Final project report
EcoFruit – Managing ecosystem services for fruit production in different European climates

Project acronym	EcoFruit
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Coordinator of the project (company/organization)	University of Freiburg
Project coordinator (Name)	Alexandra-Maria Klein
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Author of this report	Alexandra-M. Klein and all project partners
Title, first name, surname	Prof. Dr. Alexandra-Maria Klein
Telephone	0049-203-67770
E-mail	alexandra.klein@nature.uni-freiburg.de
Date of writing	30.09.2018-15.01.2019

Indicate a contact for the project, if different from the author of the report	Same as the main author of the report

List of partners involved at the end of the project (company/organization and principal investigator)	P1= University of Freiburg: Alexandra-Maria Klein (PI), Virginie Boreux P2= CREAF Barcelona, Jordi Bosch (PI), Anselm Rodrigo Domínguez, Laura Roquer Beni P3= University of Stockholm: Peter Hambäck (PI), Ulrika Samnegård & Marco Tasin (Alnarp) P4= University of Oviedo, PIs Daniel García & Marcos Miñarro (SERIDA) P5= University of Darmstadt: Nico Blüthgen (PI), Karsten Mody, Anne-Kathrin Happe

1. Summary

Apple is the most important European fruit crop and production of commercial varieties benefit to certain extent from pollination and natural pest control. The EcoFruit project studied the effect of management practices on pollinating and pest-controlling insects plus predatory spiders and fruit production. Orchard management were considered at three different scales (1) orchard scale with organic versus IP (integrated pest) management, (2) adjacent orchard scale with woody/herbaceous habitat in direct proximity to the orchards, and (3) different landscape variables such as the amount of woody habitat in the wider landscape in >100 orchards in Germany, Spain and Sweden.

Main findings /research statements are: (1) The availability of flowers in and adjacent to orchards increase pollination without compromising fruit production; (2) High pollinator diversity in low intensity orchards indicates stability in pollination services to climatic changes caused by redundancy in the use of climatic niches. Spatial complementarity in high-stem orchards on the contrary indicate a risk to less pollinated tree parts when pollinator groups disappear; (3) Interspersed planting scheme and organically managed orchards promote the pollination effectiveness of honeybees; (4) Orchard management and woody habitat in the landscape influence predatory arthropod communities but the influences are regional specific with different responses between countries; (5) Woody habitat serve as sink habitats attracting earwigs by providing alternative prey and shelter in IP, but not in organic

orchards; (6) Effective biological control of the apple blossom weevil can be achieved to maintain the pest at non-harmful levels, through combined management of the pest, its habitat and its natural enemies; (7) Multi-scaled farming management, involving both within-field practices and regional land-use schemes, should be considered to promote win–win scenarios in low-input apple orchards, whereby species-rich communities of insectivorous birds provide effective pest control service; (8) No inherent trade-off between species richness and fruit production; and (9) Early apple blooming caused by climate change does not necessarily reduce the beneficial services of insects to fruit production, but biodiversity suffers.

In conclusion, our project shows management options to promote agro-biodiversity and related ecosystem services in European fruit production. Some organic orchards showed high diversity of beneficial insects and production outcomes as high as the mean IP orchards. High biodiversity in low-intensity orchards have the advantage to buffer negative effects of environmental changes.

Pollination: Left-hand site: Apple quantity and quality of the organic variety Topaz after hand-, open (bee)- and self-pollination (parthenocarpy) from left to right (Photo: Alexandra-Maria Klein, University of Freiburg, Germany). Right-hand site: Bumblebees (*Bombus terrestris)* and sweat bees (Halictidae) are complementing pollination by partly different foraging activities during the day (Photo: Marcos Miñarro, SERIDA, Asturias, Spain).

Natural pest control: The blue tit (*Cyanistes caeruleus*) is a major predator of the rosy apple aphids (*Dysaphis plantaginea*) (Photo: Photo: Marcos Miñarro, SERIDA, Asturias, Spain)

2. Objectives of the research

2. Objectives

The overarching goal of our project was to understand how European AES (Agri-Environmental Schemes) and landscape diversity influence biodiversity and ecosystem services (ES: pollination, pest control) and to understand negative effects of biodiversity (pest levels) in relation to fruit production in three climatic regions across Europe. To achieve this goal, we measured morphological and physiological traits of bees and predators to assess effect traits on pollination/natural pest control and response traits of pollinators/predator to climate and land-use change. In accordance with our proposal text, we focused on the following main objectives:

1. Investigate how biodiversity of functional groups is affected by AES implemented on two spatial scales depending on the landscape context

2. Investigate how the effectiveness of AES on biodiversity translates into multiple functions or intermediate services affecting the final service fruit production

3. Investigate if biodiversity increases multiple ecosystem services when the ecological communities include a diverse array of traits (functional complementarity)

4. Show how biodiversity drives ES by spatial and conditional complementarity

5. Investigate how AES at different spatial scales affect the diversity of traits (response diversity) and the specificity of food webs

6. Investigate if species-specific responses to climate cause differences in insect communities along the south-north European gradient

7. Show how expected climatic changes increase or decrease species along the north-south European gradient and how these change affect the relative importance of services and disservices in apple orchards

8. Investigate the trade-offs between service-disservice provisioning for crop production in relation to the AES in different landscape contexts.

Overall, our proposed project aimed to contribute to our knowledge of how to promote synergies and reduce trade-offs between food supply (apple production), biodiversity and ecosystem services. Additionally, our proposed project was designed to complement other pan-European research project by collecting missing trait data of pollinators and predators for ongoing and future syntheses projects.

3. Project activities and achievements

3.1. General description of activities over the duration of the project

The objectives of the EcoFruit project followed the Work package (WP) structure and each of our five partners was responsible for one of the five WPs. Although responsibility was defined per WP, all partners contributed to each WP using a common study design with the same criteria for orchard site and landscape selection in each country. The main study sites comprised 28 orchards in Spain and Sweden and 30 orchards in Germany, with half of the orchards being managed organically and the other half according to integrated pest management practices. All orchards comprised low-stem apple trees, representing high-input fruit production in Europe, and all orchards per country were presented by one common main variety (Samnegård et al. 2018). The network of orchard sites in Germany, Spain and Sweden comprised the main study gradient (site network) of EcoFruit. Freiburg, Darmstadt, Barcelona and Stockholm were responsible to collect the explanatory and response variables in the site network by using shared protocols developed and adjusted by all partners in email/phone exchange and during our annual project meetings. We additionally included 23-26 low intensity apple orchards for cider production in Asturias with Oviedo being responsible for data acquisition (Miñarro and García 2018a,b, García et al. 2018). This turned out being an advantage for EcoFruit to answer the effect of biodiversity in respect to response and effect traits and to analyse complementarity versus redundancy in pollination services as these low-input orchards harbored a much higher diversity than the low-input farms. For country comparisons, we usually did not consider the Asturias data, because of the very different management. Oviedo collected the Asturias data using the same joint protocols as the other partners. In the following the contributions of partners per WP are described structured according to the original proposal objectives:

Partner 1 (P1) – the Albert-Ludwigs ***University of Freiburg*** with Alexandra-Maria Klein and Virginie Boreux were responsible for the overall coordination of the research consortium and reporting of the project activities. Freiburg developed the webpage as part of their University homepage and updated the webpage regularly. Freiburg also ensured that brochures/flyers adapted to the specific countries to inform farmers about beneficial insects for fruit production. Freiburg ensured that all partners in all three countries participated in national press releases, interviews, print media and several documentaries including videos of research in EcoFruit

In respect to research, the University of Freiburg was additionally responsible for

WP1: ***Effectiveness of AES on pollinator diversity and pollination services***

In this first WP, we addressed the objective *to investigate how biodiversity of different functional groups is affected by AES implemented on two different scales depending on the landscape context.* Freiburg coordinated the protocols for the pollinator observations and pollination experiments and all groups participated in data collection. Freiburg conducted pre-experiments to study the difference in the pollinator community of common European environments and shared the data with other researchers (Garratt et al. 2016). Freiburg developed a manuscript analysing the pollination effectiveness of different bee species in response to the orchard management (organic versus conventional, planting scheme, landscape diversity) based on data collected in Germany, as this was the largest data set and data of the other partners were too small as staining of pollen tubes did not work appropriately (Haro et al. in submission). Orchard management and adjacent vegetation as well as different landscape variables were analysed for Asturias (Miñarro and García 2018a) and across all three countries for pollinators by Freiburg (manuscript in preparation). In addition, Freiburg wrote a conceptual framework about the multiple scales to promote pollinators based on the EcoFruit approach (Pufal et al. 2017) and identified the most-common bees visiting apples worldwide (Klein et al. 2018).

The second objective was planned *to investigate how the effectiveness of AES on biodiversity translates into multiple functions or intermediate services affecting the final fruit production service.*
The pollinator and pollination data of all three countries were analysed by Stockholm together with the pest and predator data to show how these insects contribute to fruit production in relation to orchard management (Samnegård et al. 2018).

Partner 4 (P4) - Universidad de Oviedo (***University of Oviedo***) with Daniel García and Marcos Miñarro was responsible for
WP2: *Effectiveness of AES to the diversity of natural enemies and pest control*
This second WP was centered around the same research questions as in WP1 but focusing on predation and pest control. Oviedo used their data sets from Asturias to analyse the pest infestation and biocontrol of the apple blossom weevil (Miñarro and García 2018b). This WP additionally focused on the effects of birds as pests and predators of insect pest species and their effects on fruit production (García et al. 2018). Oviedo contributed to the analyses and writing of the overall EcoFruit datasets on pests and predators with all partners (Samnegård et al. 2018, Happe et al. 2019). Additionally, Sweden analysed the effects of management on pollinators and predators using biodiversity parameters and different functional groups (Porcel et al. 2018).

The first two WPs (WP1, WP2) were responsible to show when and to what extent organic management, adjacent vegetation and landscape variables promote multiple biodiversity-based ecosystem services and how this translate to fruit production.
The next two WPs (WP2, WP4) were responsible to focus on the functional importance of biodiversity for pollination and pest control.

Partner 2 (P2) – Barcelona, CREAF (Research Center for Ecology and Forestry Applications) with Jordi Bosch and Anselm Rodrigo responsible for
WP.03: ***Functional importance of pollinator diversity and the role of response traits for pollination***
Within the low-input orchards of Asturias, Oviedo showed that flowers were visited by more than 80 pollinating species (Barcelona, Freiburg and Stockholm found less than half of the species in the high-input orchards in Spain, Germany and Sweden). Hence, Oviedo analysed functional pollinator redundancy and complementarity in response to land-use and climate variables (Miñarro and García 2018a). This study contributed to the third and fourth objectives of our proposal to investigate *if pollinator diversity increased pollination services when communities include a diverse array of traits (functional complementarity) and how pollinator diversity drives pollination by spatial and conditional (climatic) complementarity.*
Barcelona collected functional and life-history traits for pollinators of the overall site network of EcoFruit. As we missed a continuous measurement for hairiness of pollinators, we had to develop a new method. Hairiness measurements of all flower-visiting insects were jointly developed by Barcelona at the University of Freiburg (manuscript in preparation). The protocol to measure hairiness as a continuous variable and the data collected complement existing pollinator trait data-bases. These data will then be used in follow up work to investigate how AES at different scales affect the diversity of traits of the flower-pollinator community interactions and to explore the relationship between hairiness and pollinating effectiveness (Roquer-Beni et al. in preparation).

