RestPoll case-study network

WP1: ESTABLISHING AND TESTING CO-ADAPTIVE MANAGEMENT IN A EUROPEAN RESTORATION NETWORK
TASK 1.1: ESTABLISH THE RESTORATION CASE-STUDY AREA NETWORK OF POLLINATOR HABITATS

Deliverable D1.1

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RestPoll

Restoring Pollinator habitats across European agricultural landscapes based on multi-actor participatory approaches

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Pollinator restoration through co-designed measures in agricultural landscapes in a pan-European case study area network

Methods to analyse co-designed pollinator restoration measures

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Abstract (350 words)

European pollinators are declining, despite agricultural policies increasingly promote conservation measures to support biodiversity. In fact, agricultural intensification is named as one of the main drivers of the decline, although agricultural production relies on pollination. To revert this trend, the restoration of pollinators is a key priority for the European Union, which has set ambitious targets. Decades of insufficient biodiversity-friendly, incentivized actions and current research suggest that co-designed restoration measures and their dissemination to practitioners and the wider public are the most promising ways of improving the state of pollinator populations in the EU. However, many transdisciplinary questions remain unanswered, ranging from the most efficient restoration measures to how they can be permanently integrated into current agricultural practices and policies, to how to sustainably fund these actions, and how restoration measures are perceived or can be adapted to changing conditions. The literature shows unambiguously that restoration measurements are not yet established to monitor the success and failure of trans-disciplinary co-designed actions to reverse wild pollinator decline.

Co-design is commonly conducted in so-called Living Labs that bring together a range of stakeholders who jointly design and implement actions within case study areas. To foster the implementation of co-designed measures to support pollinator restoration, an EU-wide approach can create synergies of mutual learning across countries and establish restored pollinator populations in multiple locations across the EU, thus covering wide ranges of species distributions. As co-designed measures are thought to gain wider acceptance among stakeholders, and case study areas also serve as demonstration and dissemination sites, their Living Lab activities will ultimately restore connected pollinator habitats across the EU.

In the EU-Horizon project RestPoll, we created a network of 14 case study areas across the EU comprising Living Labs that implement co-designed restoration measures for pollinators. The case study areas include all major farming types found within Europe and are located across various geographic zones. A growing number of co-designed pollinator restoration measures are being implemented and monitored. Monitoring includes assessing benefits for pollinators, landscape effects, and socioeconomic impacts. By providing this network for current and future restoration design and research, including their motivations and objectives, the case study area network will pave the way for transdisciplinary research and to restoring pollinators within Europe. Besides the need to counteract pollinator decline, there are multiple other EU- or world-wide challenges that may best be addressed by networks of transdisciplinary local or regional activities for which the approach introduced by our manuscript may be a useful template.

1. Introduction

1.1. STATUS AND TRENDS OF EUROPEAN POLLINATOR RESTORATION

1.1.1. Importance of pollinators

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Pollinators are important for the reproductive success of up to 87 % of flowering plants (Ollerton et al. 2011), including 75 % of crop plants (Klein et al. 2007). Not only do they provide a high economic benefit for crop production (Gallai et al. 2009, Leonhardt et al. 2013), but also contribute to the quantity and quality of crop yield (Brittain et al. 2014, Stein et al. 2017). Therefore, wild pollinators play a pivotal role in ensuring food security (Garibaldi et al. 2013, Murphy et al. 2022, Potts et al., 2016), maintaining plant biodiversity (Carrié et al. 2017), and in the stability and resilience of ecosystems and their services (Klein et al. 2012, Millard et al. 2021, Senapathi et al. 2021).

1.1.2 Status and trend of pollinators

Loss of pollination services has ecological and economic consequences that could significantly affect the maintenance of wild plant diversity, wider ecosystem stability, crop production, food security and human welfare (Aizen & Harder 2009, Gallai et al. 2009). Although important for crop production multiple drivers, including land use intensification, which affects the habitat quantity and quality of wild pollinators (Wagner et al. 2021, Leopoldina 2020), has led to their decline (Potts et al. 2010). Pollinators provide pollination services when enough nesting habitats and floral resources are available in the landscape to facilitate their populations. However, there is a lack of knowledge to understand the ecological needs of pollinators that include their habitat requirements, life cycle and community dynamics. For example, pollinators need floral resources that are spatially and temporally available by the overlap of co-flowering plants at different spatial and temporal scales (Nottebrock et al. 2017).

European and North American studies have repeatedly documented a decline in wild bee populations, especially for bumblebees (Arbetman et al. 2017; Biesmeijer et al. 2006; Cameron et al. 2011; Goulson et al. 2008; Nooten et al. 2020; Potts et al. 2010; van Dooren 2019). In Europe, there are about 2,000 different species of bees, yet only 34 % are of least concern according to the Red List, whereas over 50 % (1,101 species) are data deficient (Nieto et al. 2014). Similar for butterflies, we know that agricultural intensification negatively affects their communities (Habel et al. 2019), leading to a third (31%) of the European butterflies with declining populations and 9 % threatened (van Swaay et al. 2010). About 60 % of these threatened species are endemic to Europe. Non-bee pollinators, such as hoverflies, are also important contributors to agricultural production (Radar et al. 2016), yet 37 % (314 species) of the European hoverfly species are considered threatened and 62 % have an unknown population trend (Vujić et al. 2022). Additionally, there is a lack of long-term trend data and gaps in geographic information for all major pollinator groups. Pollinator communities are negatively impacted when their populations become increasingly isolated from valuable nectar, pollen and nesting resources (Olesen & Jain 1994; Kearns et al. 1998; Garibaldi et al. 2011), whereas those floral resources are crucial for the conservation of pollinators (Baude et al., 2016).

