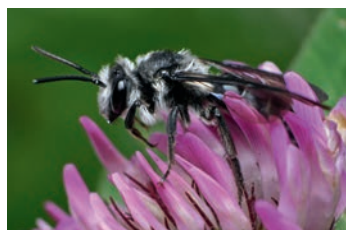
List of **critically endangered** species found only in ecological enhancement area:

(Red List Category 2 for Germany or Baden-Württemberg)

G - Germany, **BW** = Baden-Württemberg

Total number of individual specimens on the different plots, Rheinmünster

Species	Red List		Control area						Ecological enhancement area					
	G	BW	2010	2012	2013	2014	2015	2016	2010	2012	2013	2014	2015	2016
Long-fringed mini-mining bee (<i>Andrena niveata</i>)	3	2											2	3
Black mining bee (<i>Andrena pilipes</i> s.l.)	3	2							2	6	5	2	4	
Giant furrow bee (<i>Halictus quadricinctus</i>)	G	2								3				
<i>Lasioglossum aeratum</i> (furrow bee species)	3	2												3
<i>Lasioglossum lineare</i> (furrow bee species)	2	1									1	2	1	
Squat furrow bee (<i>Lasioglossum pauperatum</i>)	3	2									1			
<i>Osmia brevicornis</i> (mason bee species)		2											2	



Violet-winged mining bee
(*Andrena agilissima*)



Large bear-clawed nomad bee
(*Nomada alboguttata*)

RED-LISTED AND VULNERABLE SPECIES (Germany Red List):

In **Rheinmünster**, a wild bee species which is extremely rare throughout Germany (*Anthidium septemspinosum*, a carder bee species) and a critically endangered species (the Squat furrow bee, *Lasioglossum pauperatum*) were spotted in the ecological enhancement area. Species classified as endangered nationally were detected both in the control area and the environmental enhancement area in every year of the study. While the numbers in the control area remained relatively constant (between 1 and 4 species), they increased in the ecological enhancement area (2 species in 2010, a peak of 12 species in 2015, then 7 species in 2016).

In **Dettenheim**, two species that are classified as critically endangered in Germany were identified only in 2013 and solely in the ecological enhancement area (*Andrena limata*, a species of mining bee, and the Squat furrow bee, *Lasioglossum pauperatum*). Wild bee species that are considered to be endangered were found in both areas. In the ecological enhancement area, the number of endangered species sighted has risen from 2 to 11 over the project period to date. On the other hand, no more than two endangered species have been recorded on the control area over the years.

The highest total number of endangered species recorded in Dettenheim was 28, in 2016. The highest number of endangered species recorded in Rheinmünster was 26, in 2015.

Total number of individual specimens on the different plots, Dettenheim

Species	Red List		Control area						Ecological enhancement area					
	G	BW	2010	2012	2013	2014	2015	2016	2010	2012	2013	2014	2015	2016
Violet-winged mining bee (<i>Andrena agilissima</i>)	3	2								1	6	34	12	40
<i>Andrena limata</i> (mining bee species)	2	D									2			
Long-fringed mini-mining bee (<i>Andrena niveata</i>)	3	2									2	3	4	2
Black mining bee (<i>Andrena pilipes s.l.</i>)	3	2								1	12	4		
Giant furrow bee (<i>Halictus quadricinctus</i>)	3	2										1	1	
<i>Lasioglossum aeratum</i> (furrow bee species)	3	2									2			
<i>Lasioglossum lineare</i> (furrow bee species)	3	2								1				
Squat furrow bee (<i>Lasioglossum pauperatum</i>)	2	1							1		1			
<i>Osmia brevicornis</i> (mason bee species)	G	2										2	1	1

RED LIST CATEGORIES

Red Lists provide a system for classifying species according to their regional or national conservation status. The categorization is based on many years of regional or national risk analyses. The German Red List has 10 categories, the first four of which comprise the Red List of endangered species in the narrower sense. Here is an excerpt of the category names which are used in the above tables, thus specifically relating to the Red List for Germany:

