Pollinator biodiversity *in agriculture*

Ecological enhancement measures foster species diversity of wild bees and butterflies

EDITORIAL

Dear readers,

Biodiversity is important for all of us – we all enjoy the beauty of a diverse landscape that offers habitat to a wide range of different animal and plant species.

The value of biodiversity, however, goes far beyond aesthetics, for it offers many practical benefits, so-called ecosystem services. One of them is the pollination service provided by insects. Globally, about 90% of flowering plant species depend at least partly on pollen transfer by insects or other pollinators. These plant species form an important part of many ecosystems, and they offer food and habitat to a great number of fauna species. An estimated 5-8% of our agricultural production depend directly on pollination by insects or other pollinators. The global economic value of this service amounts to several hundred billion Euros per year. Especially fruits and vegetables like cherries and squash would practically be non-existent without pollinators. In many crops, pollination is more efficient – resulting in higher yields – if the insect pollinator community is rich in species. Which shows that measures to maintain species diversity are vital.

Unfortunately, the structure of today's agricultural landscapes no longer offers adequate habitats for many species. There is, however, a toolbox of effective measures at hand to counter this trend. Many farmers are already implementing these measures today, for example by creating landscape features, such as flowering strips or hedgerows, to offer food and nesting places for wild pollinators.

Besides providing habitats for pollinators, these landscape features also offer erosion protection and contribute to soil fertility.
The project described in this brochure is one of the first to test ecological enhancement measures in a real-life agricultural landscape over the course of many years (since 2010), subsequently evaluating the results on a quantitative and qualitative basis. The results are promising.

In the future, we hope to expand our efforts beyond flowering strips and establish further landscape-related ecological upgrade measures. These measures need to go across the farm level, because scope is important to make a real impact on species diversity. Success also depends on efficient guidance and on anchoring these measures firmly both in the individual farming operations and in the agricultural communities. That is how we can pave the way for pollinator protection and for enhancing and maintaining biodiversity.

Best regards,
Dr. Christian Maus, Julia Köbele and Dr. Bärbel Hundt, Bayer AG

Dr. Rainer Oppermann and Dr. Sonja Pfister, Institut für Agrarökologie und Biodiversität (IFAB

Arno Schanowski, Institut für Landschaftsökologie und Naturschutz (ILN)

„As a science-based company that is strongly involved in crop protection and crop breeding, Bayer has close links with agriculture and is aware of the extraordinary significance of pollinators and their diversity. That is why our global sustainability strategy involves supporting and protecting pollinators. Creating habitats in agricultural landscapes is part of this effort.

Our long-term research project described in this brochure investigates in detail the positive impact of flowering strips and other structural features on pollinator diversity in agricultural landscapes. The project also demonstrates our engagement in the field of pollinator protection.“

Dr. Christian Maus, Julia Köbele, und Dr. Bärbel Hundt, Bayer AG

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INTRODUCTION

Male *Lasioglossum costulatum* on a musk mallow flower

The project “Ecological enhancement measures in Upper Rhine valley cropland” has been commissioned by Bayer and is implemented by the “Institute for Agroecology and Biodiversity“ (IFAB) in Mannheim (Germany) and the “Institut für Landschaftsökologie und Naturschutz (ILN)” in Bühl (Germany). The location of the project is at two sites under intensive cultivation in the Upper Rhine valley in the Southwest of Germany. After a baseline survey of the original insect population in 2010, wildflower areas and nesting places for wild bees were created from 2011 onwards.

The goal of the project is to make a quantitative and qualitative analysis of how ecological enhancement measures affect species diversity of wild bees and butterflies in agricultural landscapes over long times.

AT A GLANCE

The results obtained so far from the ecological enhancement measures carried out between 2011 and 2020 have shown that a continuous supply of annual, biennial and especially perennial wildflower mixtures on 5-10% of the area can make a valuable contribution towards promoting the abundance and species diversity of wild bee and butterfly populations.

POLLINATORS AND THEIR ROLE IN AGRICULTURAL LANDSCAPES

A wide range of plant species in many ecosystems depends on pollinators for their reproduction. A viable network of plants and pollinators is therefore vital for the stability of many ecosystems. Plant and pollinator diversity are mutually dependent in these systems.

Apart from the well-known honey bee *(Apis mellifera)*, Germany boasts more than 500 wild bee species. If you add other pollinator insects, you end up with several thousand species that contribute to the local pollinator networks.

In the past decades, structural landscape changes, mainly in agricultural areas, have reduced the number of suitable nesting places for many wild bee species, and impoverished the available flower resources. This diversity decline in farmland plants has significantly deteriorated the habitat availability for many pollinators. There are areas where even honey bees may encounter seasonal bottlenecks in their food supply.

Creating dedicated wildflower strips or wildflower areas within the agricultural landscape can help to remedy the flower scarcity. Several factors determine the success of this ecological enhancement approach: the composition of the flower mixture, the size and number of flower areas, and the connectedness of the flower patches in the agricultural landscape. For additional positive impact, we recommend high flower diversity (featuring species that are adapted to local conditions) and continuous flower supplies from spring to autumn.