1.1.3 Ecological needs of pollinators (Habitat requirements, life cycle, group specific)

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Wild pollinators depend on functioning ecosystems that support all life stages. Pollinators like wild bees spent most of their time, in many cases up to 10 months as larva, pupa or imago in their nests, followed by a short period of a few weeks to month of activity as pollinators (Westrich 2019, Dankforth et al. 2019). Nest sites of most species are undisturbed soils, whereas fewer species nest in above-ground cavities and most bumblebees in abandoned rodent nests or other shelters, such as dead wood, grass and moss. For nutrition and larval provision, wild bees visit flowers to collect nectar and pollen (Parreño et al. 2022). About a quarter for European bees are specialized on a flowering plant species or family (Nieto et al. 2014, Westrich 2019). If either of the resources, undisturbed nesting sites or flower availability during the short activity phase is missing, the bee population is suffering or unable to exist (Roulston and Goodell, 2011, Antoine and Forrest 2021). Similarly complex, but less flower-specific are life cycles of syrphids and butterflies. Even though butterflies are more generalist pollinators, they can move greater distances between flowers, which reduces the chance of self-pollination and makes them more effective as pollinators (Ollerton 2021). Syrphids thrive in diverse habitats, such as wildflower meadows, woodlands, and wetlands, which provide both larval food sources and nectar-rich plants for adult (Merritt et al. 2009). Some butterfly species require a specific plant species for their larval development (Boggs et al. 2003, van Swaay et al. 2010). Both require sheltered and undisturbed places for their pupation and over winter diapause. Therefore, a restoration measure that aims at supporting a pollinator population does not only provide one of the resources like flowers, but also all other required resources for example areas in which soils stay permanently undisturbed.

1.2. CURRENT RESTORATION MEASURES AND HOW THEY FALL SHORT

Efforts to counteract pollinator decline and restore pollinator populations emphasize reducing known stressors such as pesticide exposure, lack of floral resources and nesting site limitation (Cariveau et al., 2020; Dixon, 2009, Kleijn et al. 2015, Giribaldi et al. 2021, Hanberry et al. 2021). These efforts include, for example, habitat restoration to increase floral and nesting resources, pesticide reduction, and increasing public awareness and education (von Königslöw et al. 2022; Pérez & Freire, 2024; Rundlöf et al., 2022). However, current measures to support biodiversity, such as subsidies to farmers for biodiversity-friendly practices, fall short in the European Union (Pe'er et al. 2020, Tyllianakis and Martin-Ortega 2021). Reasons for this shortfall include that restorations are not adapted to local site conditions (Tyllianakis and Martin-Ortega 2021), subsidized restoration efforts in high-nature-value farmland are underrepresented rather than prioritized, subsidies are not results-based and greater involvement of practitioners is needed (Mupepele et al. 2021, Hölting et al. 2022).

While some progress has been made to protect pollinators, measures are not yet implemented permanently to reach long-term impact (Cabin et al., 2010; IPBES, 2016, European Court of Auditors 2020, Mupepele et al. 2021). However, the EU Nature Restoration Law, states the ambition that 30 % of terrestrial ecosystems must be under restoration or restored to good condition with improved biodiversity, and the decline of pollinators must be reverse by 2030, accompanied by a required monitoring of

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biodiversity trends (European Parliament & Council of the European Union, 2024). Therefore, more systemically effective restoration pathways must be investigated and installed.

1.2.1. Transdisciplinary approach to restoration

To achieve effective pollinator restoration, it is essential that stakeholders such as scientists, policymakers, farmers, other land managers, and the public collaborate (Mohr et al., 2023; Wyborn et al., 2012; Hölting et al. 2022). Ongoing research, accompanying pollinator restoration measures, and adaptive management strategies of pollinator restoration measures are crucial for the success of restoration measures that aim to sustain and expand pollinator populations. Involving stakeholders through co-designed restoration measures likely results in improved restoration effectiveness, higher acceptance rates, and encourages knowledge exchange among stakeholders (Adamsone-Fiskovica & Grivins, 2022; Kurle et al., 2022).

Pollinator conservation is multifaceted and requires continued adaptations of research, outreach, and practice to keep in pace with ongoing scientific progress, ongoing climate and land-use change, and changing societies and policies. As the European and National Red Lists show (European Commission: Directorate-General for Environment et al. 2022, IUCN 2024, Wirth et al. 2024, Nieto et al. 2024, Westrich 2019), the decline is far from halted, many research questions are unanswered and social, economic, and legislative barriers are awaiting identification and overcoming in the future.