Category 1 = Threatened with extinction

Category 2 = Critically endangered

Category 3 = Endangered

Category R = Extremely rare

Category G = Assumed to be endangered

Category D = Data deficient

Westrich, P., Frommer, U. R., Mandery, K., Riemann, H., Ruhnke, H., Saure, C. & Voith, J. (2011): Rote Liste und Gesamtartenliste der Bienen (Hymenoptera, Apidae) Deutschlands. 5th edition, last updated in February 2011. – in Bundesamt für Naturschutz (ed.): Naturschutz und Biologische Vielfalt, 70 (3), Rote Liste gefährdeter Tiere, Pflanzen und Pilze Deutschlands. Band. 3: Wirbellose Tiere (Teil 1): 373 – 416.

Westrich, P., Schwenninger, H. R., Herrmann, M., Klatt, M., Klemm, M., Prosi, R. & Schanowski, A. (2000): Rote Liste der Bienen Baden-Württembergs (Hym.: Apidae). – Landesanstalt für Umweltschutz Baden-Württemberg (ed.), Fachdienst Naturschutz, Naturschutzpraxis, Artenschutz 4: 48 S.



Mason bee species
(*Osmia brevicornis*)

CHANGES IN THE ABUNDANCE OF INDIVIDUAL WILD BEE SPECIES

In **Dettenheim**, the number of wild bee specimens per sampling area in the ecological enhancement area increased from an average of 14 specimens in 2010 to 724 in 2013 and 332 in 2016. In the control area, the numbers were much lower, with an average of 16 in 2010 and a maximum of 64 in 2013, with 26 bee specimens per sampling area in 2016. A total of 1,661 wild bee specimens were counted in the ecological enhancement area in 2016, compared to less than 200 in the control area.

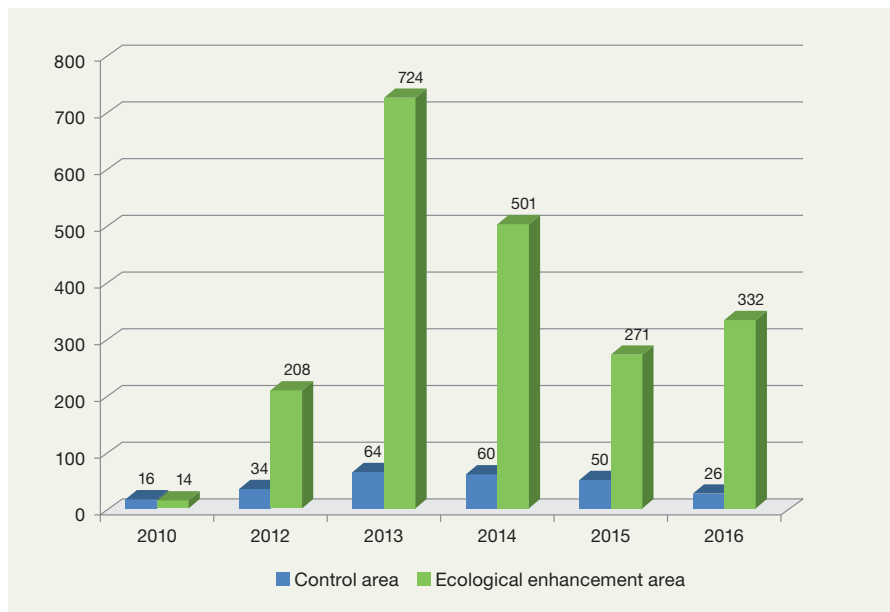


Wildflower area in Dettenheim



Common carder bee
(*Bombus pascuorum*)