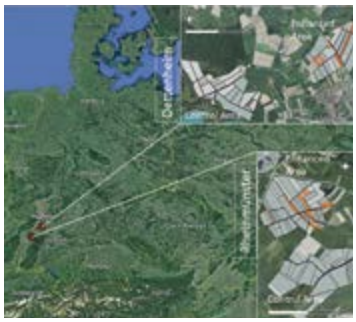
In Germany, the Federal States offer dedicated environmental programs to support the planting of wildflower strips in agricultural areas. Most Federal States now also provide funds for perennial flower areas.

WILDFLOWER STRIPS

Ecological enhancement measures such as wildflower strips in agricultural landscapes can improve the living conditions of wild insects like wild bees and butterflies.

Flower mixture: Veitshöchheimer Bee Pasture 2020
in Rheinmünster (fourth year after planting)

THE PROJECT



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

PROJECT AREAS

The project is conducted at two agricultural sites in the Upper Rhine valley in the Federal State of Baden-Württemberg (Germany): at Bolzhof farm in Dettenheim and at Birkenhof farm in Rheinmünster. At both sites, two project areas of 50 hectares each were established – one enhancement area and one control area. All four project areas are located in intensively farmed agricultural landscapes consisting of about 95 % arable land and a very low share of grassland. The predominant crops are corn and cereals (2020: 72 % / 95 % of the arable land in the enhancement areas; 84 % / 98 % in the control areas). Throughout the project, the structure of the landscape changed only marginally.

Changes in the Rheinmünster enhancement area involved planting field grasses in addition to corn and cereals in 2014, 2019 and 2020. In the Dettenheim enhancement area alfalfa was added from 2015 to 2018. In the Dettenheim control area, some sugar beet was cultivated occasionally. Since 2015 there was a small scope of project-independent flower areas in the enhancement areas, since 2017 in the control areas as well.

Corn and cereal fields in Rheinmünster

Cereal field in Dettenheim

ECOLOGICAL ENHANCEMENT MEASURES

Since 2011, two types of enhancement measures were carried out on originally 10 % (5 ha) of the agricultural area:

- Planting wildflower mixtures (since 2013 mostly perennial mixtures)
- Creating so-called “bee banks” or mounds as nesting places for soil-nesting wild bees

An important factor in the project design phase was to spread flower areas evenly, thus creating a coherent network in the landscape to keep travel distances for pollinators as short as possible. In 2018, the Dettenheim enhancement areas were halved to determine if an enhancement area of 5 % (instead of 10 %) of the cropland is sufficient to promote and maintain a diverse pollinator community. In 2021, the reduction was also implemented in the Rheinmünster project area.

In the control areas, no measures were carried out by the project team, but as of 2019, flowering areas with annual flowering mixtures areas were created independently of the project.

DEVELOPMENT OF ENHANCEMENT MEASURES 2011 – 2020

ANNUAL FLOWER MIXTURES

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

BIENNIAL AND PERENNIAL FLOWER MIXTURES

In subsequent years, biennial and perennial mixtures were planted both in spring and in autumn (September / October). Since autumn 2012, perennial flower mixtures were planted to complement annual and biennial mixtures. The results were so positive that in 2013 the decision was made to increase the share of autumn seeding under the project. Areas planted in autumn provide forage for insects as early as April / May. Based on the track record of the previous years, new site-adjusted biennial and perennial flower mixtures were developed. These were planted since 2014.

Surveying of wild bee and butterfly populations in a flower area

Flower mixture IFAB, autumn 2019 in Rheinmünster
(2nd year after planting)

After plowing existing project areas, all flower strips in the Rheinmünster project area were replanted in spring 2016. In Dettenheim only 8 of 13 wildflower areas were re-sown. One annual and two different perennial flower mixtures were used in the process.

"BEE BANKS" – A HOME FOR SOIL-NESTING WILD BEES

Complementing these enhancement measures, the project team created so-called bee banks – mounds of loose soil, 10-20 meters long – to provide a nesting place for ground-nesting wild bee species. The mounds were created by plowing in opposite directions. They offer the advantage of drying and warming up faster than the surrounding soil. It is important that the soil be loose enough to enable soil-nesting wild bees to dig their burrows, but compact enough to ensure the stability of the burrows. The original mounds were 30-50 centimeters high but became overgrown fast. In 2013, new mounds were created, featuring a height of 80-100 cm. However, these mounds were also overgrown fast by plants whose seeds exist in the top soil layer so that the sprawling vegetation had to be removed regularly.

All in all, the bee banks did not prove successful in the project area and were abandoned after 2019. Weeds thrived on the nutrient-rich soil and keeping them at bay turned out to be too much of an effort. In other projects, at places where soils were nutrient-poorer, nesting mounds for wild bees were created with more success.

BASELINE SURVEY OF 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.

The butterfly surveys recorded butterflies at a maximum distance of five meters straight lines (transect sampling).

This bee bank in Dettenheim was created in spring 2019, in June it was already partly covered with plants. Bee banks need steady maintenance so that the slopes are free of vegetation for easy colonization.

PROJECT RESULTS TO DATE

The results of the ecological enhancement measures over the period of 10 years (2011 to 2020) show that wild bee and butterfly abundance and species diversity can be enhanced by providing a continuous supply of combined annual, biennial and perennial flower mixtures.