1.2.2. Design challenges in collaborative stakeholder research

In collaborative stakeholder processes, it is an inherent challenge to co-design effective solutions while maintaining scientific rigor and hence interpretability of results for evidence-based solutions. Challenges can include balancing expert- and user-driven processes, negotiating scientific knowledge claims, and integrating knowledge transfer and peer-to-peer learning (Adamsone-Fiskovica & Grivins, 2022). Specifically for pollinator restoration, these challenges could include (i) adequately addressing stakeholder concerns, such as effectiveness of measures to support pollinator populations, reduced crop yield and increased pest abundance; (ii) designing convincing incentives allowing to invoke farmer perceptions to engage in the implementation of long-term pollinator-friendly measures; or (iii) ensuring consistent implementation of agreed measures. Managing expectations and ensuring that outputs are tangible, feasible, and realistic is important for making the process achievable (Wang et al., 2022).

1.3. THE NEED FOR A PAN-EUROPEAN APPROACH

Our goal in this manuscript is to provide evidence highlighting the importance to provide the society with tools to reverse wild pollinator declines and to position Europe as a global leader in pollinator restoration. Thus, we have developed a highly trans-disciplinary multi-actor participatory approach to address the challenge to innovative pollinator restoration. We focus on high acceptance rates with stakeholders, flexibility and ongoing co-design to ensure local and intentional actions to reverse wild pollinator decline and stabilize pollination services and their societal benefits.

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In this approach, we will introduce an effective network of case study areas for implementing and monitoring restoration effects and living lab activities and for the analysis of co-designed pollinator restoration measures across a multi-national network of restoration sites in different landscapes. Using this network, we aim to address all aspects of restoration, including its impact on the natural environment, social acceptance, the local and regional market, and in policy development. Our general approaches and definitions are adaptable to restoration targets for organisms other than pollinators. Furthermore, we highlight transdisciplinary questions that can be answered with this approach and how this can benefit stakeholders and restoration efforts.

Box 1: Definitions of terms used within the paper

DEFINITIONS	
CO-ADAPTIVE	Refers to a process in which two or more systems, entities, or groups adapt to each other over time through continuous interaction and mutual influence. The concept is often used to describe situations where different components or actors adjust their behaviour, structures, or functions in response to changes in one another, leading to an evolving and dynamic equilibrium (Armitage et al., 2007; Tittonell et al., 2016)
CO-BENEFITS	Refers to the additional positive outcomes or benefits that arise from implementing a particular measure or restoration plan, beyond the primary intended effect. These benefits are often unintended but desirable, and they typically contribute to the overall improvement of environmental health, sustainability, or community well-being. For example, planting a wildflower strip next to a crop field to increases the diversity of pollinators, may also increases the abundance of pest antagonists as a co-benefit which may led to even higher yields or reduced pesticide demands (Cappellari et al. 2023, Geldenhuys et al. 2021, Mateos-Fierro et al. 2021, Lichtenberg et al. 2017).
CO-DESIGN	This is a collaborative and participatory approach that actively involves practitioners and further stakeholders (such as researchers, policy-makers, agencies, companies, NGOs and community members) in the design process, decision-making, and implementation processes of a solution for a given problem. This approach emphasizes collaboration, inclusivity, and shared ownership and ensures that the final product, service, or system meets the needs and reflects the input of all stakeholders (Hölting et al. 2022; Kurle, 2024; Kurle et al., 2022)
UNILATERAL DESIGN	This is a designing process that is conducted by one party alone. An example would be a restoration measure designed by a nature conservation NGO, which may have high conservation value but potentially a high risk of low acceptance by a wider range of stakeholders.
LIVING LABS (LL)	These are (local) collaborative networks that foster topic-oriented innovation by actively involving diverse stakeholders, such as citizens,

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	practitioners (farmers), researchers, private sector, and policy makers, in ~~the~~ co-creating solutions that bridge the gap between research and real-world application (Marselis et al., 2024; Schliwa & McCormick, 2018)

2. A pollinator case study area network

The pan-European Horizon Europe project "RestPoll: Restoring Pollinator habitats across European agricultural landscapes based on multi-actor participatory approaches" (www.restpoll.eu) is a transdisciplinary initiative which aims to restore habitats for, and enhance connectivity of, wild pollinator populations in Europe by strengthening society-wide capability to reverse wild pollinator decline and stabilize pollination services and societal benefits. The project develops, tests, evaluates, and refines transdisciplinary and co-designed pollinator restoration approaches through the collaborative expertise of natural and social scientists, along with NGOs, companies, and ministries and local authorities within living labs. Living labs aiming at restoration of pollinator habitats are only recently becoming established locally. By creating a network of case study areas in which living labs are active, the project brought together, and established new, Living Labs to increase exchange and foster efficiency. The pan-European network is also reflecting the pollinators needs, as pollinator populations span large areas of Europe and hence their conservation requires joint efforts of all European countries to create a network of connected pollinator populations that is resistant to emerging threats such as climate change. Besides the benefits in practical understanding of implementation success by comparing different landscapes and socio-economic backgrounds it is of benefit that European agriculture is regulated on a common basis (European Commission 2023). By installing Living Labs with demonstration sites as examples of pollinator-friendly farming and management practices across Europe, RestPoll created the most optimal starting point of adoption and propagation of these practices. Therefore, the outcomes of implemented restoration activities are and will benefit EU-pollinators, biodiversity and citizens today and even more in the future.