Partner 5 (P5): University of Darmstadt with Nico Blüthgen, Karsten Mody and Anne-Kathrin Happe was responsible for
WP.04: ***Functional importance of predator diversity and the role of response traits for pest control***
The University of Darmstadt coordinated the development of the joint sampling protocols to access the pests and predators across countries. They were also strongly involved in coordinating the landscape, vegetation and orchard management data. Using the site-network of EcoFruit, they assessed how arthropod predators respond to orchard management and landscape composition (Happe et al. 2019). With data only collected in Germany and Spain, they analysed earwigs as important generalist predators in apple orchards in response to different management variables (Happe et al. 2018). Oviedo additionally contributed with their low-input orchards to show how orchard and landscape variables influenced the apple blossom weevil, a common pest species in European apple orchards and their natural enemies. To

include another higher trophic level, they experimentally excluded birds from apple trees (Miñarro and García 2018b, García et al. 2018). Responses of predator diversity were analysed by Stockholm (Porcel et al. 2018). Darmstadt measured predator trait data on metabolic rates and energy use and collected traits such as biomass, voltinism, mobility and predation behaviour for spiders. With a follow up grant, Sweden will analyse the diversity of diets of apple orchard spiders using molecular gut analyses. WP 4 therefore contributed to the objective to investigate *predator diversity to control apple pests in relation to orchard and landscape management.* As the predator communities could not be completely sampled for common European pest species, the objective to investigate *how orchard management affect the specificity of predator-pest food webs* can only be assessed in our follow up projects.

Partner 3 (P3): Stockholm University with Peter Hambäck and additionally Marco Tasin (Alnarp) was responsible for

WP.05: ***Response traits to buffer changing climatic conditions for services and disservices***

Stockholm was responsible for the objective *to investigate the trade-offs between services-disservices provisioning for crop production in relation to the AES in different landscape context* (Samnegård et al. 2018). They were also responsible to the objective *to investigate response traits to climatic changes* (investigated by Oviedo, Miñarro and García 2018a) and for the objective *to show how expected climatic changes increase or decrease pollinator and pest-predator interactions*. Research questions to climatic response traits could be party answered by our management and across country gradients. With an experimental manipulation, we induced phenological shifts in apple trees and looked at the effects on pollinators, herbivorous pests and natural enemies in Hungary, together with the German (Freiburg) partners (Körösi et al. 2018). This study was designed by Freiburg for our first, more-comprehensive, EcoFruit proposal that did not get funded, but Hungary received funding to conduct this experiment.

3.2. Table of deliverables

Notice: We expanded the number of deliverables (but not of the milestones) as the list turned out to be too short in the original proposal; C= Coordination

Deliverable and Milestone			Lead partner (country and designation)	Date delivered (dd/mm/yyyy)	Comments
Work package	*Deliverable or Milestone*	*Full name*			
C	*D1.1*	*Design of project website available*	*P1*	15/04/2015	As planned - Website was designed as part as the University webpage to avoid costs after the project is finished. The first webpage was available with the start of the project; we set up a new one in the beginning of 2016 and regularly updated it with project achievements
C	*D1.2*	*Site selection finalized and criteria list available to all partners*	*P1*	15/04/2015	Earlier as planned - We started with the site selection prior to project start otherwise we would have lost one year. Notice: we could not find enough apple orchards with flower strips that were actively managed under an Agri-environmental scheme and which fulfil all other selection criteria in all three countries. We decided to use orchards with spontaneous vegetation strips but not all were actively managed under an Agri-environmental scheme. The organic orchards were managed under AES in all three countries.
C	*D1.3*	*Interview outcome with growers of all countries available to all partners*	*P1 (P2,P3,P4,P5)*	04/2015, 01/2016, 11/2016	Partly as planned - Head to be readjusted to ask more questions than originally planned to get more detailed management information.
C	*D1.4*	*Quantifying agri-environment schemes & landscape (GIS) and data available to all partners*	*P1 (P2,P3,P4,P5)*	05 to 06/2015 & 04/2016	As planned - Delivered to all involved partners as planned
WP1	*D1.5*	*Flower-visitor and pollination data of the site-network summarized*	*P1*	02/2017	As planned - Delivered to all involved partners as planned; data are not yet published; data on fruit quality still need to be delivered to all partners
WP2	*D1.6*	*Predator data of the site-network summarized for all partners*	*P5*	02/2018	As planned - This was originally assigned to P4 but as we decided to select orchards in two different regions of Spain and because the Asturias data were difficult to analyse together with the data of the other regions we decided that Darmstadt will take over the responsibility, data published
WP3	*D1.7*	*Functional traits of pollinators collected and measured to be available to all involved partners*	*P2*	02/2018	Partly delayed - Traits from the literature and measured are available, first manuscript is written and more will follow. As we had to develop a new method, the publication process of this project goal was delayed
WP4	*D1.8*	*Functional traits of predators available to respective partners*	*P5*	02/2018	As planned - Traits from the literature and measured are available for important predators and several papers were published.

Deliverable and Milestone			Lead partner (country and designation)	Date delivered (dd/mm/yyyy)	Comments
WP5	*D1.8*	*Trade-offs between pollination/pest damage/predation and fruit production to be available to all partners*	*P3*	02/2018	As planned - Data available and published; an additional experiment was conducted with P1 to access phenological mismatch
C	*D1.9*	*Annual progress report to BiodivERsA*	*P1*	03/2016, 07/2017	As planned - Reports were delivered on BiodivERsA requests as well as the national reports on request of national funders. For some countries all reports are delivered, for some the reporting is due later e.g. Sweden
C	*M2.1*	*Project kick-off meeting*	*P1*	02/2015	As planned - Earlier than planned - Prior project start to discuss and initiate site selection; this was done before project start to start sampling in 2015
C	*M2.2*	*BiodivERsA kick-off meeting*	*P1*	29/04/2015	As planned - P2 (Karsten Mody) joined the meeting and introduced the project and reported to the coordinator
C	*M2.3*	*Webpage published*	*P1*	01/05/2015	As planned for a first version
C	*M2.4*	*Interviews of growers finalised for detailed management information*	*P5*	01/09/2017	This was planned for month 4, but due to time constraints and because we later decided to ask for more information interviews were adjusted in 2017 and finalised later than planned
C	*M2.5*	*Selection of orchards finalised*	*P1*	10/04/2015	As planned
WP1	*M2.6*	*Flower visitation and species identification completed*	*P1*	01/03/2016	As planned, but more data were collected in follow-up years
WP1	*M2.7*	*Quantification AES finalised, site characteristic, hedges, flowering habitat characterised*	*P1/P5*	01/03/2016	As planned
WP1	*M2.8*	*Pollination success data finalised*	*P1*	15/12/2015	As planned
WP2	*M2.10*	*Bird observation and impact data finalised*	*P4*	01/10/2016	Planned for first year but had to be done in the second year because of time contraints
WP2	*M2.10*	*Predator impact data collected*	*P5*	01/05/2015	As planned
WP2	*M2.11*	*Fruit production/quality data*	*P1/P5*	01/05/2015	As planned
WP3/4	*M2.12*	*Morphometric and physiological trait data*	*P3/P5*	10/10/2018	Delayed for some measurements as we had to develop appropriate method for hairiness and first had to buy equipment for it
WP1	*M2.13*	*Intermediate project meetings to exchange and discuss data and analyses*	*P1,P2,P3,P5*	03/2015 in Freiburg; 01/2016 in Barcelona; 01/2017 in Stockholm; 11/2017 in Darmstadt	As planned plus additional meetings
WP3/4	*M2.14*	*Trait data from the literature*	*P3/P5*	31/12/2016	As planned
WP5	*M2.15*	*Modelling of climate niches and response traits to climate change*	*P3*	31/12/2016	Partly as planned - Responses to climate change were analysed and published for the high diversity sited of Oviedo; modelling of climate niches within the site network is planned with additional data to be collected by the responsible partner in a follow-up grant.

Deliverable and Milestone			Lead partner (country and designation)	Date delivered (dd/mm/yyyy)	Comments
WP2	*M2.16*	*Survey pests and natural enemies including species identifications*	*P2*	15/03/2017	As planned
WP1	*M.2.17*	*Pollination effectiveness data*	*P1*	01/03/2017	As planned but were not sufficient for 2 countries. Manuscript on German data written
WP1,2, 3,4,5	*M2.18*	*Statistical analyses for main objectives finalised*	*P3 – all partners*	01/11/2017	Main analyses as planned but many data are still in process and statistics need to be adapted continuously due to the complex data structure
WP1	*M2.19*	*Brochures for dissemination*	*P1 and all partners for their respective regions*	01/02/2018	First flyers/brochures spread to growers in the first year and continuous development during the project time and after the project in countries with follow-up projects
WP1	*M2.20*	*Country-specific workshops for stakeholders for dissemination*	*P1 and all partners for their respective regions*	01/02/2018	As for the brochures, all countries organised dissemination workshops in their regions and still have ungoing dissemination workshops financed by follow-up projects
WP1	*M2.21*	*First draft of key manuscripts written*	*P1*	31/03/2018	As planned, most are published, two shortly before submission and one manuscript is not yet finalised for the main objectives given in the original proposal

3.3. Scientific outcomes

In the following, we present the main scientific results for pollinators, followed by the results for natural pest control and by showing the trade-offs and synergies between the conservation of biodiversity and fruit production, followed by results on phenological mismatch. To keep the report within the predetermined page limit, we only visualise few unpublished results, otherwise we refer to our published papers. Important research messages are highlighted in bold.

Pollinators in European apple orchards

Top European apple pollinators

The EcoFruit site network comprised around 90 high-intensity/low-stem orchards (notice that number of study orchards slightly differ for different analyses). Across these orchards, we observed a total of 7791 flower visits by 64 species. The managed European honeybee, *Apis mellifera* was the most frequent flower visitor, with respectively 72.2, 81.2 and 72.3% of the visits in Germany, Spain and Sweden. Besides *Apis mellifera*, two bumblebee species (*Bombus terrestris*, *Bombus pascuorum)* and the European orchard bee *(Osmia cornuta)* were foraging on apple flowers in all three countries. Nine flower-visiting species were found in two countries, with seven species found in Germany and Sweden (*Andrena fulva, A. haemorrhoa, Bombus hypnorum, B. lapidarius, B. pratorum*, *Coccinella septempunctata*), two in Germany and Spain (*Andrena flavipes, Episyrphus balteatus*) and only one in Spain and Sweden (*Andrena nigroaenea*). The results point to a more similar flower-visiting community between Germany and Sweden compared to Germany and Spain and the most distinct community between Sweden and Spain. The remaining 51 species were only found in one country, showing the huge difference of the pollinator communities in different European countries (see also Garratt et al. 2016 including a pre-experiment for EcoFruit showing the flower-visiting communities across European apple varieties).

In the 26 low-intensity cider apple orchards of Asturias, Oviedo found 3405 flower visits of 83 species. This was almost twice as many compared to visits and species numbers in the EcoFruit site network (Miñarro and García 2018a). Besides *A. mellifera*, seven wild insect species were the top flower visitors in Asturias (*Bombus terrestris, Eristalis tenax, Episyrphus balteatus, Eristalis similis, Sphaerophoria scripta, Bombus pratorum and Andrena nigrocaenea*). *Bombus pascuorum* was also found in Asturias and we therefore conclude that "**Only two bumble bee species (buff-tailed bumblebee, common**

carder bee), the European orchard bee, and the European honeybee are dominant flower-visitors across European apple orchards"
Andrena hemorrhoa was found in three orchards in Asturias and could therefore be classified as a common wild bee species in European apple orchards, although more abundant in north to middle Europe than in southern Europe. Of the other four dominant bee species in all countries, only *B. pascuorum* was never managed in our study regions and could therefore be identified as the only dominant wild bee species across European apple orchards. Using our apple and other crop literature database, we could show that "***B. terrestris* is under the top ten wild bee species visiting crop flowers and the most important species beside *A. mellifera* for apple pollination globally"** (Klein et al. 2018).