In the enhancement areas, abundance and species diversity of wild bees increased significantly. This also applied to butterflies, albeit to a lesser extent. It needs to be added that strong fluctuations in species diversity and especially in abundance also occur naturally, depending on factors such as weather and climate conditions.

Bee banks were less successful than flower areas. The mounds were only used as nesting places, if they were kept free of overgrowing vegetation.

CORE FINDINGS

The creation of wildflower areas on up to 10% of the arable land in the ecological enhancement areas resulted in considerable and lasting increases in the abundance and species diversity of wild bees and butterflies.

Long-horned bee
(Eucera nigrescens)

Queen of Spain fritillary
(Issoria lathonia)

Red-tailed bumblebee *(Bombus lapidarius)* on meadow sage blossom

IT IS PARTICULARLY IMPORTANT THAT…

1) …. especially biennial and perennial wildflower areas are created. They offer flower supplies early in the year and perennial flower mixtures usually contain more species (about 40) than annual mixtures (10-15 species), including wild species that are important for pollinators.

   In addition, perennial mixtures create flower areas with a richer structure than annuals, so they also offer nesting places and overwintering habitats. As a result, perennial mixtures promote a significantly greater diversity of pollinator species. Seeding suitable flower mixtures in autumn can also help to cope with spring drought and to avoid weeds that germinate in spring.

   The diversity of flower areas can be enhanced by combining spring and autumn seeding, using different seed mixtures and by dividing the areas to allow the combination of different mixtures and seeding times.

2) …. wildflower areas are available continuously and also in winter as refuges and overwintering habitats for insects. However, they should be renewed, section by section, every 2-5 years, because over the years, individual plant species can start dominating the area, thereby superseding important pollen sources for some of the food specialists. Systematic flower area management with regular maintenance (mowing/mulching, if necessary) and re-seeding can help to provide and control optimal flower resources and correct undesired developments.

3) ….flower areas cover sufficient percentage of the total area and that the individual strips and areas are part of a network of flower areas and other habitats. The maximum distance between the different elements of the network should be less than 200 m.

The development stages of a perennial flower mixture (“Veitshöchheimer bee pasture”):

In the first year after seeding, the dominating species are crop plants such as sunflowers, buckwheat, flax, borage and marigold, as well as pioneer species such as cornflower and poppies. Spring-sown plants start flowering in June

Autumn-sown plants start flowering in mid-May. (“Veitshöchheimer bee pasture”).

Perennial wildflower area in the second year after planting (“Veitshöchheimer bee pasture”). It is rich in structures and plant species, thus offering food, nesting places, and overwinter habitats for a great variety of pollinators.

Great banded furrow bee
(Halictus scabiosae) on milk thistle

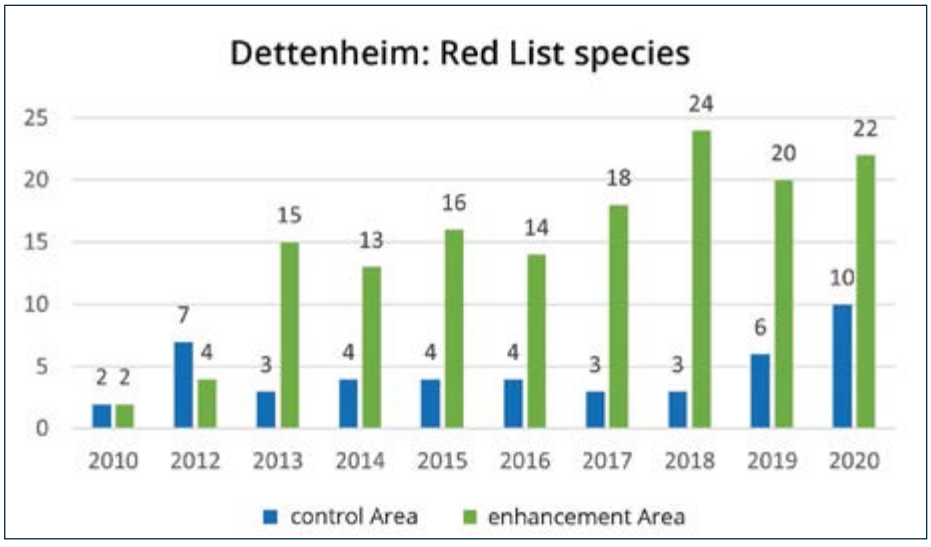
Black-veined white *(Aporia crataegi)* on corncockle

RED LIST SPECIES

In both enhancement areas the abundance and diversity of threatened bee species was high, as was the number of bee species specialized on certain pollen sources to feed their brood. Over the years, the provision of wildflower areas increased the abundance and diversity of threatened species both in Dettenheim and in Rheinmünster. The highest total number of threatened species (24 species) was registered in the Dettenheim enhancement area in 2018. In Rheinmünster, the peak number of threatened species was 21 in 2020.