2.1. THE DESIGN OF THE CASE STUDY AREA NETWORK

The establishment of a network of case study areas should consist of a minimum of three different transdisciplinary stakeholder groups that are interested in hosting a living lab that addresses the transdisciplinary co-design of pollinator restoration measures (or other aims). While each case study area may have their own, separate solutions, they should share a common goal and be connected through a network partner responsible for communicating within the overall network. For example, in RestPoll, activities of each case study area started independent from each other, however, they are influenced by the researchers that are in exchange via the project, by knowledge exchange, shared aims and protocols. The network aims to provide the infrastructure to monitor restoration success for pollinators and to conduct research that determines the value and effectiveness of these initiatives from the natural science, social science, economic, political, and land-management perspective and to communicate the results to stakeholders through outreach. The network is intended to

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support additionalinitiatives in the future, which will bring pollinator restoration into all landscapes of Europe and allow many recursive cycles of co-design and co-adaptations for continually adapting restoration to the needs of pollinators, stakeholders and scientific progress.

2.1.1. Transdisciplinary motivations

The objectives and questions that should be explored are composed of scientific and conservation goals which differ in importance to diverse partner and stakeholder profiles. From a natural science perspective, the goal should be to assess how well the restoration measures deliver the intended environmental effects and factors that may alter these effects. For example, if co-designing of restoration measures results in larger, more diverse or more functional pollinator populations. Social science research should focus on assessing the efficiency and success of participatory activities for promoting restoration measures and on exploring the economic and societal conditions for, and implications of the restoration measures. Land managers, in turn, have technical and economic constraints as well as value-based concerns, with individual variations in priorities. While land managers generally consider the economic value of the measures for their business but also the environmental and health effects of their practices and their contribution to a greener agriculture and a better image of agriculture, politicians or local governments are primarily interested in the efficient design, acceptance and feasibility of policies regulating restoration measures in balance with further societal interests.

2.1.2. Natural scientific objectives

Understanding restoration measures in a landscape context: Pollinator are mobile organisms that move over larger or smaller areas with a diversity of requirements among the different species to fulfil their lives and maintain long-term population persistence (Danforth et al book). Therefore, restoration measures that are often done at the local field-scale should be viewed at the relevant scale for pollinators, which is often larger than a local scale. For example, a pollinator may have its larval host plant or development habitat in one location while their flowering foraging habitat is located elsewhere (Smith et al. 2014). A local restoration measure may target one but not the other of these requirements and only provides a part of the resources needed for survival and reproduction. In addition, restoration measures may be set in different landscape contexts and therefore complement or supplement already existing resources and have different species pools that can respond to the restorations (Smith et al. 2014). The amount or quality of habitat in the surrounding landscape of a restoration measure can also influence their success (Tscharntke et al. 2012). For example, the influence of wildflower strips on wild bee abundance depended on the contrast in local flower species richness that they created and the landscape wide availability of flower resources (Scheper et al. 2015). The research objectives are addressing questions related to habitat quality, quantity and connectivity, through space and time as an interplay with the locally and regionally occurring and potentially

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occurring pollinator communities. **Understanding how co-design moderates the effects of restoration measures:** While the effect of any pollinator restoration measure can be determined in a comparison to a control site, it is more challenging to determine if a co-designed measure outperforms a unilaterally-designed one. Co-design might lead to a compromise between the involved parties (Lupp et al., 2021), however in an effort to please all involved parts, the restoration measures will be less effective. Whereas unilaterally-designed measures might be initiated by a single land-owner, which may have a local impact, but does not secure a meta-structure of a restored area. It is likely that co-designed restoration measures might have a lower short-term or perceived value for pollinators compared to those designed unilaterally. However, over time we would expect co-designed measures to persist longer and generate a higher acceptance across disciplines and among stakeholders (de Snoo et al., 2013; Hölting et al., 2022). The better acceptance of co-designed measures could eventually lead to their wider diffusion and replication across space and time, potentially outperforming pollinator benefits of unilaterally-designed measures in the long term (Basnou et al., 2020).

2.1.3. Soco-economic objectives

Effect of the restoration on the society: Restoration measures may be perceived in contrasting ways, while one sees the untidiness, workload and drawbacks for a business, others perceive how they positively enhance the beauty, structure, or functionality of the landscape, ensuring also essential ecosystem services such as pollination, clean air, water filtration, carbon sequestration, flood control, and soil fertility improvement (Zerbe 2023, Matzek and Wilson 2021). Also, the living labs offer a perspective on how to navigate these different perspectives and negotiate solutions that can be seen as acceptable or legitimate for everyone (European Commission 2022).

Ecosystem services are crucial for human wellbeing, and natural spaces are known to reduce stress, anxiety, and encourage outdoor activities (such as hiking, biking, etc.; Shuda et al., 2020). Having access to restored natural areas has been linked to improved mental and physical health (Jimenez et al., 2021). Economic benefits from restoration (i.e. crop yields, crop quality, tourism, job creation, etc.) also have a positive effect on the local community (de Groot et al., 2013; Newton et al., 2021). Therefore, all these benefits should be quantified to measure the direct and co-benefits provided by pollinator restoration.

Effect of society on the restoration: Society can also influence restoration, as the engagement and involvement of local communities can influence the priorities or the goals of the restoration and significantly enhance its success through creating a sense of ownership and pride (Cranston et al., 2022). Social norms can influence individual and collective behaviour (Knapp et al. 2021, Geppert et al. 2024). In communities where environmental stewardship is valued, individuals may be encouraged to participate in or support restoration efforts, creating a positive feedback loop that reinforces restoration

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goals (de Snoo et al., 2013; Pretty, 2003). Implementing co-designed measures can reflect the input and priorities of society on restoration. Furthermore, consumers can play a role in the effort of restoring pollinators, through their demand for food products that have been produced with pollinator friendly methods and comply with a pollinator certification scheme.