Pollinator diversity and effectiveness to pollinate apples in relation to orchard/landscape management
We first described conceptually how local management and landscape effects should be considered for crop pollination studies, but for this project, we could not measure entire farms and were restricted to the orchard-, the adjacent orchard-, and the surrounding landscape scale in a 1km-radius (Pufal et al. 2018).
Considering the different flower-visiting communities between the three countries, we first analysed and highlight some results per country (manuscript in preparation including all partners). Using the orchards of the EcoFruit site network, in Spain, bee species richness and wild flower visitation was best explained by the interactions between orchard management, amount of adjacent bee habitat and bee habitat in the landscape. This pattern was best explained by the flower availability caused by these management practices at the three different scales. The cover of flowering plants at the orchard and adjacent orchard scale increased fruit production, while increasing amount of bee habitat in the landscape decreased fruit production. The results indicate that providing flowering plants as cover crops in apple orchards and flowering hedgerows and herbal flower habitat adjacent to the orchards seems more effective to increase biodiversity and fruit production than conserving bee habitat in the landscape.
In Germany, bee species richness and wild flower visitation were also best explained by the interactions between the three spatial scales. The responses of bee richness and wild flower visitation was different for organic and IP orchard. For organic orchards, but not for IP orchards, bee habitat in the landscape increased species richness and flower visits. Also fruit production was highly influenced by the interactions between orchard-, adjacent orchard- and landscape management. Fruit production in the IP orchards was increased by the amount of bee habitat in the landscape. Similar to Spain, flowering plants in the orchards and adjacent to the orchards increased species richness and wild flower-visitation frequency and fruit production.
In Sweden, bee species richness and wild flower visitation were also explained by the interactions between orchard management, amount of adjacent bee habitat, and bee habitat in the landscape. In Sweden, we could show that species richness and wild flower visitation increased when herbaceous habitat was available adjacent to the orchards, but not with woody adjacent habitat. Anyway, the positive effect of herbaceous compared to woody adjacent habitat did not influence fruit production. Fruit production in Sweden was mainly affected by honeybees and not by the richness and flower visitation of wild bees. This was different in Germany and Spain.
In summary, organic management and adjacent flowering habitat increased biodiversity of pollinators but fruit production was always higher in IP compared to organic management. "**The availability of flowers in and adjacent to orchards can increase pollination without compromising fruit production"** (Samnegård et al. 2018). Therefore, apple growers can promote pollinator diversity on their land by actively planting flowering plants or to enhance the quality of woody habitat by planting flowering plants into the woody habitat. In a follow-up project in Germany, we are testing the effects of managing available woody habitat for bee biodiversity and apple pollination. In follow up analyses with bee and pollination data of the EcoFruit site network, we aim to analyse if managing flowering habitat at the orchard-, adjacent orchard, and landscape scale can mitigate the negative effects of increasing agricultural land in European high intensity fruit production.
With the high pollinator diversity of the low-intensity orchards with high-stem fruit trees of Asturias, our partners in Oviedo showed that honeybees, bumblebees, wild bees and syrphid flies mainly approached the flowers from the top, while all other flies mainly collected nectar from the side of the

flowers (Miñarro and García 2018a). They also showed that honeybees switched more often between trees than other flower visitors, and bumblebees visited flowers more frequently from the upper part of the tree and syrphid flies from the lower part. In respect to visitation hours, honeybees, syrphid flies, and other flies were more active than other flower-visiting insects between 09-11am, wild bees and beetles mainly visited between 12am-3pm and bumblebees were the most frequent flower visitors between 4-6pm (Miñarro and García 2018a). These results show spatial complementarity in high-stem fruit production, which cannot be observed in low-stem production (no clear spatial niches in and between trees) and they showed temporal complementarity with daytime, which remains to be tested in the EcoFruit site network. Oviedo also showed that the number of flower visits of all flower-visiting groups increased from low temperature-high humidity to high-temperature-low humidity. This result indicates high redundancy to climatic changes (temperature/humidity). In conclusion, the **"High pollinator diversity in the low intensity orchards indicates stability in pollination services to climatic changes caused by redundancy in the use of climatic niches. The spatial complementarity in the high-stem trees on the contrary indicate a risk to less pollinated tree parts when pollinator groups disappear from the orchards"**.

In Germany, Freiburg collected 390 stigmas of flowers bagged before pollination to open them for specific flower visits by honeybees, bumblebees (*Bombus terrestris*) and by sand bees (mainly *Andrena haemorrhoa*) from 18 orchards to measure their species-specific pollination effectiveness. Additionally, the pollination effectiveness was related to the planting scheme and orchard management. Pollination effectiveness was measured by the number of pollen tubes starting to grow on the stigma, the proportion of carpels with at least one pollen tube starting to grow on the stigma, number of pollen tubes growing to the ovary, and the proportion of carpels with at least one pollen tube growing to the ovary. We assume that pollination effectiveness is best explained by the last variable (tube set in the ovary). We showed that pollination effectiveness was not significantly different between sand bees, bumblebees and honeybees. The pollination effectiveness of honeybees was higher in an interspersed (where trees of pollen providers and receivers are planted in the same tree rows) compared to an adjacent planting scheme (where trees of pollen provider and receiver are planted in separate tree rows with larger distances between compatible apple varieties, Fig. 1) and in organic compared to IPM orchards (Fig. 2). We therefore conclude that an **"Interspersed planting scheme and organically managed orchards promote the pollination effectiveness of honeybees"**. This can be explained by the higher diversity of wild bees in organic orchards, which are known to disturb honeybees to switch more often between trees of different varieties.

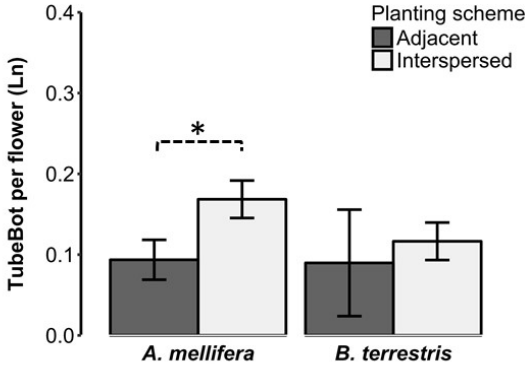


Fig 1: TubeBot (proportion of carpels with at least one pollen tube growing to the the ovary) per flower after a single *A. mellifera* or *B. terrestris* visit in an adjacent and interspersed planting scheme. Barplots show means and standard errors.

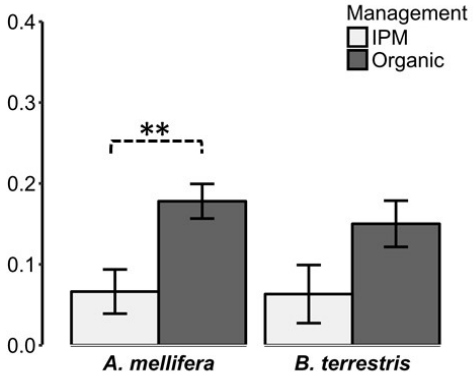


Fig. 2: TubeBot (proportion of carpels with at least one pollen tube growing to the the ovary) per flower after a single *A. mellifera* or *B. terrestris* visit under IP and organic management.

To explain pollination success and pollinator responses to changes, we measured effect and response traits to land use and climate change. For this objective, we developed a method to measure hairiness of all flower-visiting insects collected in our project. Hairiness (pilosity) is a salient trait in pollinating insects (manuscript in preparation). It has been associated with thermoregulation (response trait) and

pollen collection, transportation and pollinating effectiveness (effect trait). Up to date, hairiness is mostly lacking from pollinator trait databases or estimated in categories, due to a lack of standard effective methods to measure this trait. Barcelona and Freiburg developed a new method based on the use of a stereomicroscope equipped with a live measurement module software that allowed to quantitatively measuring hair density and hair length.

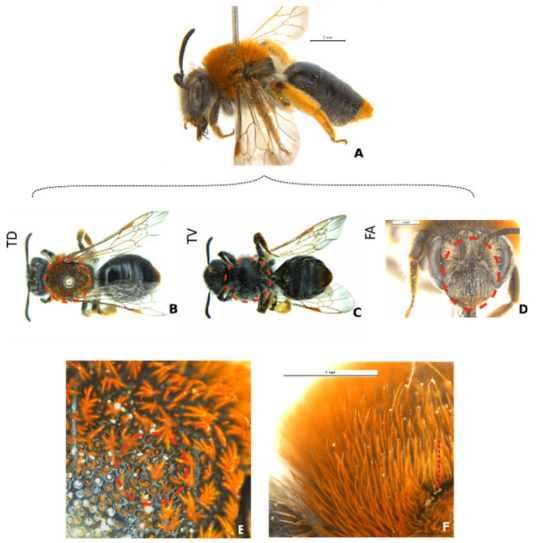


Fig. 3: Body parts for hairiness measures of (A) a pinned *Andrena haemorrhoa*; TD= thorax dorsal (B), TV= thorax ventral, face (D), and close-ups to measure hair density (E) and hair length (F).

The two project partners combined these two components into a simple index to provide an overall measure of hairiness. We used three body parts of 112 flower-visiting species to analyze the relationship between hair length and hair density. Barcelona also analyzed the relationship between the two components of hairiness and body size, and between hairiness of different body parts. We also tested if the proposed methodology allows us to discriminate pollinator groups and bee genera. We showed that **"Butterflies were the hairiest pollinator group, followed by bees, hoverflies, beetles and other flies. Among bees, *Bombus* and *Osmia* were the hairiest taxa, followed by Anthophorinae, *Andrena* and Halictini"**
Barcelona and Freiburg will now use the results of this method to explain pollinating effectiveness and responses to climate change and pollinator functional diversity using the EcoFruit data.

Natural biological control of herbivorous pests in European apple orchards

The most common herbivorous pests in our partner countries are aphids, especially the rosy apple aphid (*Dysaphis plantaginea*) and the woolly apple aphid (*Eriosoma lanigerum*), but also the fruit tree red spider mite (*Panonychus ulmi*) and in the low-intensity orchards of Asturias the apple blossom weevil (*Anthonomous pomorum*).
In order to study the natural pest control by all partners, the EcoFruit site network was used (here 30 orchards in Germany and 28 in Sweden and in Spain, respectively, half of all orchards managed under IP and half organically (Happe et al. 2019). Using standardized beating protocols for 24 randomly selected branches per orchard, the predatory community of herbivorous species were sampled and related to orchard management (IP versus organic and reduced and targeted application of synthetic agrochemicals) and landscape variables, e.g. cover of woody habitat in a 1 km radius. Darmstadt calculated community energy use as a proxy for the predation potential of the predator community based on biomass and metabolic rates of predatory arthropods. We found that the predator communities differed between management types and countries. Several groups, including beetles (Coleoptera), predatory bugs (Heteroptera), flies (Diptera) and spiders (Araneae) were promoted by organic management depending on country. Woody habitat and IP supported harvestmen (Opiliones). High cover of woody habitat reduced earwig abundances in Germany but enhanced their abundance in Sweden, and high natural plant species richness tended to reduce predatory bug abundance in Sweden and IP orchards in Spain. We therefore conclude that "**Orchard management and woody habitat in the landscape influence predatory arthropod communities but the influences are regional specific with different responses between European countries"**. These results highlight that organic management improves the living conditions for effective predators in European apple orchards (Happe et al. 2019).
Our partners from Darmstadt and Barcelona studied the woolly apple aphid and earwigs as a generalist predator consuming these aphids in the 58 apple orchards of the EcoFruit site network in Germany and

Spain (Happe et al. 2018). They assessed the influence of organic management, adjacent agri-environmental structures, orchard management, and the landscape on earwig populations on trees 30-32 randomly chosen trees for infestation by the woolly apple aphid (WAA) and they excluded experimentally the earwigs from the aphid populations and sprayed trees with standardized pesticide treatments. They found that the common earwig, *Forficula auricularia*, was negatively influenced by IP management in Spain with more aphids in organic orchards and the presence of woody habitat adjacent to the orchard reduced the abundance of earwigs in IP but not in organic orchards in Germany. Therefore the low aphid infestation in Germany could be controlled by woody habitat in the landscape but not by orchard management. These results suggest that "**Woody habitat adjacent to the orchards and in the landscape serve as sink habitats – potentially attracting earwigs by providing alternative prey and shelter – in IP (but not in organic) European fruit orchards"** (Happe et al. 2018).