In the Dettenheim enhancement area, the number of observed threatened species grew from 2 in 2010 to a peak number of 24 species in 2018. In the control area, three to four threatened species were observed between 2013 and 2017, reaching a peak in 2020 when 10 species were observed. In 2020, twice as many Red List species and four times as many individuals of these species were counted in the enhancement areas than in the control areas (in absolute figures: 22 species and 166 individuals in the five flowering areas vs. 10 species and 35 individuals in the four control plots). Between 2010 and 2020, 47 Red List species were observed in the enhancement area, including 16 endangered species. In the control area, only 25 Red List species were registered, among them 11 endangered species.

In Rheinmünster, the development was similar. In 2020, three times more Red List species and five times more individuals were observed (in absolute figures: 21 species and 101 individuals in the five flowering areas vs. 7 species and 17 individuals in the four control plots).



An overview of the categories of the Red List can be found on page 17.

Hoverfly on coriander blossom

From 2010 to 2020, a total of 35 Red List species were observed in the Rheinmünster enhancement area, among them 13 endangered species. In the control area, only 14 Red List species were observed, including 5 endangered species.

The following wild bee species classified as “vulnerable” in the German Red List were seen frequently and continuously in the enhancement areas of both Rheinmünster and Dettenheim: the violet-winged mining bee, *(Andrena agilissima)*, the end-banded furrow bee *(Halictus leucaheneus)*, the giant furrow bee *(Halictus quadricinctus)*, and the southern furrow bee *(Halictus submediterraneus)*. Three of these species are endangered in the state of Baden-Württemberg. The squat furrow bee *(Lasioglossum pauperatum)*, which is critically endangered, was also identified in the wildflower areas: in six different years in Rheinmünster, but only one single individual in Dettenheim. In Dettenheim, the project team even discovered one specimen of the eryngo mining bee *(Andrena decipiens)*, a species that was thought to be extinct in Baden-Württemberg.

In Rheinmünster’s enhancement area the seven-spined wool carder bee *(Anthidium septemspinosum)* – an extremely rare wild bee species in Germany – was sighted in several years, as well as the endangered squat furrow bee *(Lasioglossum pauperatum)*. In addition, there was the occurrence of the endangered Blüthgen furrow bee *(Lasioglossum bluethgeni)* in 2013, and the leafcutter bee *(Megachile genalis)* in the years 2019 and 2020.

In all study years, species classified as threatened on a countrywide scale were found in both the control and in the enhancement areas.

In Dettenheim four species classified as endangered on a country level, were seen in the enhancement area only (2013 the squat furrow bee *(Lasioglossum pauperatum)*, 2018 the eryngo mining bee, *Andrena decipiens*, the Schwerin mining bee *(Andrena suerinensis)*, and the Blüthgen furrow bee *(Lasioglossum bluethgeni)*. Wild bee species classified as vulnerable occurred in both areas.

You will find a list of the Red List species classified as “endangered” which were observed in the enhancement and control areas on pages 18/19.

Both in Rheinmünster and in Dettenheim, three to five times as many food specialists were found in the enhancement areas than in the control areas (36 species in the Dettenheim study area, 28 in Rheinmünster).

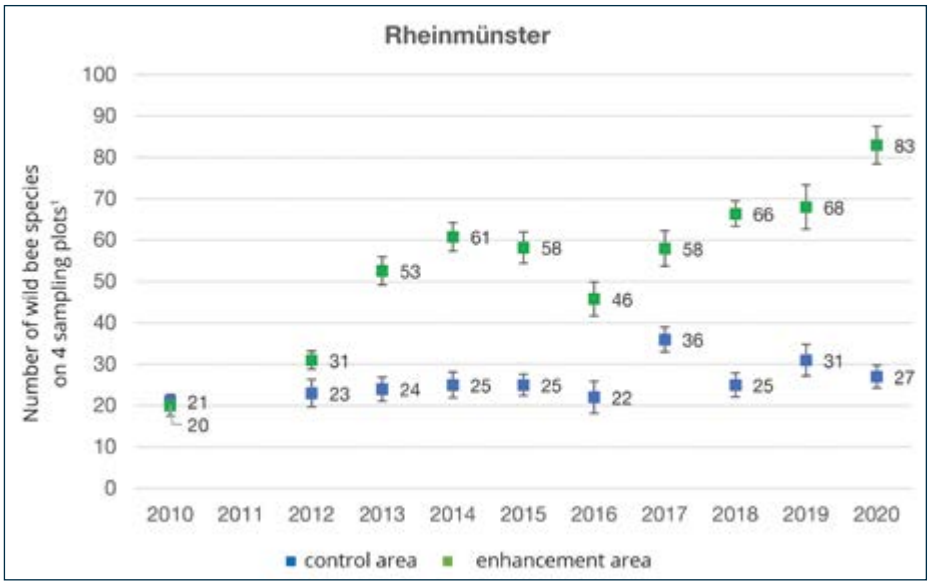
Two-cell mining bee *(Andrena lagopus)* on a mustard flower