Effect of the restoration on the policies: The success of restoration measures can influence policy through the development of new policies or strengthening and/or modification of existing policies and regulations (Esmail et al., 2023). Likewise, documentation of successful restoration measures or projects can lead to the introduction or expansion of incentive programs that encourage restoration, conservation and sustainable practices or market-based policies such as Payments for Ecosystem Services (PES).

Effect of the policies on the restoration: Governance at various levels develop and adopt policies that directly or indirectly promote or hinder restoration efforts. Policies that support or hinder restoration efforts can vary based on how well they align with ecological goals and local contexts (Tedesco et al. 2022). Likewise, the allocation of funding for incentives or resources is important as they can determine the scale and scope of restoration activities and ultimately their success (Wiegant et al. 2022).

The economic benefits of restoration: Local communities are interested in the economic benefits of ecosystem services as they may depend on the natural resources to sustain their livelihoods, are interested in improving local infrastructure, increase access to natural spaces, or to build resilience against environmental changes and disasters. Implementation of these services are important in the decision-making process. In addition, consumer surveys, will identify the market segments that are positive towards pollinators conservation, therefore increasing the effectiveness of marketing strategies for the establishment of "pollinator-positive" value chains. The development of business models around pollinator-friendly systems, can contribute to producers generating income.

Acceptance of restoration in society: Local actors and land managers are crucial for successful implementation of pollinator restoration and may be engaged for different reasons, including economic reasons, altruistic concerns, improving public image, comply with sustainability standards, or take part in incentive programs. Similarly, experiencing tangible results from successful projects can build confidence and acceptance. The ability to replicate successful restoration efforts can also enhance acceptance, as it shows that the approach is effective and adaptable.

2.1.4. Land manager objectives

Effect of restoration on land managers: Implementation of restoration measures may incur economic benefits, if land managers receive direct costs or subsidies for implementing restoration measures. However, they could also incur losses, if the implemented measures fail to be successful or cost more to implement than what is

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produced. On the other hand, there are other indirect benefits that come from implementation of restoration measure that help increase the co-benefits, such as increased value by society, higher conservation value on the land, better soil conditions, and continual education of the community.

Effect of land managers on restoration: Land managers also have an impact on restoration as they have specific knowledge about their land and the processes and can evaluate the success of a measure from their previous experiences. However, the organisational structure of the area also can impact the success of the measures, as the scale and scope for a large company differs compared to a single farmer or a local company. In sum, natural and social scientists, land managers, and other stakeholders can hold different objectives. Yet these differences can be successfully used when combined, when research is co-designed and transdisciplinary. In RestPoll, the Living Lab loop is used to leverage outcome for science and society.

2.2. LIVING LAB CO-DESIGN AND CO-ADAPTATION LOOP FOR POLLINATOR RESTORATION

The goals of implementing pollinator restoration measures as viewed from the perspective of different stakeholder groups can vary both in their content and prioritisation, which can make the design and adoption of systemic (e.g. considering all relevant factors) solutions to restoration challenging. Yet, the co-design process allows for multiple loops of alignment, feedback and adaptation (Rădulescu et al., 2022). For example, the main objective of natural scientists or conservation interested stakeholders is to determine whether co-designed restoration measures effectively facilitate pollinator restoration and restoration of pollination services. Together they can then become aware of whether the restoration measure led to desired goals (e.g. pollinator restoration and pollination services). Together with other stakeholders like social scientists (e.g. monitoring of participatory action and exploring the economic and societal aspects of restoration) they can judge on whether this measure is valuable relative to implementation costs (e.g. time, money, etc.). With the feedback from even further stakeholders (evaluating for example social costs and benefits or the legislative restrictions) measures can be co-adapted or maintained to be used as demonstrations for co-beneficial restoration measures that reflect the best compromise for all stakeholders under the current situation and local circumstances. Importantly, restoration methods can be flexible and improved over time as this co-design loop allows continuous improvement of methods. Additionally, this flexibility allows restoration efforts to adapt to changing political frameworks, funding opportunities and needs of stakeholders.

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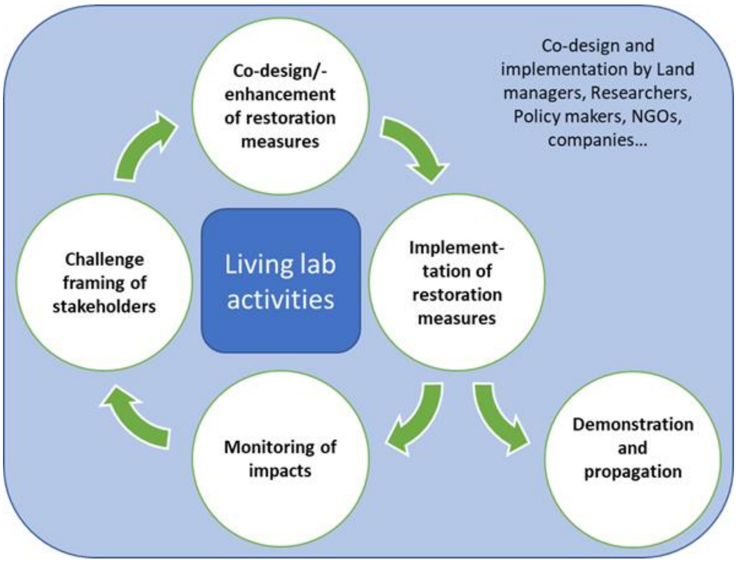