In the low-intensity orchards of Asturias, Oviedo used the apple blossom weevil (*Anthonomus pomorum*) as a model pest to unravel the management variables driving pest infestation and its natural control using the complete life cycle of the pest and combined large-scale observation (23 orchards) with a small-scale experimental approaches (Miñarro and García 2018b). Weevil attack (0.4–37.4% of flowers) and their abundance increased with the proportion on apple trees in the immediate orchard neighbourhood and with woody habitat in the surrounding landscape and decreased with tree distance to orchard edge and the apple bloom status. Thus, the prevalence of the pest depended on the availability of the various resources required for foraging, egg-lying and overwintering. Three types of natural enemies supplied complementary pest control by preying on weevils at different stages in their life cycle: seven parasitoid species attacked immature weevils (6.4–81.5%), while the additive effects of birds and crawling arthropods were evident in terms of the removal of adult weevils (31–44%). The results suggest that the **"Effective biological control of the apple blossom weevil can be achieved to maintain the pest at non-harmful levels, through combined management of the pest, its habitat and its natural enemies"**.

Using the same low-intensity orchards of Asturias, Oviedo observed insectivorous birds and included bird exclosure experiments to estimate the potential of birds for controlling arthropod abundance and pest outbreaks in apple trees (García et al. 2018). They observed twenty-nine tree-dwelling, insectivorous bird species in one year, inside and around the apple orchards, with six dominant bird species. Bird abundance and richness increased with the availability of semi-natural woody habitats (hedgerows, remnant trees, and forest patches) both in the immediate neighborhood of the orchard and in the landscape within a 1-km radius of the orchard. Orchards with higher cover of apple tree canopy also harbored a greater abundance and richness of birds. Apple tree branches that were cage-excluded from birds and manually infested with aphids suffered increased shoot damage and aphid outbreak, compared to those that were aphid-infested but open to birds. Bird exclusion increased abundances of pest insects other than aphids, and also of other arthropods considered as natural enemies or mutualists of pests. Arthropod abundance was lower in those orchards showing higher abundances of insectivorous birds during spring and summer. To conclude this study **"Multi-scaled farming management, involving both within-field practices and regional land-use schemes, should be considered to promote win–win scenarios in low-input apple orchards, whereby species-rich communities of insectivorous birds provide effective pest control service"**.

Trade-offs/synergies of biodiversity conservation and fruit production / phenological shifts

In a joint-analyses with all partners, we quantified the direct and indirect effects of management (organic versus IP) on species richness of beneficial arthropods, pest abundance and damage, pollination and fruit production using 85 apple orchards of the EcoFruit site network, including all three countries (Samnegård et al. 2018). We assessed management effects of these variables at three spatial scales: within orchards, adjacent to orchards, and in the surrounding landscape. Organic management resulted in 48% lower yield than IPM, and also the variation in fruit production between orchards was large, with some organic orchards having a higher yield than the average yield of IP orchards. The lower yield in organic orchards resulted directly from management practices, and from higher pest damage in organic orchards across countries. The negative yield effects could only be partly mitigated by indirect positive effects from more natural enemies and higher flower visitation and pollination in organic orchards. Two factors other than management affected species richness and ecosystem services. Higher cover of

flowering plants within and adjacent to the apple trees increased flower visitation rates by pollinating insects and a higher cover of apple orchards in the landscape decreased species richness of beneficial arthropods. The species richness of beneficial arthropods in orchards was not correlated with fruit production, suggesting that diversity can be increased without large yield loss. At the same time, organic orchards had 38% higher species richness than IP orchards, an effect that is likely due to differences in pest management. The results indicate that **"Organic management is more efficient than integrated pest management in developing environmentally friendly apple orchards with higher species richness"**. We also demonstrate that there is "**No inherent trade-off between species richness and fruit production"**. Development of more environmentally friendly means for pest control (establishing adjacent perennial, flowering habitat), which do not negatively affect pollination services, needs to be a priority for sustainable apple production.

In an additional experiment not directly funded by EcoFruit but based on ideas of the first Biodiversa application of the coordinator, we studied in Hungary how climate change alters the phenology of trophically interacting organisms, which may lead to increased asynchrony between the plant and the interacting arthropods and their related ecosystem services (Kösösi et al. 2018). Although phenological mismatches are reported from several ecosystems, experimental evidence for altering multiple ecosystem services is hardly available. We examined with our Hungarian partners (could not be officially in our consortium) how the phenological shift of apple trees affected the abundance and diversity of pollinators, generalist and specialist herbivores and predatory arthropods. We stored potted apple trees in the greenhouse or cold store in early spring before transferring them into orchards to cause mismatches and sampled arthropods on the trees repeatedly. Communities of flower-visiting insects on the manipulated and control trees differed markedly, but their overall abundance was similar indicating a potential **"Insurance effect of wild insect diversity to ensure fruit set in flower-pollinator mismatch conditions"**. Nevertheless, specialized herbivores were almost absent from manipulated trees, while less-specialized ones showed diverse responses, confirming the expectation that "**More specialized interactions are generally more vulnerable to phenological mismatch"**. Natural enemies also responded to shifted apple tree phenology and the abundance of their prey. While arthropod abundances either declined or increased, species diversity tended to be lower on apple trees with shifted phenology. Hence this study indicates, that **"Early apple blooming caused by climate change does not necessarily reduce the beneficial services of insects to fruit production, but species diversity will suffer"**.

3.4. Outcomes for the consortium / added value

	Rating (3=major outcome, 2=moderate outcome, 1=minor outcome, n/a= not applicable)
1. increased research capacity	2
2. improved scientific evidence base	2
3. new method, data or technology	2
4. new / improved product or service	n/a
5. new technical process	n/a
6. new organisational process	2
7. better access to international networks / markets	2
8. better understanding of other European cultures / issues	2
9. enhanced research network to compete for future European project funding	2
10. better understanding of stakeholder needs	3
11. increased knowledge transfer to society	3

One of the strengths of the project was its transnational character. Only with a site-network including different European countries with different climates, it was possible to identify general management recommendation at the EU level. Our data also shows that the insect communities and the management effects can strongly differ between countries. Hence regionally adapted management needs to be considered besides the broader general recommendations at the EU level. This would not be possible in a national study. Our project also benefited by the integration of the low-intensity management of Asturias. The mechanisms of the advantages of high biodiversity could only be shown in these low-intensity orchards. We were not aware of this at the start of the project.

3.5. Follow up activities and plans for further exploitation of the results

a) Did your project achievements lead to additional funding during or after the completion of the BiodivERsA/FACCE-JPI project?	Yes, (1) new EU consortium of a Horizon 2020 call (Poshbee) on pollinator health in apple plantations across Europe for the period 2018-2023; (2) a follow up project for Germany to enhance pollinators in supplemented hedgerows and flowering habitat financed by Bayer Crop Sciences for the period 2018-2021; (3) spatially extended food webs: The role of the surrounding landscape for biocontrol in apple orchards. Carl Tryggers Stiftelse för Vetenskaplig Forskning for Sweden, involving partners from Germany and Spain for the period 2019-2020; (4) bee and wasp monitoring with schools including observation of flower visitors on apple trees in urban environments financed by the Robert-Bosch foundation, 2018-2021
b) If yes, does the follow-up project involve…	1. Further research - yes 2. Implementation of results obtained - yes 3. Commercialization of outcomes – probably yes, but still waiting for the official approval of the funding to use the data and pictures of pollinator species of this project to finalise a crop pollination book 4. Other (please specify)
c) Follow up activities and plans for further exploitation of the results: Follow up works include more research to analyse pest-predator food webs using gut analyses of spiders, using our hairiness measurements of flower-visiting insects as a response and effect trait to climate change, to study the active enhancement of pollinators for hedgerows to promote pollination services, to analyse the health status of honeybees, solitary bees and bumblebees using the EcoFruit study orchards and to collect data to analyse the effects of pesticides at the field and landscape scale. Habitat to increase beneficial insects and biodiversity in intensive fruit-producing landscapes is currently being implemented with different annual and perennial flower mixtures together with our stakeholder network. We also educate teachers and students at different schools to observe and monitor bees and wasps with input of our beekeeper network that increased with our field work in EcoFruit. Finally, press releases ending in TV, radio and printmedia contributions lead to follow up collaborations with the media.	

4. Stakeholder engagement before, during and after project's life

Main stakeholders of the EcoFruit project were fruit (apple) growers, extension companies and personals. We also strongly interacted with conservation agencies and personals, beekeepers and with policy departments e.g. the Ministry of Environmental Sciences in Baden Württemberg, the county of our study sites in Germany.

We involved stakeholders before or at project start in all partner countries with a workshop to explain project goals and we adapted our detailed research questions based on their comments. For example, the organic growers in Germany asked us to study not only apple varieties commonly used in IP but also a typical organic variety. As we worked on more than 100 orchards with more than 100 fruit growers, we had to contact them prior the project and we stayed in contact with all during the whole period of the project and also after the end of the project. We organized altogether 15 workshops for stakeholder. For details see Excel file in the spreadsheet "SH_engagement"

5. Dissemination of results

5.1.1 Internationally peer-reviewed publications (see also spreadsheet publications in the excel file)

Happe, A.K., Alins, G., Boreux, V., Bosch, J., García, D., Hambäck, P., Klein, AM., Martínez-Sastre, R., Miñarro, M., Müller, AK., Porcel, M., Rodrigo, A., Roquer-Beni, L., Samnegård, U., Tasin, M., Mody, K. 2019: **Predatory arthropods in apple orchards across Europe: responses to agricultural management, adjacent habitat, landscape composition and country**. Agriculture, Ecosystems and Environment 273:141-150.

García, D., Miñarro, M. & Martínez-Sastre, R. 2018: **Birds as suppliers of pest control in cider apple orchards: Avian biodiversity drivers and insectivory effect**. Agriculture, Ecosystems & Environment 254: 233-243.

Happe, A.K., Roquer-Beni, L., Bosch, J., Alins, G. & Mody, K. 2018: **Earwigs and woolly apple aphids in integrated and organic apple orchards: responses of a generalist predator and a pest prey to local and landscape factors**. Agriculture, Ecosystems and Environment 268: 44-51.

Miñarro, M. & García, D. 2018a: **Complementarity and redundancy in the functional niche of cider apple pollinators**. Apidologie. online first. doi: 10.1007/s13592-018-0600-4.

Miñarro, M. & García D. 2018b. **Unravelling of pest infestation and biological control in low-input orchards: the case of apple blossom weevil**. Journal of Pest Science 91: 1047-1061.

Samnegård, U., Alins, G., Boreux, V., Bosch, J., García, D., Happe, A.K., Klein, A.M., Miñarro, M., Mody, K., Porcel, M., Rodrigo, A., Roquer-Beni, L., Tasin, M. & Hambäck, P. 2018: **Management trade-offs on ecosystem services in apple orchards across Europe: direct and indirect effects of organic production**. Journal of Applied Ecology. online first. doi: 10.1111/1365-2664.13292.

Klein, A.M., Fornoff, F., Mupepele, A.C., Boreux, V. & Pufal, G. 2018: **Relevance of wild and managed bees for human well-being**. Current Opinion in Insect Science 26: 82-88.

Kőrösi, Á., Markó, V., Kovács-Hostyánszki, A., Somay, L., Varga, Á., Elek, Z., Boreux, V., Klein, A.M., Földesi, R. & Báldi, A. 2018: **Climate-induced phenological shift of apple trees has diverse effects on pollinators, herbivores and natural enemies**. PeerJ: 6: e5269.