DEVELOPMENT OF WILD BEE SPECIES DIVERSITY

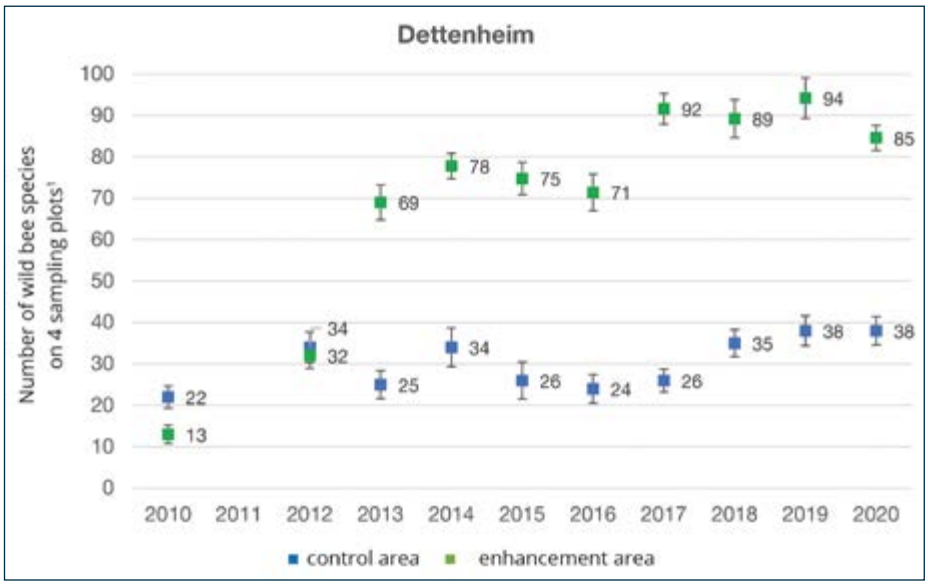
In the Rheinmünster enhancement area, wild bee diversity increased from 20 species in 2010 to a peak number of 83 species in 2020. In the control area, diversity remained stable over the years, at a level of 21 species. (Peak year with 36 species in 2017; 27 species in 2020). In 2016, the number of species declined in the enhancement area, because all flower areas were plowed and re-seeded simultaneously.

In the Dettenheim enhancement area, the number of species increased more strongly than in Rheinmünster (Peak year with 94 species in 2019). At both sites the number of wild bee species in the enhancement areas was three times as high as in the control areas.

Numbers of wild bee species between 2010 and 2020 in the enhancement and control area in Rheinmünster.



Numbers of wild bee species between 2010 and 2020 in the enhancement and control area in Dettenheim.



[1] To allow direct comparisons of results between different numbers of sampling plots in the enhancement and control areas, the sample figures of the enhancement areas were adjusted to four sample areas.

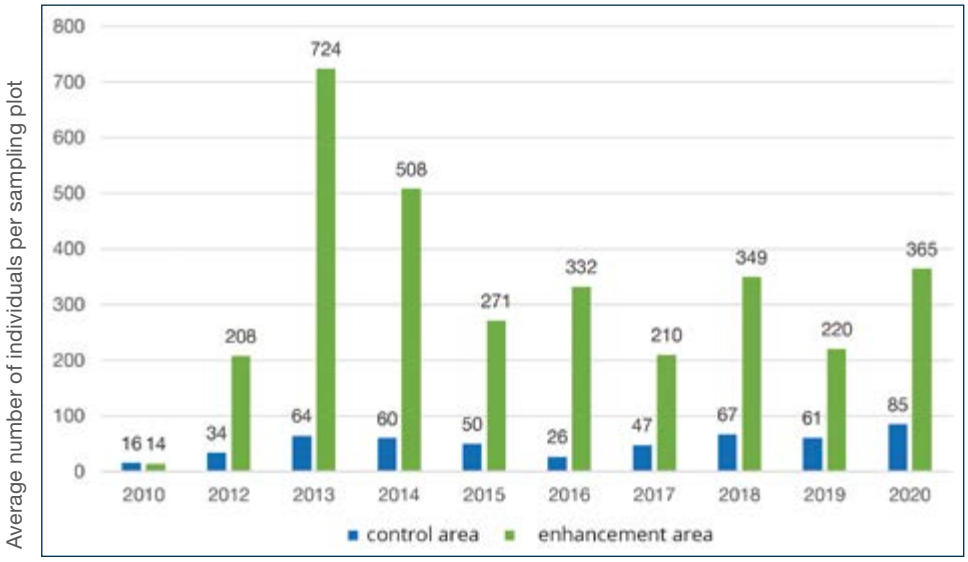
DEVELOPMENT OF THE ABUNDANCE OF WILD BEES

In the Dettenheim enhancement area, the number of wild bees per sampling plot increased from an average of 14 individuals in 2010 to a peak number of 724 in 2013 and fluctuated between 210 to 365 individuals in the years 2015 to 2020. In the control area, the numbers remained significantly lower: with an average of 16 individuals in 2010 and a peak number of 85 per sample plot in 2020. In the last four years, the number of wild bee individuals in the wildflower areas was on average four times higher than in the control plots.

Fluctuations in the number of individuals over the years are mainly due to the varying number of bumble bees (in particular buff-tailed and red-tailed bumblebees). Their number is heavily dependent on springtime weather conditions and on the supply of plant species with major nectar yield (such as phacelia, red clover, and sweet pea) at the right time in the wildflower areas. Large numbers of individuals develop when the flowering of plants with big nectar yields coincides with the development of the colonies (like, for example, in 2013).