Figure 1: Conceptual figure demonstrating the Living Lab co-design and co-adaptation of pollinator restoration measures in case study areas of the pan-European network. Transdisciplinary stakeholders co-design and co-implement restoration measures, monitor and evaluate their impacts and adapt restoration measures to new challenges, while demonstrating the restoration measure to other stakeholders that might integrate them into their land management.

2.3. ESTABLISHING A CASE STUDY AREA NETWORK

A case study area network should cover different locations, climates, and agricultural and socio-economic landscapes as shown here for RestPoll (Figure 2). It should include areas that are managed for pollinator restoration by land managers from both the public sector such as municipalities and the private sector such as various farm types (livestock, arable and fruit). This diversity in case study areas can result in a similar diversity in land ownership, management practices, and implemented restoration measures. Most relevant information for RestPoll as an example is shown in Table 1 and we provide a detailed description of the case study area network in Appendix 1, which includes details of the restoration measures, spatial extent and current land use in the area. Information on management and ownership should be anonymous but details of the site location and site spatial configuration is needed for site-specific analyses. Due to the protection of private information, we obscured the coordinates in the map as well as the location of the sampled area placed within a circle. With such baseline data, similarities and complementarity of cases study areas is accessible, and serves as a basis for research activities.

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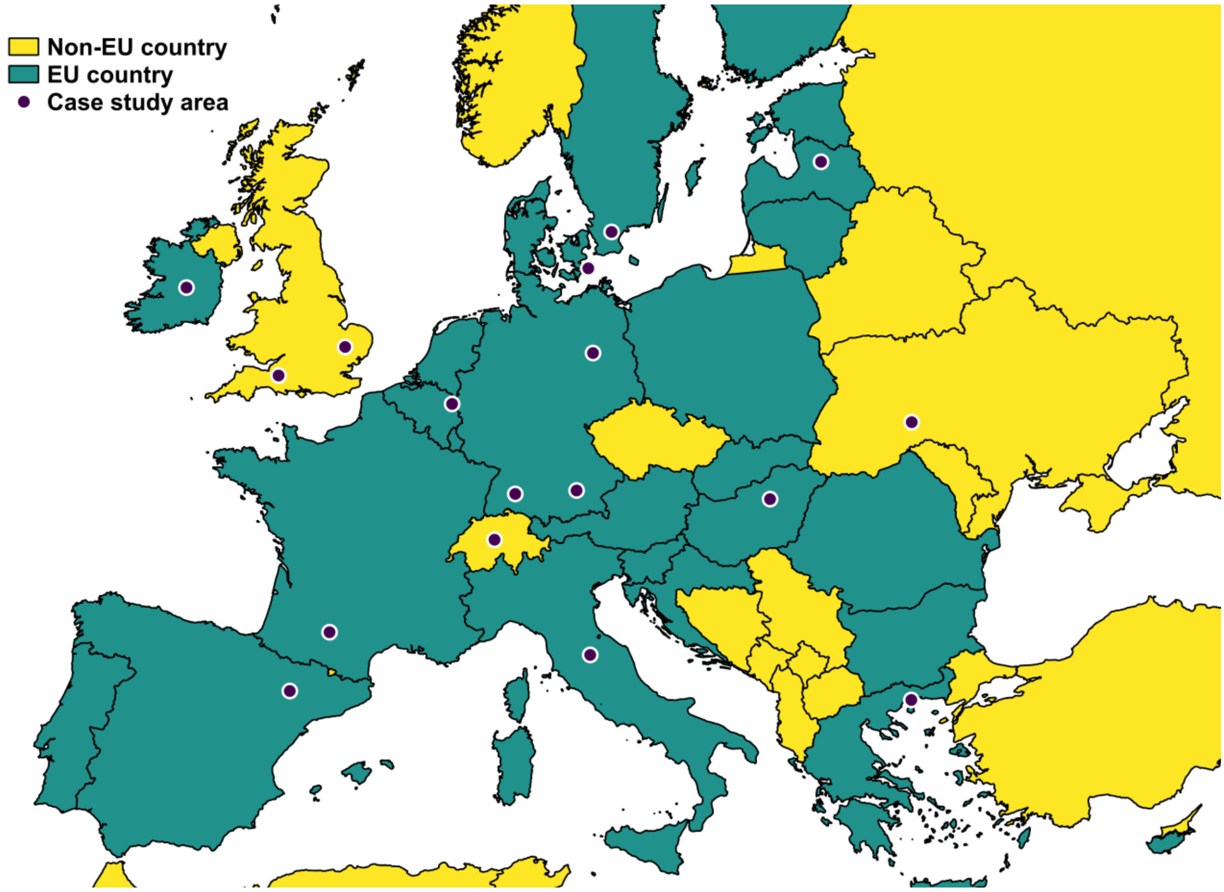

Figure 2: Map of the 17 case study areas in 14 European countries hosted by 26 RestPoll partners, showing the different socio-ecological differences needed for general recommendations and to learn from each partner.