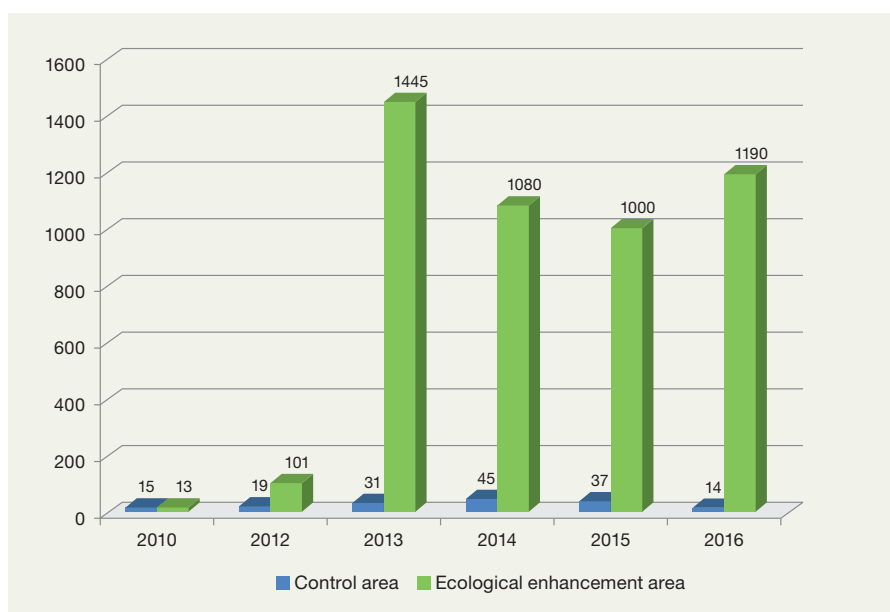
Average number of wild bee specimens per sampling area in Dettenheim



The results in both study areas are consistent and the observed trends comparable.

The pattern in the numbers of wild bee specimens in Rheinmünster is shown in the graph below.

Average number of wild bee specimens per sampling area in Rheinmünster

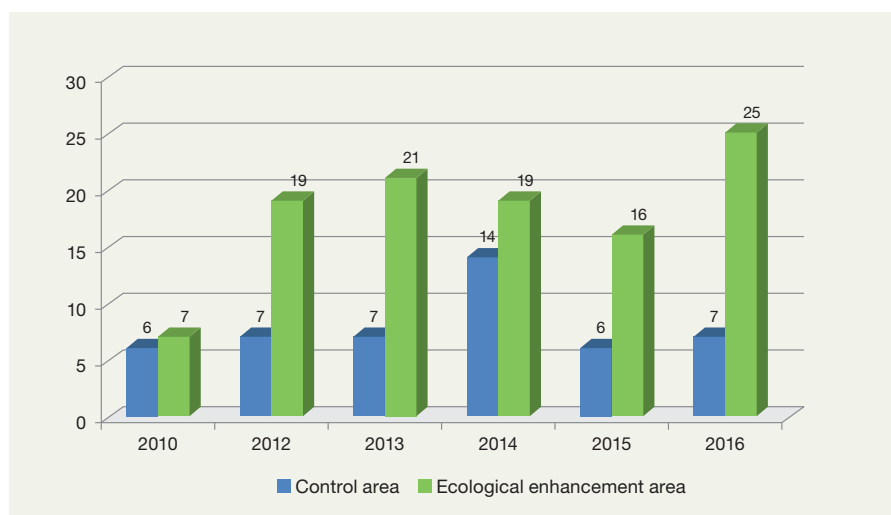


CHANGES IN THE NUMBERS OF BUTTERFLY SPECIES

When the **Dettenheim** site was first surveyed in 2010, 6 butterfly species were recorded in the control area and 7 in the ecological enhancement area. While the number in the ecological enhancement area rose to 21 in 2013, only 7 species were observed in the control area. A transitory increase occurred in the control area in 2014, but this increase was not registered in following years. The number of species observed in the ecological enhancement area between 2012 and 2015, at 16 - 21 species, was much higher than in the control area. In 2016 it rose to 25 species – the highest number to date.

Sightings included the Short-tailed blue (*Cupido argiades*) and the Small copper (*Lycaena phlaeas*), two species classified as “vulnerable” in Baden-Württemberg, along with the Mallow skipper (*Carcharodes alceae*).

Comparison of numbers of butterfly species in control and ecological enhancement area in Dettenheim



Because the results in Rheinmünster and the observed trends are comparable, only the graph showing the pattern in the species numbers in Dettenheim is displayed here.

In **Rheinmünster**, 10 species were observed in the control and ecological enhancement area in 2010. Until 2015, the number of species sighted in the ecological enhancement area rose continuously to 23. In 2016, just 12 species were recorded.