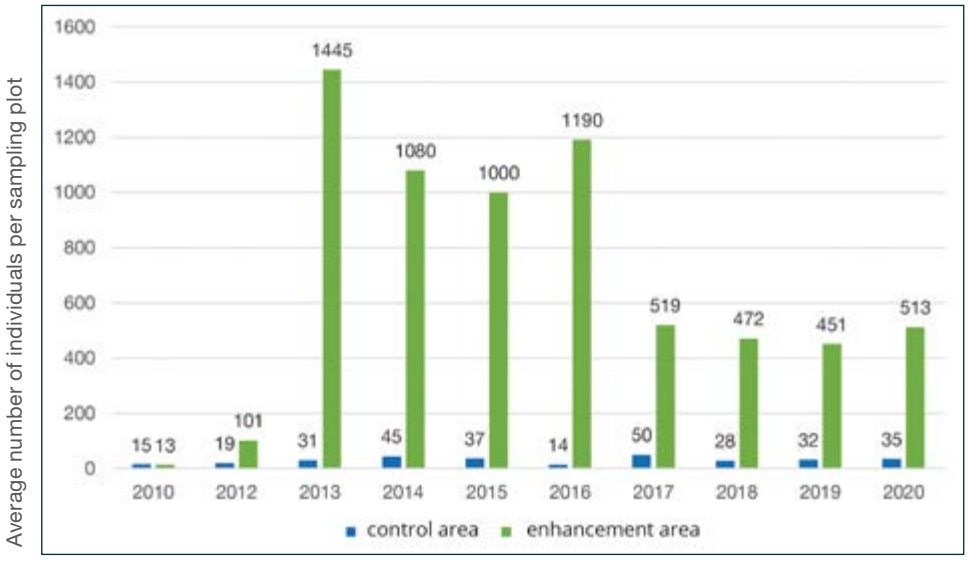
Average number of wild bee individuals per sampling plot in Dettenheim:

Abundance of wild bee individuals in the enhancement and control areas in Dettenheim from 2010 to 2020: The bars in the graph show the average number of individuals per plot.



Since 2013, in Rheinmünster more individuals were found in the wildflower areas than in Dettenheim. From 2017 – 2020, the number of individuals per sampling plot was on average 14 times higher in the wildflower areas than in the control plots.

The bars in the graph show the number of wild bee individuals in Rheinmünster



The results in the two enhancement areas are consistent and the trends observed are comparable.

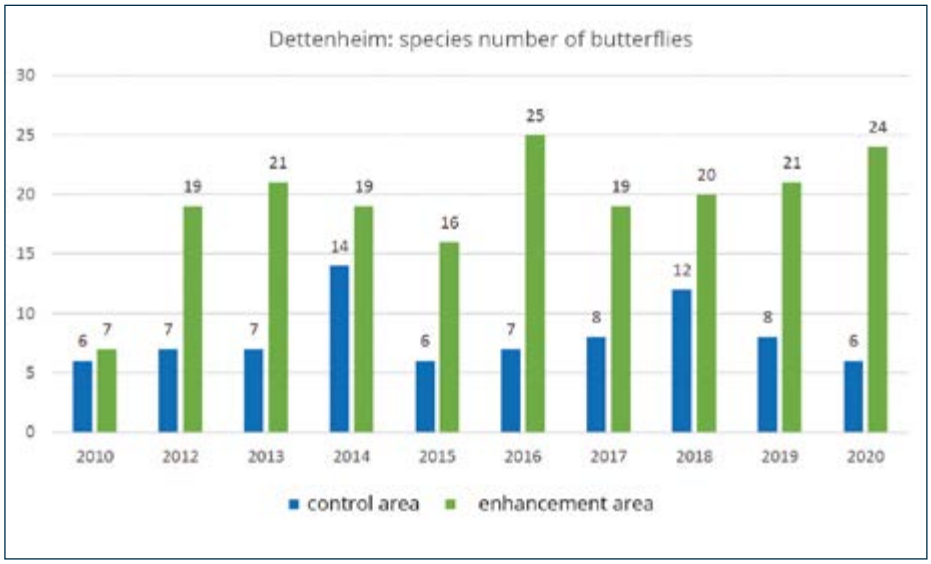
DEVELOPMENT OF THE BUTTERFLY SPECIES DIVERSITY

In Dettenheim, the 2010 baseline survey showed 6 diurnal butterfly species in the control area, and 7 in the enhancement area. While their number rose to 21 in 2013 in the enhancement area, the control area figures remained unchanged.

In 2014 and 2018 there was a temporary increase in species numbers in the control area, a development that was not seen in subsequent years. In the enhancement area, the number of species observed between 2012 and 2020 was significantly higher than in the control area: It rose from 16 to 25 species.

From 2014 onwards, the mallow skipper *(Carcharodus alceae),* which is classified as vulnerable, was regularly found in the wildflower areas. It successfully reproduces in areas featuring mallows. In addition, in 2020 a large copper *(Lycaena dispar)* was seen ovipositioning in one of the flower areas.