Porcel, M., Andersson, G., Pålsson, J. & Tasin, M. 2018: **Organic management in apple orchards: higher impacts on biological control than on pollination**. Journal of Applied Ecology 55: 27779-2789.

Pufal, G., Steffan-Dewenter, I. & Klein, A.M. 2017: **Crop pollination services at the landscape scale**. Current Opinion in Insect Science 21: 91-97.

Garratt, M.P.D., Breeze, T.D., Boreux, V., Fountain, M.T., McKerchar, M., Webber, S.M., Coston, D.J., Jenner, N., Dean, R., Westbury, D.B., Biesmeijer, J.C. & Potts, S.G. 2016: **Apple pollination: Demand depends on variety and supply depends on pollinator identity**. PLOS ONE 11: e0153889. doi: 10.1371/journal.pone.0153889.

Garibaldi, L.A., Aizen, M.A., Cunningham, S.A., Harder, L.D. & Klein, A.M. 2016: **Incremental contribution of pollination and other ecosystem services to agricultural productivity: effects of service quantity and quality**. In: Gemmill-Herren, B. (ed.) Pollination Services to Agriculture: Sustaining and enhancing a key ecosystem service (Issues in Agricultural Biodiversity). Routledge, Abingdon, pp. 33-42.

5.1.2 National publications

Miñarro, M., García, D. & Martínez-Sastre, R. 2017: **Los insectos polinizadores en la agricultura: importancia y gestión de su biodiversidad**. Ecosistemas 27: 81 -90.

Hambäck, P. & Tasin, M. 2016: **Rönnbärsmal - vilsen förlorare i äpple**. Natur och Trädgård, Vol 3.

Hellqvist, S. & Hambäck, P. 2016: ***Platypalpus leucocephalus* (von Roser) (Diptera: Hybotidae) found in apple orchards in Scania – first record from the Nordic countries**. – FaZett 29: 58-62.

Klein, A.M. 2016: **Fliegen, Motten, Wanzen. Honig- und Wildbienen haben viele Helfer, doch ersetzbar sind sie nicht**. ADIZ - Die Biene – Imkerfreund 4: 34-36.

Miñarro, M., & García, D. 2016: M**anzana, kiwi y arándano: sin insectos no hay frutos ni beneficios**. Tecnología Agroalimentaria-SERIDA 18:4-8.

5.1.3 Internationally peer-reviewed publications under review or shorty before submission (manuscripts can be send on request)
Hambäck, P.A., Porcel, M., Tanin, M. & Samnegård, U. 2020: **Predatory arthropod community composition in apple orchards: Orchard management, landscape structure and sampling method.** Journal of Applied Entomology 00: 1-9, doi: 10.1111/jen.12832.

Martinez-Sastre,R, Minarro,M. & Garcia, D. 2020. **Animal biodiversity in cider apple orchards: Simultaneous environmentaldrivers and effects on insectivory and pollination.** Agriculture, Ecosystem and the Environment 296: 106918.

Roger-Beni, L., Rodrigo, A., Arnan, X., Klein, A.M. Fornoff, F., Boreux, V., Bosch J 2020. **A novel method to measure hairiness in bees and other insect pollinators. Ecology and Evolution**, early view, doi.org/10.1002/ece3.6112.

Dainise, M. et al. 2019: **A global synthesis reveals biodiversity-mediated benefits for crop production. Science Advances 5,** eaax0121. DOI: 10.1126/sciadv.aax0121.

Samnegård, U., Hambäck, P. & Smith, H. 2019: **Pollination treatment affects fruit set and modifies marketable and storable fruit quality of commercial apples.** Proceedings of the Royal Society, Series B 6, https://doi.org/10.1098/rsos.190326.

5.2.1. Dissemination of results to scientists and scientific organisations
For all the following oral and poster presentations BiodivErsA and FACCE-JPI were acknowledged:

Happe, A.K., Bosch, J., Roquer-Beni, L., Alins, G. & Mody, K. 2018: **Earwigs and aphids in apple orchards – influence of agri-environmental measures and landscape factors**, 18th International Conference on Organic Fruit-Growing 2018, Hohenheim, Germany – talk

Happe, A.K. 2018: **Lebensräume für Wildbienen in der Agrarlandschaft – Forschungsbeispiele**. Workshop by Bund für Umwelt und Naturschutz Deutschland (BUND) Landesverband Rheinland-Pfalz e.V. November 17, 2018, Mainz, Germany – talk

Happe, A.K., Blüthgen, N., Boreux, V., Bosch, J., García, D., Hambäck, P.A., Klein A.M., Miñarro, M., Mody, K., Rodrigo, A., Roquer-Beni, L., Samnegård, U., Alins, G., Porcel, M., Martínez Sastre, R. & Tasin, M. 2018: **Management von Ökosystemleistungen für die Obstproduktion in Europa**, 6. Nationales Forum zu IPBES, 21.-22. Februar 2018, Bonn - poster

Martínez-Sastre, Miñarro, M., Peña, R. & García, D. 2018: **Top-down effects of insectivorous birds on arthropod richness and abundance in cider apple orchards**. International Congress of the Spanish Society of Ethology and Evolutionary Ecology, Mieres, 4-8.09.2018, Spain – talk

Boreux, V., Klein, A.M., Bosch, J., Hambäck, P., Roquer, L., Alins, G., Rodrigo, A. & Samnegård, U. 2017: **Effectiveness of Agri-Environmental Schemes on pollinator diversity in apple orchards**. BES 2017 - talk

García, D., Miñarro, M., Donoso, I., Rodríguez-Pérez, J. & Martínez-Sastre, R. 2017: **Ecosystem services by birds in Cantabrian agroecosystems: Biodiversity matters**. XXIII Congreso Español de Ornitología, SEO-BirdLife, Badajoz, 2-5.11.201, Spain – talk

Happe, A.K., Mody, K., Bosch, J., García; D., Hambäck, U., Klein, A.M., Miñarro, M., Rodrigo, A. & Blüthgen, N. 2017: **Generalist predators in apple orchards and their functional traits: responses to orchard management, woody habitats and landscape composition**, BES/GfÖ 2017, Session: Agricultural Science, Ghent) - talk.

Martínez-Sastre, R., Miñarro, M. & García, D. 2017: **Animal-driven ecosystem services in Asturian cider apple orchards: biodiversity factors and effects**. Workshop ECOFLOR 2017, 30-31.01.2017, Grupo de Trabajo ECOFLOR-AEET, Sevilla, Spain - talk

Martínez-Sastre, R., Peña, R., González-Ibáñez, A., Miñarro, M. & García, D. 2017: **Parasitismo sobre *Cydia pomonella* Linnaeus (Lepidoptera: Tortricidae) en plantaciones de manzano de Asturias**. X Congreso Nacional de Entomología Aplicada, SEEA, Logroño, 16-20.10.2017, Spain – talk

Martínez-Sastre, R., Miñarro, M. & García, D. 2017: **Animal-driven ecosystem services in Asturian cider-apple orchards: biodiversity factors and effects**. XIV Reunión Anual de la Red Temática Ecoflor (Ecología y Evolución Floral), Sevilla, 30-31.01.2017, Spain – talk

Miñarro, M. & García, D. 2017: **Infestación y control biológico del gorgojo del manzano, *Anthonomus pomorum*, en pomaradas de Asturias: condicionantes locales y paisajísticos**. X Congreso Nacional de Entomología Aplicada, SEEA, Logroño, 16-20.10.2017, Spain - talk

Miñarro, M., Martínez-Sastre, R. & García, D. 2017: **Diversidad funcional de polinizadores en manzano de sidra**. X Congreso Nacional de Entomología Aplicada, SEEA, Logroño, 16-20.10.2017, Spain - talk

Roquer-Beni, L., Rodrigo, A., Boreux, V., Klein, A.M., Alins, G., Miñarro, M., Samnegård, U., P, Hambäck, P., Bosch, J. 2017: **Effects of local and landscape factors on pollination services in European apple orchards**. Workshop ECOFLOR 2017, 31.01.2017 - talk

Boreux, V., Klein, A.M., Bosch, J., Roquer, L., Alins, G., Rodrigo, A., Samnegård, U., Hambäck, P. 2016: **Effectiveness of Agri-Environmental Schemes (AES) on visitor abundance and diversity in apple orchards**. British Ecological Society, Liverpool, UK - talk

Bosch, J. & Roquer, L. 2016: **Biodiversitat functional. Marges florits, tanques vegetals i pollinitzadors. Jornada tècnica**. LLEIDA, dimecres 30 de novembre de 2016. Spain - talk

Bosch, J. & Roquer, L. 2016: **VIII Jornada de fructicultura ecològica**. Jornada tècnica. ALFARRÀS, dijous 26 de maig de 2016. Spain - talk

Happe, A.K., Hoffmann, S. & Mody, K. 2016: **Landscape and management effects on biocontrol: Wooly apple aphids and earwigs**. GfÖ Tagung 2016, Marburg. Germany - talk

Happe, A.K. 2016: **Biological pest control in apple orchards.** First results of the BiodivERsA EcoFruit project. Department of Ecology, University of Szeged, November, 2016. Hungary - talk

Miñarro, M. & García, D. 2016: **Contribución de los insectos a la polinización del manzano de sidra en Asturias**. Workshop ECOFLOR 2016, 4-6.02.2016, Grupo de Trabajo ECOFLOR-AEET, Vigo, Spain - talk

Miñarro, M. & García, D. 2015: **Contribución de los insectos a la polinización del manzano de sidra en Asturias**. IX Congreso Nacional de Entomología Aplicada, 19-23.10.2015, SEEA. Valencia, Spain - talk

García, D. 2015: **From Biodiversity to Ecosystem Services in the real world: A case study with Cantabrian birds**. Dipartamento de Scienze Agraria e Forestali, Università degli Studi di Palermo, Italia (16.12.2015) – talk

García, D. 2015: **Biodiversidad y funciones ecológicas de aves en la Cordillera Cantábrica**. Seminario "La Cordillera Cantábrica como centinela de los efectos del Cambio Global", Universidad Internacional Menéndez Pelayo, 17-21.08.2015, Santander, Spain - talk

García, D., Miñarro, M & Rayón, F. 2015: **Control biológico de carpocapsa y riqueza de aves en pomaradas asturianas**. IX Congreso Nacional de Entomología Aplicada (SEEA), Valencia, 19-23.10.2015, Spain – talk

García, D., Miñarro, M & Rayón, F. 2015: **Control biológico de carpocapsa y riqueza de aves en pomaradas asturiana**s. IX Congreso Nacional de Entomología Aplicada, 19-23.10.2015, SEEA. Valencia, Spain - poster

Miñarro, M. & García, D. 2015: **Contribución de los insectos a la polinización del manzano de sidra en Asturias**. IX Congreso Nacional de Entomología Aplicada (SEEA), Valencia, 19-23.10.2015, Spain - talk

5.2.2: Scientific events

We organized 4 project workshops for scientific exchange for all partners and additionally invited few other scientists for advice of data analyses:

1. Kick-off meeting with all partners in March 2015 before project officially started because of short time left before apple blooming to decide about the site selection criteria at the University of Freiburg, Germany;
2. Annual project meeting in January 2016 with all partners to homogenize data and discuss next steps at Barcelona, Spain;
3. Annual project meeting in January 2017 with all partners to homogenize data and discuss next steps at the University of Stockholm, Sweden;
4. Annual and final project in meeting from 06.11.2017 to 08.11.2017 with all partners except Oviedo. Mrs. Cornelia Andersohn of the DLR (German funding organization of the project), joined the meeting at the University of Darmstadt, Germany.