2.3.1. Case study area site requirements

Within each case study area (CSA), smaller areas, i.e. sites, should be sampled for monitoring purposes (see section 3 for more details on monitoring). In RestPoll we have five different types of sites that can be used for sampling in each CSA (see Box 2 for definitions). Four requirements must be met for each CSA. Firstly, each CSA must contain a living lab site (LLS) or an implementation site (IMS) and an internal control site (ICS) or an out control site (OCS). Ideally the CSA contains all four site types, plus a positive control site (PCS) when possible. Secondly, we defined the minimum replication to be five per site type per CSA. Thirdly, control sites (ICS / OCS / PCS) should be grouped (as pairs, triplets, etc.) with living lab (LLS) or implementation (IMS) sites. Each site in the group should express the same environmental (i.e. soil type, altitude, etc.) characteristics, besides one being improved whilst the other area managed conventionally. Finally, as one implementation or living lab site might include different restoration measures or combinations of measures which may vary between sites within one case study area, it is recommended to consider higher numbers of replicates for each restoration measure (e.g. three or more per restoration measure type/combination), while keeping the number of control sites to five.

Box 2: Definitions of different monitored sites within the case study area network

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SITE DEFINITIONS	
LIVING LAB SITE (LLS)	A site that contains one or more co-designed pollinator restoration measures. An example of this could be a farmer, a nature conservation NGO and a local authority collaboratively implementing a flower strip with bare ground patches along the side of a crop field using a local seed mixture, to increase floral and nesting resources for bees.
IMPLEMENTATION SITE (IMS)	A site with non-co-designed pollinator restoration measures. An example of an IMS would be a flower strip promoted by policy incentives and implemented regularly by farmers along the side of a crop field. These sites form the basis for comparing the effectiveness of co-designed versus top-down or bottom-up measures for pollinator restoration.
INTERNAL CONTROL SITE (ICS)	A site ideally within close proximity (<2km) to LLSs or IMSs, but lacking restoration measures. An example of this would be a conventionally managed cornfield. The ICS is ideally paired with an LLS.
OUT CONTROL SITE (OCS)	A site in more distant proximity (>2km) to LLSs or IMSs, but lacking restoration measures. For example, a conventionally managed crop field, similar to the ICS, but at a further distance from the LLS / IMS.
POSITIVE CONTROL SITES (PCS)	A reference habitat that represents the best available natural state according to local conservation standards with comparable environmental conditions to LLSs.

2.4.

2.5. 2.4 CASE STUDY AREAS (CSAS) AT DIFFERENT SCALES AND SITE DESCRIPTIONS

The set-up of CSAs should reflect the diversity of landscapes, habitats and management practices within them. For example, one CSA may contain only groupings of paired living lab sites (LLS) and out control sites (OCS, Figure 3c), whereas another area may contain groupings of all five site types (Figure 3d).

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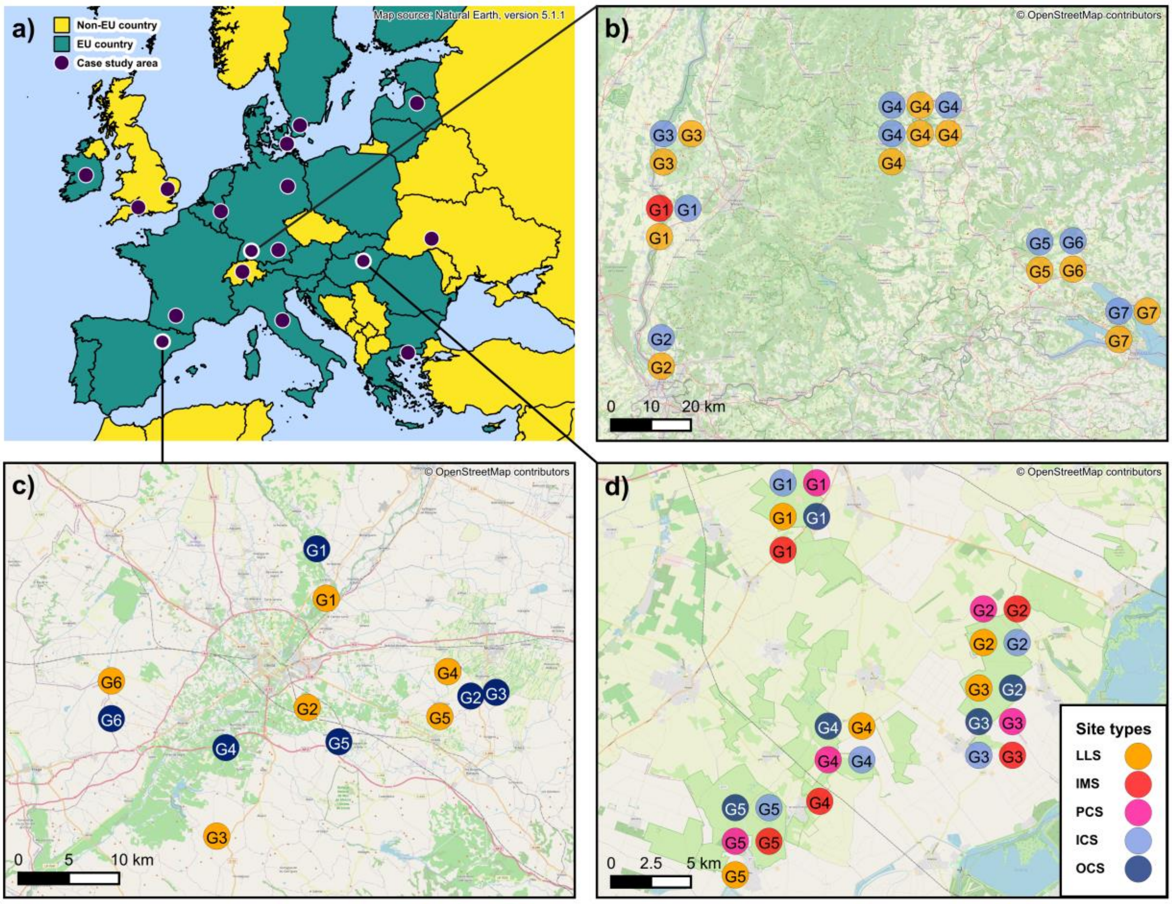