Number of butterfly species in the Dettenheim control and enhancement areas



As the results and trends observed in Rheinmünster and Dettenheim were similar, only the development of species numbers in Dettenheim is represented in the graph.

At the start of the project in Rheinmünster, 10 butterfly species were found in both the control and the enhancement area. By 2015 the number of species observed in the enhancement area increased steadily to 23. In 2016, after plowing and re-seeding the flower areas, the figure went down to 13 species. In 2018 the number rose to 21 species, in 2020, however, only 11 species were found in the enhancement area and only 6 in the control area. In the control area, their number fluctuated between 5 and 11 species over the years.

Throughout the project, 12 species were observed in the enhancement area that were not found in the control area, among them several near threatened species. It needs to be added though that some of them were only seen in one single year, or only in very small numbers.

Detailed study results covering the years 2010 to 2015 have been published in a scientific journal and can be downloaded under https:// doi.org/10.1186/s12898-018-0210-z

Buhk, C., Oppermann, R., Schanowski, A., Bleil, R., Lüdemann, J., Maus, C. (2018): Flower strip networks offer promising long-term effects on pollinator species richness in intensively cultivated agricultural areas. – BMC Ecology.

SUMMARY

The monitoring of the ecological enhancement measures carried out from 2011 to 2020 show that providing a continuous supply of wildflower areas – offering a combination of annual, biennial and perennial flower mixtures covering up to 10% of the cropland – can make a valuable contribution to support wild bee and butterfly populations and the species diversity of these groups.

Since the third project year, abundance and diversity of wild bees increased significantly. The number of species increased at both sites. In Rheinmünster, the average number of individuals was 90 times higher in 2016 than at the start of the project. In Dettenheim, the numbers were 23 times higher than in 2010. It should be noted that the numbers of species, and especially numbers of individuals can be subject to considerable natural fluctuations between years – caused, for example, by differences in weather conditions.

It is particularly noteworthy and relevant that many threatened wild bee species (with Red List rating in one of the different categories) were found in the flower areas of the enhancement areas. In Dettenheim, with 24 Red List species the highest number was recorded in 2018. In Rheinmünster, a peak number of 21 species was observed in 2020.

Combining different perennial mixtures, seeding in spring and autumn, and staggering both maintenance and re-seeding processes seem to have a positive impact on the numbers of species. Since 2013, flower mixtures were fine-tuned to the needs of the local wild bee fauna.

For butterflies, the increases in species and individual numbers are less pronounced than for wild bees. In Dettenheim, a significant increase in species numbers was already observed in 2012; in 2016, the highest number to date was sighted. In Rheinmünster, the species numbers developed continuously upwards and reached their highest value to date in 2015. Threatened species were also found among the butterflies.

The bee banks were less successful than the flower strips. They were only used as nesting places when they were kept free of weeds.

All in all, the study shows that targeted ecological enhancement measures, featuring wildflower areas or flower strips with a diverse mixture of flowering plants sown at different points in time, can greatly increase species diversity of pollinators in intensively farmed landscapes.

Split wildflower area established in a staggered management scheme (left: Veitshöchheimer bee pasture in its second year after planting; right: IFAB mixture in its first year, after sowing in the preceding autumn)

Veitshöchheimer bee pasture at Rheinmünster in its third year after planting

PRACTICAL TIPS AND HINTS TO SUPPORT POLLINATOR BIODIVERSITY

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.

THIS IS HOW YOU DO IT:

Select flower mixtures that are suited for the site. In Germany, the Federal States subsidize local flower mixtures in agriculture, and most of them include perennial mixtures in their programs. The benefit of perennial mixtures: they are adapted to the needs of the pollinators, contain many different wild plants, and offer long-lasting flower supplies.

In some German states, there are certified “regional seed mixtures” (e.g. in Baden-Württemberg the mixtures “Lebendiger Acker (Living Field)”, “Blühende Landschaft (Blooming Landscapes)” and in Thuringia and Saxony-Anhalt mixtures with 100 % wild plant content).

Many mixtures contain information about the location, even often in the name, e.g. the mixtures “Lebendiger Acker (Living Field)”, “Lebendiger Waldrand (Living Forest Edge)”, “Lebendiger Gewässerrand (Living Bank)” or the mixture “Blühende Landschaft (Blooming Landscapes)” in four variants for the regions north, east, south, and west. In addition, there is often information provided on the preferred site properties.

HERE ARE THE MOST IMPORTANT THINGS TO REMEMBER:

- Make sure to plant several different perennial mixtures in both spring and autumn
- Prepare the seedbed thoroughly like for a culture (it should be vegetation free, loose, and finely crumbled)
- Leave the vegetation of the flower areas in place over winter, with staggered reseeding over 2 to 5 years.
- Newly seeded areas should not be mulched before late winter (end of February). In general mulch or mow only half the area, as insects use it for overwintering and oviposition.
- Plant perennial flowers, and split flower areas to stagger maintenance and re-seeding.
- Watch for the emergence of weeds in the flower areas to avoid overspreading. When flower areas become weedy or dominated by just a few plant varieties, they need cupping cuts, mowing or mulching, or even re-seeding.

Please note: If new flower areas are state-subsidized, it is of course necessary to comply with the respective legal requirements.