We organized a workshop on apple pollination for different research questions of broader (global) scope with help of a Cost Action (Super B). The EcoFruit coordinator Alexandra M. Klein, Mike Garratt and Simon Potts organized the workshop with the following participants (all researchers working on apple

pollination): Robert Paxton, Michelle Fountain, Arjen de Groot, Jordi Bosch, Tom Breeze, Gesine Pufal, Mia Park, Deepa Senapathi, Matthias Albrecht, Romina Rader, Megan McKerchar, Sean Webber. 17-19.5.2016 University of Reading, UK. There are currently three manuscripts to be developed from the workshop that are likely to get published in 2019.

5.2.3. Interactions with other FACCE-JPI or BiodivERsA projects

Karsten Mody, partner of the University of Darmstadt joined the general BiodivERsA/FACCE-JPI kick-off meeting at 29.04.2019 at INRA, Paris, France. Other meetings took place during field work and as we were short in scientists for field work because of maternity leaves, we could not join these meetings. We discussed collaborations with other BiodivERsA/FACCE-JPI projects and shared data with people involved these projects e.g. with Matthias Albrecht/Felix Herzog, Agroscope, Switzerland and with Ingolf Steffan-Dewenter, Univeristy of Würzburg. We also planned joint-collection of data with these scientists but do to lack of time within their specific projects, joint data collection was finally not carried out. Additionally, Anne-K. Happe initiated a cooperation with Deniz Uzman, PhD student at Hochschule Geisenheim University, working on the BiodivERsA project PromESSing, to present project results of both projects during a workshop for nature conservationists "Wildbienenbotschafter-Fortbildung" organized by the German NGO Bund für Umwelt und Naturschutz Deutschland (BUND) Landesverband Rheinland-Pfalz e.V.

5.3. List of dissemination activities with stakeholders

Dissemination of results to fruit growers involved flyers/posters/brochures, workshops, reports in their specific newspapers/journals, all adapted to their specific languages of their countries. Dissemination of results to land manager, conservationists and beekeepers involved presentations and discussions on their meetings. Dissemination to all stakeholders and the general society was done within 70 press releases, contribution to printmedia, internetmedia, TV and radio across all three countries. See Excel also file in the spreadsheet "SH_dissemination". Please notice that we only list contributions that include contributions based on experience and findings of our project. We presented project outcomes in other talks and printmedia related to the consequences of insect declines in Germany.

Workshops for stakeholders

- García, D. 2018: Biodiversidad y gente: importancia de las aves silvestres en el bienestar humano. Coordinación y generación de contenidos por Daniel García García), 25.04.2018, Club de Prensa Asturiana, Oviedo, Spain
- García, D. 2018: Valor de la biodiversidad de aves en Asturias: el papel de las ONG". Presentación y exposición audiovisual de ONG de Asturias (SEO/BirdLife, COA, Mavea, GIA/Torquilla), 26.04.2018, Facultad de Biología de Oviedo, Spain
- García, D. 2018: 3. Seminario Biodiversidad y servicios ecosistémicos de aves: de la investigación a la gestión", 27.04.2018, Facultad de Biología de Oviedo, Spain
- Klein, A.M., von Königslow, V. 2018: Stakeholder workshop am Bodensee mit Vertretern vom Kompetenzzentrum Obstbau Bodensee (KOB) und der Fördergemeinschaft Ökologischer Obstbau (Föko e.V.) für am Projekt beteiligten Betriebsleitern und Beratern für den integrierten Apfelanbau. An dem Tag haben wir die EcoFruit Ergebnisse diskutiert und ein Folgeprojekt vorgestellt, Bodensee, Deutschland
- Bosch, J. 2017. Pollinators and their threats. Workshop: Informative conference about pollinators at ICEA (Catalan Institute of Agricultural Sciences), 20.04.2017, ESAB (UPC): Upper School of Agriculture of Barcelona. Castelldefels, Spain
- Happe, A.K 2018: Workshop on wild bees in agricultural landscapes: "Ausbildung Wildbienenbotschafter" for volunteers in nature conservation. BUND Landesverband Rheinland-Pfalz e.V., workshop participants, Deniz Uzman, (BiodivERsA project ProESSinG), Germany
- Klein, A.M, Mupepele, A.C., Skarbek, C., Staab, M., von Königslöw, V. 2017: Gefährdung, Schutz & Förderung von Wildbienen und die Bestäubung an Obstbäumen, Freiburger Wissenschaftsmarkt, 14.07.2017 bis 15.07.2017, Freiburg, Germany

- García, D. 2017: Biodiversidad: qué, por qué y cómo" Exposición gráfica abierta al público general dentro de las actividades "Mostrando la cienca" de la XVII Semana de la Ciencia y la Tecnología de la Universidad de Oviedo, 13-19.11.2017, Edificio Histórico de la Universidad de Oviedo, Oviedo, Spain
- Klein, A.M., Happe, A.K 2017: Stakeholder workshop am Bodensee mit Vertretern vom Kompetenzzentrum Obstbau Bodensee (KOB) und der Fördergemeinschaft Ökologischer Obstbau (Föko e.V.) für am Projekt beteiligten Betriebsleitern und Beratern für den integrierten und ökologischen Apfelanbau, März 2017, Bodensee, Germany
- Bosch, J. 2016. Functional biodiversity. Flowering margins, floral strips and pollinators. Workshop for organic fruit growers and farm advisors. 30.11.2016, Lleida, Spain
- Miñarro, M. & Garcia, D. 2016: Workshop on the project objectives (Asturian Cider Regulatory Council D.O.P "Sidra de Asturias"), land managers (Director of the "Reserva Natural Parcial de la Ría de Villaviciosa"), environmental ONG's (Spanish Ornithological Society, SEO-Asturias) and researchers (SERIDA; Universidad de Oviedo). 23/06/2016 Villaviciosa, Asturias, Spain
- Happe, A. et al. 2016: Workshop of the initial results to planters and stakeholders in, organized at the University of Darmstadt, Germany
- Happe, K., Mody, K. 2015: Kick-off meeting mit Bio-Apfelerzeugern am Julius-Kühn Institut Darmstadt, February 6, 2015: Weitere Teilnehmer: Iris Motzke, Annette Herz, Regina Kleespies, Karsten Mody, Bert Krämer, Nikolaus Glocker, Dierk Augustin, Jan Kalbitz, Jutta Kienzle, Dietrich Stephan, Carina Ehrich. Darmstadt, Germany
- LRF frukt (The Federation of Swedish Farmers – LRF): "Annual meeting of the fruit growers" in Kristianstad 19. January 2017, organized by Marco Tasin. Participants: Beside growers, advisors belonging to Hushållningsällskapet and to growers co-operative. Sweden

Press activities – TV, radio and print/online media

- Klein, A.M. Radio interview, Deutschlandradio Kultur „Wenn das Summen verstummt", 27.10.2015
- Klein, A.M. Interview for print media, „Die fleißige Biene ist in guter Gesellschaft" Badische Zeitung, 05.12.2015
- García, D. Radio interview, "Insectos y aves desempeñan un papel fundamental en el cultivo del manzano de sidra", Noticias/Universidad de Oviedo, 23.06.2016
- García, D. Radio interview, "Insectos y aves, aliados de las pumaradas asturianas", La Nueva Espana, 23.06.2016
- García, D. Radio interview: "Investigadores analizan el papel de insectos y aves en el cultivo del manzano de sidra", europa press, 23.06.2016
- García, D. Print media, "Identifican 40 especies de insectos que favorecen la polinización en las pumaradas," El Comercio, 23.06.2016
- García, D. Print media, "Investigadores analizan el papel de insectos y aves en el cultivo del manzano de sidra", La Informacion, 23.06.2016
- Klein, A.M. Interview for print media, „Ein bunter Früchtekorb – Wissenslücken über die Bestäubung von Kulturpflanzen schließen" Beenow: Das Magazin für Bienengesundheit, 01/2016
- Klein, A.M. Interview online media with Sebastian Tilch für „Ohne Nachweis des Ausmaßes der Verluste wird man keine politische Aufmerksamkeit erreichen", Netzwerkforum für Biodiversitätsforschung Deutschland, 26.02.2016
- Klein, A.M. TV documentation: Fünf Euro pro Apfel? Folgen des Insektensterbens, WDR1 Interview zur Sendung: Bienen: Gefahr durch Monokultur, 17.06.2017
- Klein, A.M. Interview print media "Auf der Spur der Insekten" Verschwinden gerade Käfer, Bienen, Fliegen und Schmetterlinge? Warum es so schwierig ist, das zu beantworten, Interview in "DIE ZEIT" Rubrik: Wissen, 16.08.2017
- Klein, A.M., Happe, A.K. TV Doku: Ausgebrummt - Insektensterben in Deutschland, ZDF Reihe: planet e, 17.09.2017 Erstausstrahlung und später Übersetzung und Transfer auf Filmfestivals in andere Länder

- Klein, A.M. TV discussion; Wie läuft das mit der "industriellen" Bienenbestäubung in den USA? Was würde passieren, wenn alle Bestäuber sterben würden? Harald Lesch und Dirk Steffens im Gespräch mit Alexandra-Maria Klein, ZDF Reihe Wissen: Arche Noah 2017, 08.10.2017
- Klein, A.M. Interview print media "Lebt wohl", Beitrag in "Die Zeit" Rubrik: Politik/Insekten -Bald kommt jeder Schutz für Insekten zu spät, 26.10.2017"Insect armageddon - the devil is in the detail", The Ecolgist, 03.11.2017
- Klein, A.M. Interview print media "Das Insektensterben bedroht unsere Lebensgrundlagen, Interview in "Süddeutsche Zeitung" Rubrik: Wissen/Biologie, 04.11.2017
- Radio discussion with Prof. Dr. Alexandra-Maria Klein/ Josef Tumbrinck "Ausgesummt - Was tun gegen das Insektensterben", Deutschlandfunk Kultur - Rubrik: Landwirtschaft und Ökologie - Im Gespräch, 11.11.2017
- Klein, A.M. Interview for online/print media with Juliette Irmer am 21. November 2017 für „Welche Folgen hat das Insektensterben“, wird im Laufe des Dezembers in BioPro erscheinen, 14.12.2017
- García, D. Print media: “Una investigación evidencia el papel beneficioso de las aves para el manzano de sidra”, europa press, 01.02.2018
- García, D. Print media: “Pájaros para proteger las pumaradas”, El Comercio, 02.02.2018
- García, D. Print media: “Las pumaradas enriquecen el campo asturiano”, La Voz de Asturias, 01.02.2018
- García, D. Print media: “Una investigación muestra los beneficios de las aves para el manzano de sidra”, RTP /Asturias, 01.02.2018
- García, D. Print media: “Una investigación evidencia el papel beneficioso de las aves para el manzano de sidra”, La Vanguardia/Asturias, 01.02.2018
- García, D. Print media: “Una investigación evidencia el papel beneficioso de las aves para el manzano de sidra,” europa press, 01.02.2018
- Hambäck, P. Print media: “Ekologiska äppelodlingar har 38% fler arter och kan ge bättre skörd”, Natursidan.se, 16.11.2018
- Hambäck, P. Print media: “Blommor ger fler äpplen”, Sverige radio – Vetenskapsradion, 14.11.2018
- Hambäck, P. Print media: “Fler blommor runt äppelodlingarna kan ge högre skörd” Food supply”, 13.11.2018
- Hambäck, P. Print media: “ForFler blommor runt äppelodlingarna ger högre skörd.” Forskning.se, 13.11.2018.
- Hambäck, P. Print media: “Fler blommor runt äppelodlingarna ger högre skörd” MyNewsDesk” 13.11.2018
- Hambäck, P. Print media:”Fler blommor runt äppelodlingarna kan ge högre skörd” Expertsvar” 13.11.2018
- Hambäck, P. Print media: “More flowers around apple orchards can yield higher harvest”, PhysOrg.com, 13.11.2018
- Hambäck, P. Online media: “More flowers around apple orchards can yield higher harvest”, LongRoom.com, 13.11.2018
- Klein, A.M. Interview for print media „Bienen in Gefahr“, Sächsische Zeitung, 28.02.2018
- Klein, A.M. Print media „Bienen in Gefahr: Werden Neonicotinoide von den Feldern verbannt?“, Greenpeace Magazin, 28.02.2018
- Klein, A.M. Print media „Das hat die Biene nicht verdient“, Frankfurter Allgemeine – Wissen, 01.03.2018
- Klein, A.M. Print media „Eine Entfremdung von der Natur“, Badische Zeitung am 11.05.2018
- Klein, A.M. Interview for print/online media „Drohnen statt Bienen oder vielleicht sogar Ameisen?“, MDR Wissens Interview, 18.04.2018
- Klein, A.M. Interview for print media: "Vom großen Nutzen der Wildbienen" Badische Zeitung 23.04.2018
- Klein, A.M. Interview for print media „Jedes Insektizid könnte sich als schädlich für Bienen herausstellen“, Süddeutsche Zeitung, 27.04.2018