In the control area, the number varied between 5 and 10 species over these years.

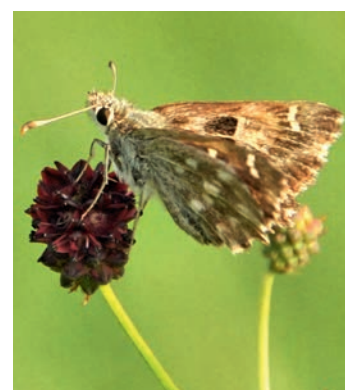
Over the same period, 16 species, some of them vulnerable, were sighted in the ecological enhancement area but not found in the control area. It should be noted, however, that some of these species were recorded in one year only or in some cases only in very small numbers.



Short-tailed blue
(*Cupido argiades*)



Small copper
(*Lycaena phlaeas*)



Mallow skipper
(*Carcharodus alceae*)

SUMMARY



Wild carrot with different fly species



Bordered straw
(*Heliiothis peltigera*)

The results of the ecological enhancement measures between 2011 and 2016 show that providing a continuous supply of wildflower areas and strips, including a combination of annual, winter-hardy and perennial wildflower mixes, on 10 percent of the arable land, can make a valuable contribution to supporting the numbers of species and wild bee specimens and butterflies and their species diversity.

Notable increases in the number of wild bee species and individual bees were recorded in the first years of the project. The number of species increased in both areas. In Rheinmünster, the average number of bee specimens was some 90 times higher in 2016 than at the start of the project; in Dettenheim it was 23 times higher than in 2010. It should be noted that the number of species, and especially numbers of individual insects, can be subject to considerable natural fluctuations between years – caused, for example, by differences in weather conditions.

The presence of endangered wild bee species (vulnerable species and species of various Red List categories) in the wildflower areas of the experimental plots is particularly significant. In 2016, a total of 28 species was recorded at the Dettenheim site. The highest number recorded in Rheinmünster was 26 species, in 2015.

The combination of annual, winter-hardy and perennial plants and the composition of the wildflower mixes, which has been tailored specifically to the needs of wild bee fauna since 2013, seem to have a positive impact on species numbers. The increase in the numbers of butterfly species and specimens was less pronounced than for wild bees. In Dettenheim, a significant increase in species numbers was observed in 2012, and the highest number to date was seen in 2016. In Rheinmünster, the numbers of species rose continuously, the highest to date being achieved in 2015. Endangered species of butterflies were also recorded.

The bee banks proved to be less successful. They are only used as nest sites when the vegetation is cleared on a regular basis.

Overall, the studies show that targeted ecological enhancement of intensively farmed landscapes with wildflower areas and strips of diverse composition – using different sowing strategies – can greatly increase the species diversity of pollinators.

GET INVOLVED – HOW YOU CAN HELP

You can help boost the diversity of wild bees and butterflies in areas used for agriculture, **by creating wildflower strips or areas on fields or adjacent to them.**

Here's how it's done:

- Choose wildflower mixes that suit the conditions of the site.
- Choose species with different flowering periods to prolong the supply of forage.
- Sow in spring and in fall.
- Leave the growth over the winter and don't mulch until the end of winter (late February), and only in half of the area.
- Use a combination of annual and perennial seed mixes – alternating 50 percent new sowings / 50 percent previous years planting left in the ground for overwintering and egg laying of insects.
- Actively manage weeds in wildflower areas to prevent them from creating too much undergrowth.

OUTLOOK

This project is being continued (study results 2017 currently being analyzed). Future work will include analyses of how and to what extent the numbers of species and specimens in the study areas vary when the proportion of ecologically enhanced areas changes. The aim of this analysis is to determine whether similar results can be achieved with a smaller proportion of areas with enhancement measures. Overall project results will also be analyzed in detail to allow for better interpretation of fluctuations in the number of species and specimens, and to show how diverse pollinator populations can be maintained.

We hope that these project results will be taken into account in the creation of ecological enhancement programs and their large-scale implementation, to make a valuable contribution to the maintenance and promotion of biodiversity in our countryside.



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