Red-Tailed bumblebee *(Bombus lapidarius)* on a hairy vetch flower

Buff-tailed bumblebee *(Bombus terrestris)* on nigella flower

OUTLOOK

The project will be continued. More data will be gathered, for example, to establish what happens, when the share of enhancement area in the cropland is changed. Will abundance and species diversity be impacted? And if so, how? In 2018 the proportion of flower areas was reduced to 5 % at one of the sites, and in 2021 the second site followed suit. The data gathered in the coming years will provide insights on the effect of these changes.

The complete data set, covering the entire project will also be analyzed thoroughly to help interpret the fluctuations in abundance and species diversity, and to show how diverse pollinator populations can be maintained.

We are confident that the project results will be taken into account when ecological upgrade areas are planned and implemented on a bigger scale. Our results can make a valuable contribution to maintaining and promoting biodiversity in our cultivated landscape.

RED LIST CATEGORIES

All in all, there are 10 categories, but only the first four belong to the Red List in the narrower sense. Here is a short overview of the categories mentioned in the tables below.

Category 0	=	extinct
Category 1	=	critically endangered
Category 2	=	endangered
Category 3	=	vulnerable
Category R	=	extremely rare
Category G	=	threat of unknown extent
Category V	=	near threatened
Category D	=	data deficient

Pease note: The classification of species refer to the Red Lists of Germany (D) and of the Federal State of Baden-Württemberg (BW); however, the names of the categories were adapted to the terms of the internationally used IUCN classification

Red List species of the category “Endangered” found in the enhancement and control areas

Rheinmünster	**Red List**		**Control Area**										**Enhancement Area***									
Species	**D**	**BW**	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020
Violet-Winged Mining Bee *(Andrena agilissima)*	3	2										3					2	3	1	2	3	7
Black Mining Bee *(Andrena pilipes* sensu lato*)*	3	2								1				2	6	5	2	4	10		1	3
Hairy-Saddled Colletes *(Colletes fodiens)*	2	3																		3		
Giant Furrow Bee *(Halictus quadricinctus)*	3	2																	1		1	17
Southern Furrow Bee *(Halictus submediterraneus)*	3	2	3		2	5	1	1	3		3	4	1		2	4		2	1	2	6	7
Ore Furrow Bee *(Lasioglossum aeratum)*	3	2	2	1	4	17	6		2	2	1	4	2	3		5	1	1	1	1	1	3
Blüthgen Furrow Bee *(Lasioglossum bluethgeni)*	G	2													3							
Linear Furrow Bee *(Lasioglossum lineare)*	3	2							4									3	4	4		4
Squat Furrow Bee *(Lasioglossum pauperatum)*	2	1														1	2	1		1	4	1
Four-spotted Furrow Bee *(Lasioglossum quadrinotatum)*	3	2		1	1												5	1		1	5	
Ashy Furrow Bee *(Lasioglossum sexnotatum)*	3	2														1					1	1
Leafcutter Bee *(Megachile genalis)*	2	2																			1	3
Large Bear-Clawed Nomad Bee *(Nomada alboguttata)*		2															2					1

Dettenheim	Red List		Control Area										Project area*									
Species	D	BW	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020
Violet-Winged Mining Bee *(Andrena agilissima)*	3	2										6		1	6	34	12	40	10	5	15	34
Eryngo Mining Bee *(Andrena decipiens)*	2	0																		1		
Black-haiered Mining Bee *(Andrena limata)*	2	D										18			2					1		2
Long-fringed Mini-mining Bee *(Andrena niveata)*	3	2								1		1			2	3	4	2	4	27	4	3
Black Mining Bee *(Andrena pilipes* s.l.*)*	3	2									1			1	12	4				1	2	1
Schwerin Mining Bee *(Andrena suerinensis)*	2	1																		1		
Hairy-saddled Plasterer Bee *(Colletes fodiens)*	3	2																			1	
Giant Furrow Bee *(Halictus quadricinctus)*	3	2									1					1	1			4	14	16
Golden Furrow Bee *(Halictus submediterraneus)*	3	2				3					1				2	2	3	3	3	6	8	9
Ore Furrow Bee *(Lasioglossum aeratum)*	3	2											1		2					2		
Cliff Furrow Bee *(Lasioglossum angusticeps)*	G	***														1						
Blüthgen Furrow Bee *(Lasioglossum bluethgeni)*	2	G																		1		
Linear Furrow Bee *(Lasioglossum lineare)*	3	2												1								
Squat Furrow Bee *(Lasioglossum pauperatum)*	2	1													1							
Ridge-cheeked Furrow Bee *(Lasioglossum puncticolle)*	3	2				1							1					1	6			1
Pygmy Furrow Bee *(Lasioglossum pygmaeum)*	G	2						1														
Four-spotted Furrow Bee *(Lasioglossum quadrinotatum)*	3	2	1												1		1	4	2		2	
Ashy Furrow Bee *(Lasioglossum sexnotatum)*	3	2		2																		
Leafcutter Bee *(Megachile genalis)*	2	2										1										
Short-horned Mason Bee *(Osmia brevicornis)*	G	2														2	1	1	2		4	5

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