- Klein, A.M. Radio interview „Die Wildbienen kommen“, Deutschlandfunk, 04.05.2108
- Klein, A.M. Radio interview „EU verbietet Bienengifte – und jetzt?“, WDR 1, 27.04.2018
- Klein, A.M. Interview for print media „Wilde Bienen“, Süddeutsche Zeitung, Thema Umweltschutz, 04.05.2018
- Klein, A.M. TV interview im ZDF Mittagsmagazin: "Bienen/Insekten und Landwirtschaft" 23.05.2018
- Klein, A.M. Written interview „Insektenschwund- was Ökologen und Insektenforscher der Regierung und uns allen empfehlen“, RIFF Reporter Flugbegleiter, 30.05.2018
- Klein, A.M. TV interview „EU will Neonikotinoide verbieten“, Heute Journal am 01.03.2018
- Klein, A.M. Interview for print media „Auch Unkräuter akzeptieren“, Freiburger Wochenbericht, 06.06.2018
- Klein, A.M. TV Interview „Insektenrückgang und Neonikotinoide“, Tagesschau am 09.05.2018
- Klein, A.M. TV interview Bienen/Insekten in der Landwirtschaft, zdf- Mittagsmagazin, 18.05.2018
- Klein, A.M. Interview print/online media "Blumen nützen den Apfelplantagen", Studie: Der Bioanbau sorgt für eine viel größere Artenvielfalt und mehr Bestäuber. Süddeutsche Zeitung, 16.12.2018
- Klein, A.M. TV documentary „Bestäubungsexperiment am Bodensee“, in der SWR Reihe "Odysso - Wissen" Mensch gegen Biene Das Bestäubungsexperiment - Gäbe es ohne Bienen noch Äpfel?, 11.10.2018
- Klein, A.M. Interview for online media „Mehr Blüten, Mehr Bestäuber – Apfelplantagen profitieren von Artenreichtum“, n-TV, 18.11.2018

Brochures/Flyers for stakeholders

- Apfelplantagen in der Rheinebene: Bestäuber und Fruchterfolg. www.nature.uni-freiburg.de/publikationen/Brosch_Flyer
- Apfelplantagen am Bodensee: Bestäuber und Fruchterfolg. www.nature.uni-freiburg.de/publikationen/Brosch_Flyer
- Insektenhaus - Wohn- und Überwinterungsstätten für solitäre Bienen und Wespen. www.nature.uni-freiburg.de/publikationen/Brosch_Flyer
- Los polinizadores del manzano de sidra. SERIDA-Universidad de Oviedo. DL: AS 04117-2018. www.unioviedo.es/danielgarcia/pdfs/Triptico_Polinizadores.pdf
- Aves y control de plagas en el manzano de sidra. SERIDA-Universidad de Oviedo. AS 04116-2018. www.unioviedo.es/danielgarcia/pdfs/Triptico_Aves.pdf

Talks to stakeholders (apple growers, beekeepers, politicians, conservationalists) or open the general public

- Klein, A.M. 2019: **Warum sterben die Insekten?** Aha Festival Luzern, 25.01.2019 Luzern, Switzerland
- Happe, A.K. 2018: **Lebensräume für Wildbienen in der Agrarlandschaft – Forschungsbeispiele**. Vortrag bei einem Workshop vom Bund für Umwelt und Naturschutz Deutschland (BUND) Landesverband Rheinland-Pfalz e.V. 17.11.2018, Mainz, Germany
- Klein, A.M., Böhning-Gaese, K., Gerowitt, B., Lakner, S. 2018. **Artenrückgang in der Agrarlandschaft: Was wissen wir und was können wir tun?** Berlin-Brandenburgische Akademie der Wissenschaften, 24.10.2018 Berlin, Germany
- Klein, A.M 2018: **Entwicklung des Naturschutzes in Obstgebieten.** Strategiegespräch 19.07.2018 im Umweltministerium von Baden-Württemberg, Germany
- Klein, A.M. 2018: **Causes and consequences of insect decline - what do we know and what can we do.** 13.11.2018 Ecology and Evolution Seminar, Universität Bern, Switzerland

- Klein, A.M. 2018: **Wie sähe das Leben einer Honigbiene ohne Wildbienen aus? Ausstellung: Mensch und Biene.** 06.11.2018 Städtisches Museum Natur und Mensch Freiburg, Germany
- Klein, A.M. 2018: **Bienensterben? Insektensterben? Wer stirbt wirklich und warum?** Senckenberg Vortragsreihe „Bedrohte Vielfalt – Der Artenschwund und seine Folgen. 31.10.2018 Senckenberg Naturmuseum und Goethe-Universität Frankfurt, Germany https://video.uni-frankfurt.de/Mediasite/Catalog/catalogs/BedrohteVielfalt2018
- Klein, A.M. 2018: **Was gehen uns Insekten an?** A Summers´s Tale Festival, 04.08.2018 Luhmühlen, Geramany
- Klein, A.M. 2018: **Auswirkungen und Ursachen des „Insektensterbens“** 17.07.2018 bei der Tagung für Naturschutzbeauftrage in Emmendingen, Regierungspräsidium Emmendingen, Germany
- Klein, A.M. 2018: **Grußwort über die Bedeutung von Insekten zum Tag der Artenvielfalt**, 17.06.2018 Ökostation Freiburg, Germany
- Klein, A.M. 2018: **„Insektensterben“ zur Ausstellung Microsculpture** – Die Insektenportraits von Levon Biss. 16.05.2018 Hessisches Landesmuseum Darmstadt, Germany
- Klein, A.M. 2018: **Bienen- und Insektenrückgang: Ursachen, Auswirkungen und Handlungsempfehlungen.** 14.05.2018 Grüne Ortsverband Staufen-Münstertal/Stubenhaus in Staufen, Germany
- Klein, A.M. 2018: „**Insektensterben“ – Definition, Auswirkungen, Ursachen.** Freiburger Umweltgespräche. 03.05.2018, Jazzhaus, Freiburg, Germany www.youtube.com/watch?v=4S1wN4Ha0Zo
- Klein, A.M. 2018: **„Insektensterben“ – was ist das eigentlich?** Workshop „Insektendämmerung? Interdisziplinäres Gespräch über das beschleunigte Artensterben im 21. Jahrhundert“, 27.04.2018, Universität Würzburg, Germany
- Klein, A.M. 2018: **„Insektensterben“ - Ursache und Gegenwirkung**. 20.04.2018, NABU Hauptversammlung, Ettenheim, Germany
- Klein, A.M. **Ursachen und Auswirkungen des Insektenrückgangs - Was wissen wir und was können wir tun?** Kolloquium Natur-Landschaft und Umweltschutz, 09.04.2018 Universität Basel, Switzerland
- Klein, A.M. 2018: **“Insektensterben“ - Hat es sich bald ausgesummt?** 12.03.2018 SPD Freiburg, Gewerkschaftshaus Freiburg, Germany
- Klein, A.M. 2018: **Damit es weiter brummt und summt. Biodiversität - Handlungserfahrungen für Politik und Praxis** 02.03.2018, Ev. Ak. Bad Herrenalb, Germany
- Klein, A.M. 2018: **Bienen- und Insektenrückgang: Ursachen, Auswirkungen und Handlungsempfehlungen**. Grüne Ortsverband Staufen-Münstertal, Stubenhaus, Staufen, Germany
- Klein, A.M. 2018: **Insektensterben - Ursache und Gegenwirkung im Obstanbau.** NABU Hauptversammlung, Ettenheim, Germany
- Klein, A.M. 2018: **Insektensterben - Einblick in die Welt der Kleinlebewesen kritisch Beleuchtung der Zusammenhänge zwischen Insektenschwund, Landwirtschaft und Verbraucherverhalten**. Dreikönigscafé der GRÜNEN, Offenburg, Germany
- Klein, A.M. 2018: **Die Vielfalt der Wildbienen als Bildausstellung.** Tusculum auf Mapprach "Bienen - früher vergöttert heute bedroht", Mapprach, Hofgut Mapprach, Switzerland
- Klein, A.M. 2018: **Warum ist die Biodiversität von bestäubenden Insekten wichtig für unsere Kulturlandschaften?** Vortrag in Zusammenarbeit mit dem Naturschutzbund Ruhr (NABU) Volkshochschule Essen, Germany
- García, D. 2017: **Desentrañando el vínculo entre biodiversidad y servicios ecosistémicos de aves en agro ecosistemas cantábricos: efectos de composición, funcionales y filogenéticos.** Seminario “Evaluación, conservación y recuperación de biodiversidad y servicios ecosistémicos provistos por fauna en agroecosistemas arbóreos ibéricos.

Experiencias a partir del olivar andaluz y las pomaradas asturianas". Universidad de Jaén-SEO/Birdlife, 19.09.2017, Universidad de Jaén, Jaén, Spain

- Klein, A.M. 2017: **Die Bedeutung der Bienen für die Bestäubung von Kulturpflanzen.** Jahrestagung Imkerverein in Bieberach, Germany
- Klein, A.M. 2017: **Managing biodiversity to promote pollination services - how to increase biodiversity and why it is important for wild and managed ecosystems**. Hilgendorf Lecture, Universität Tübingen, Germany
- Bosch, J. 2016: **The use of solitary bees for orchard pollination.** At Workshop Functional biodiversity. Flowering margins, floral strips and pollinators- Lleida, Spain
- Alins, G., Roquer, L. 2016: **Who pollinates our orchards?** VIII Organic fruit growing conference, 26.07.2016, Alfarràs (Lleida), Spain
- Alins, G., Roquer, L. 2016: **Which are the most important pollinators of our orchards?** At Workshop: Functional biodiversity. Flowering margins, floral strips and pollinators, 30.11.2016, Lleida, Spain
- García, D. 2016: **¿Para qué sirven las aves? Razones para conservar su biodiversidad.** Charla de divulgación para todos los públicos, actividades del Día Mundial de las Aves organizadas por SEO/Birdlife Asturias, 1.10.2016, Centro de Interpretación "Ría de Villaviciosa", Villaviciosa, Asturias, Spain
- Klein, A.M. 2016: **Gefährdungsursachen für Honigbienen und Wildbienen und Folgen für die Bestäubung**. Imkerverein Freiburg. 07.01.2016, Freiburg, Germany
- Klein, A. M. 2016: **Förderung von Bienen in Gärten und Obstanlagen.** Landfrauen Pfaffenweiler, 14.03.2016 Pfaffenweiler, Germany
- Klein, A.M. 2016: **Bienen und ihre Bedeutung für den Menschen**, Flyingscience, 22.04.2016 Basel, Switzerland
- Klein, A.M. 2016: **Biodiversität und Bestäubung**. Vortragsreihe Vielfalt zählt, 22.06.2016, Senkenberg, Frankfurt, Switzerland
- Klein, A.M. 2016: **Bedeutung und Bedrohung von Bienen und anderen Insekten**. 23.11.2016 TU München, Germany
- Klein, A.M. 2016: **Eine Welt ohne bestäubende Insekten**…05.10.2016 Frankfurter Zoo, Frankfurt, Germany
- Klein, A.M. 2016: **Blütenbestäubende Tiere: faszinierende Vielfalt und große Bedeutung.** European Conference of Tropical Ecology & 28th Annual Conference of the Gesellschaft für Tropenökologie/Society for Tropical Ecology, Elisabeth Kalko Memorial Lecture, 24.02.2016 in Göttingen, Germany
- García, D. 2015: **From biodiversity to ecosystem services in the real world: A case study with Cantabrian birds.** Dipartamento de Scienze Agraria e Forestali, 16.12.2015, Università degli Studi di Palermo, Italy
- García, D. 2015: **Biodiversidad y funciones ecológicas de aves en la Cordillera Cantábrica.** Seminario "La Cordillera Cantábrica como centinela de los efectos del Cambio Global", Universidad Internacional Menéndez Pelayo, 19.08.2015, Santander, Spain

6. Global Impact assessment indicators

6.1. Impact statement

Our project indicate that biodiversity of beneficial arthropods can be promoted at three spatial scales in European high-intensity, low-stem fruit production without compromising production. These general results can partly be transferred to countries outside Europe and to other crop systems contributing to more biodiverse and sustainable fruit production (see for example our submitted manuscript with other researchers by Daniese et al., submitted to Nature).

6.2. Other scientific valorisation factors / Outcomes

Theses conducted in EcoFruit

PhD theses

- Anne-Kathrin Happe 2019: Managing biological control for fruit production in different European climates. Dissertation at University of Germany
- Laura Roquer-Beni, to be submitted in February 2020. Local and landscape factors affect pollinator communities, pollination services and fruit yields in orchard systems, CREAF, Barcelona, Spain

MSc theses

- Johanna Müller, Johanna 2017: Relation between the intraspecific body size variation of dominant pollinators in commercial apple orchards and the landscape context. MSc in Giessen, Germany
- Stefanie Hoffmann 2016: Influence of landscape heterogeneity, management and agri-environmental schemes on pest infestation and natural pest control in apple orchards. MSc in Darmstadt, Germany

BSc theses

- Olivia Geye 2018: Nistweise bodennistender Wildbienen in Mitteleuropa und Maßnahmen zu ihrer Förderung im Obstbau am Bodensee. BSc in Freiburg, Germany
- Lara-Sophie Heitbrink 2018: Nisthilfen zur Förderung von Wildbienen - Stört ein Gitter zum Schutz vor Vögeln hohlraumnistende Bienen und Wespen. BSc in Freiburg, Germany
- Dorothee Wesselkamp 2017: Unterschiede in Bestäubergemeinschaften von traditionellen Apfelsorten aufgrund von Blütenmerkmalen und der Verfügbarkeit von Bestäubern. BSc in Freiburg, Spain
- Johanna Sester 2017: Unterschiede in Blütenmerkmalen von traditionellen Apfelsorten. BSc in Freiburg, Germany
- Leonie Dries 2017: The influence of management and edge effects on beneficial organisms and biological pest control in apple orchards. BSc in Freiburg, Germany

6.3. Key policy relevant findings / outputs:

We presented our main results at an IPBES meeting in Bonn, Germany in 2017 for discussions how results can be used by policy makers. We additionally joint discussion how our results to conserve and restore woody flowering habitat adjacent to orchards can be integrated in the CAP 2020. The German partner is currently developing a policy paper with the German Academy of Sciences e.g. Leopoldina about the status and trends of biodiversity decline in agricultural landscapes and to provide mitigation strategies. A short policy statement was already published in December 2018 and can be found here: www.leopoldina.org/politikberatung/arbeitsgruppen/biodiversitaet-in-der-agrarlandschaft/, an English version will soon be available. Additionally, the Ministry of Environment and the Ministry of Agriculture of the state of Baden-Württemberg invited the project coordinator to discuss biodiversity conservation in high-intensity fruit producing areas. These activities all discuss the CAP 2020+. We therefore hope that our results of how to conserve biodiversity to provide pollination and pest control services without compromising production will be considered in future national and European agricultural and environmental policies.

6.6. Assessment and follow-up of personnel recruited on fixed-term contracts (excluding interns)

Identification			Before recruitment for the project			Recruitment for the project				After the project			
Surname and first name	Sex M/F	E-mail address	Last diploma obtained at time of recruitment	Country of studies	Prior professional experience, including post-docs (years)	Partner who hired the person (Organisation and Country)	Position in the project (1)	Duration of missions (months) (2)	End date of mission on project	Professional future (3)	Type of employer (4)	Type of employment (5)	Promotion of professional experience (6)
Boreux, Virginie	F	Virginie.boreux@nature.uni-freiburg.de	PhD	France, Switzerland	PhD et ETH Zürich, Switzerland	P1 – University of Freiburg, Germany	Post-doc	36 (part time and including maternity leave in 2015)	04/2018	Currently in maternity leave	University	Researcher	Gained experience to develop joint-protocols and work pan-European
Iris Kormann	F	iris.kormann@gmail.com	PhD	Germany	PhD at Uni Göttingen, Germany	P1 – University of Freiburg, Germany	Post-doc	6 (part time to replace V. Boreux to coordinate field work in 2015)	10/2015	Afterwards Postdoc in the US, currently in maternity leave, afterwards fixed-term contract at Uni Bern	University	Researcher abroad	Gained experience to coordinate large team groups in the field; current position promotes ecotox experiences on bee health
Laura Roquer-Beni	F	lauraroquerbeni@gmail.com	Diploma	Neatherlands	MSc thesis	P2 – Barcelona, Spain	PhD	36	04/2018	Scientist still working on the project to finish her PhD	University	Undergraduate student	Gained experience to communicate and work pan-European; current employment partly to finalise her thesis
Ulrika Samnegård	F	ulrika.samnegard@biol.lu.se	PhD	Sweden	PhD	P3 – University of Stockholm, Sweden	PhD	18	05/2017	Scientist, five years fixed contract as postdoc in Lund, Sweden and University of New England, Australia	University	Researcher abroad	Gained experience in path models and work pan-European; current position in the same field but broader than Europe
Carlos Guardado	M		Diploma	Spain		P4 – University of Oviedo, Spain	Technician	4	12/2015	Technician	University	EPIC, large company, other public,	Gained experience to develop joint-protocols, work pan-European and

												other private, self-employed	to work with stakeholders
Anne-Kathrin Happe	F	anne-kathrin.happe@awi.de	MSc	Germany		P5 – University of Darmstadt, Germany	PhD	36	04/2018	Scientist	Fixed-term contract at Alfred-Wegner Insitute, Bremerhaven, Germany	Knowledge and technology transfer	Gained experience to develop joint-protocols, work pan-European and to work with stakeholders and the media; current position builds up on her strong interactions with our stakeholders

6.7. Data Management and timeline for open access

The main data of the EcoFruit site network were published in Samnegård et al. 2018 and data were stored in Dryad. Data from Asturias were also published and stored with Dryad and online supplementary information of the specific journals. Data on the pollinator traits are only of general interest for the hairiness measurements. A first draft of a manuscript is written and we plan to publish these data in 2019. Additional data collected within EcoFruit e.g. fruit quality measures are available on request.

7. Comments

Please note that the following section is not mandatory and will not be evaluated by the Call Steering Committee. We would be very grateful if you could nonetheless provide the requested information if relevant.

7.1. Success stories

In Germany, we conducted a pollination experiment for which we caged several trees to exclude pollinators and for which we hand-pollinated several trees in different intensities. The project coordinator planned this experiment together with one of our site-network fruit growers. The TV accompanied the experiment from the experimental set up until harvest. The apple grower and his family pollinated the flowers together with the scientists. The scientists planted new organic tree varieties with the grower and joint harvest and therefore learned a lot about the practical part to grow apples. The grower owns several bee houses for wild bees but only with the scientists, he learned how the bees are using the nests and he learned about the difficulties of appropriate hand pollination. He invited other growers to visit our joint experiment. At harvest, we all learned that our main organic apple variety Topaz can produce without pollination (parthenocarpy). This means the tree sets few apples without pollination. In the first place the grower was happy to see that they get apples without bees. Later he understood that these apples were not suitable for the market because they were too large and without seeds and therefore few calcium (see Porcel et al. 2018). The grower is now interested in follow up joint-experiments but without the TV as we all spent lots of time with the organisation to make this happen. The film was used by several TV channels and programs and will be discussed in a talk show in March 2019 with the EcoFruit coordinator as one of the two guests. The success of this story is the mutualistic learning success with a joint experiment conducted by scientists and stakeholders and with results backed up by high-replicated experimental data of EcoFruit. We think that more of such joint-experiments with stakeholders to be equal partners as scientists needs to be conducted.

7.2. Partnering tools

	Yes / No (please provide further information for d and e)
a) FACCE-JPI web-page	No
b) BiodivERsA web-page	No
c) BiodivERsA partner search tool	No
d) Other	No

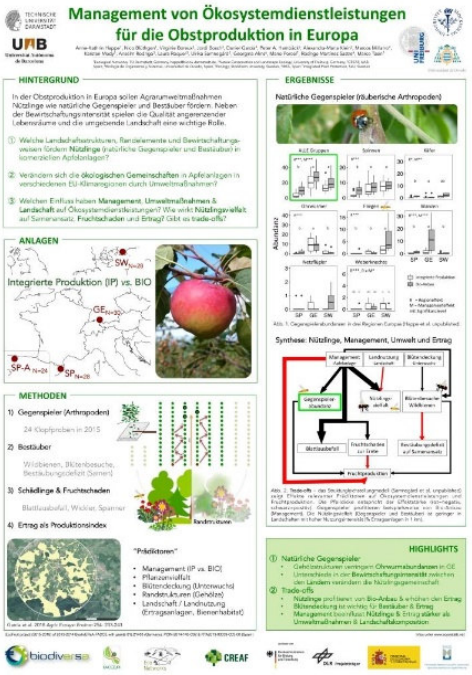
7.3. General comments

We managed to conduct a successful field season in 2015. This was challenging as the project started only few weeks before apple blooming (project started 01.04.2015 and apple blooming starts in the end of April). Additionally, the part-time postdoc hired to coordinate the field selection process was in maternity leave for the first field season and could not do field work during the second field season. Even with these challenges, all partners managed the study orchard selection. Also, the joint development of field protocols were finalised in time and data of flower-visiting insects, pests, predators and fruit production variables were jointly collected by all partners from more than 100 apple orchards. Additionally, pollination experiments were conducted in the first and second project year. In the second and third year, species were identified and we started to measuring and collecting trait data, and proceeded the pollination effectiveness data. Besides this, we conducted workshops to inform fruit growers with project start and during or the end of the project in all countries and we produced information material at project start until today. All partners presented results within talks and posters to our scientific community in national and international conferences and all partners participated in press releases and in our more many media contributions to inform the general society. Joint manuscripts were published not before the end or shortly after the end of the project and most publications are planned to come after this report (several manuscripts are in preparation, submitted and follow up projects were successfully granted for further analyses). The partly slow publication process was mainly caused by the fact that we only apply for two part-time postdoctoral students and both of them had to leave the project for certain times during maternity breaks.

We also like to mention that the applied money was limited to prepare data and analyse the data quickly. Most partners provided either more time of the PIs to the project or used co-funding and collaborations for some project achievements.

As we did not find space for examples of posters and dissemination materials, here two selected examples

Poster at the 6th national forum of IPBES, 21.-22.02.2018 in Bonn, Germany with all partners included



Poster presenting 25 pollinator species visiting cider-apple orchards in Asturias showing fruit growers the huge diversity of pollinators ensuring their yield