Figure 3: Examples of case study areas (CSAs) across Europe. **a)** Overview of the RestPoll CSA network. CSAs in **b)** South-Western Germany, **c)** Catalonia, North-Eastern Spain, and **d)** Eastern Hungary. The circles indicate approximate site locations to respect personal data protection and are coloured by site types: Living Lab sites (LLS), implementation sites (IMS), positive control sites (PCS), internal control sites (ICS), and out control sites (OCS). Sites within CSAs are locally grouped (e.g. G1, G2) following a spatially paired design to enhance comparison between restored and non- restored site types. The number of site types within each CSA can vary (see b-d).

2.5.1. Pollinator restoration measures

Likewise, the pollinator restoration measures within the CSAs are diverse (see Figure 4). Pollinator restoration measures can directly or indirectly release pressures from pollinators. Direct measures include the reduction in insecticide use or reduction in ploughing and mowing intensities, all of which can, at high intensities, directly harm the imagos (e.g. final and fully developed adult stage of an insect) or juvenile (e.g. the immature or undeveloped stage of an insect) stages of pollinators. Indirect measures are the increase in flower resources and nesting resources. Flower resource restoration measures can be, for example, the introduction of flower strips, mixed- or inter-cropping with flowering plants including trees (e.g. agroforestry systems, hedges), or set-asides. Additionally, the reduction in herbicide use in arable land and the adaptation of mowing regimes and grazing intensities to promote flowering plants in pastures and

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meadows can help increase flowering resources. Nesting resources can be restored by the addition of insect houses, the creation of bee-banks, open bare ground or the transition towards unploughed land-use types. Full list of restoration measures conducted in the RestPoll case study area network can be found in Table 2.

Table 2: List of potential pollinator restoration measures, grouped by crop system (i.e. habitat type), Land use integration (land sharing or sparing), Management action (i.e. flower addition or threat reduction), Nest site (i.e. does it add nesting sites for pollinators; yes or no), Forage (i.e. does it provide foraging for pollinators; yes or no), Improvement target (i.e. what is the target group for improvement; vegetation or pollinators), and duration (i.e. how long does the implementation last).

Restoration measure	Agriculture system	Land use integration	Mode of action	Juvenile habitat	Food habitat	Improvement target	Duration
Perennial flowerstrip	arable	sparing	flower addition	no	y	vegetation	multiannual
Flower undersowing	arable	sharing	flower addition	no	y	vegetation	annual
Reinstalled grazing	pasture	sharing	flower addition	no	y	vegetation	annual
Reduced grazing intensity	pasture	sharing	flower addition	no	y	vegetation	annual
Reduced fertilizer input	pasture	sharing	flower addition	y	y	vegetation	temporary
Reduced herbicide input	arable	sharing	flower addition	n	y	vegetation	temporary
Reduced insecticide input	arable	sharing	threat reduction	y	y	insect	temporary
Reduced tilling	arable	sharing	threat reduction	y	y	insect	temporary
Reduced mowing	pasture	sharing	threat reduction	n	y	vegetation	temporary
Reduced mowing	semi-natural grassland	sharing	threat reduction	n	y	vegetation	temporary
Intercropping	arable	sharing	flower addition	n	y	vegetation	temporary
Bee-hotels	arable	sharing	nesting addition	y	n	insect	persistent
Reduced shredding/mulching	arable (apple orchards)	sharing	threat reduction	n	y	vegetation	temporary
Using alternative pruning shredders	arable (apple orchards)	sharing	threat reduction	n	y	vegetation	temporary
Areas of bare soil	arable	sharing	nesting addition	y	n	insect	multiannual
Soil mounts	arable	sharing	nesting addition	y	n	insect	persistent

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Straw bales	arable	sharing	nesting addition	y	n	insect	annual
Deep digging	semi-natural grassland	sparing	nesting habitat	y	n	soil	persistent
Ploughing	semi-natural grassland	sparing	nesting habitat	y	n	soil	multiannual
Planting pollen plants	semi-natural grassland	sharing	flower addition	n	y	vegetation	persistent
Seeding pollen plants	semi-natural grassland	sharing	flower addition	n	y	vegetation	persistent
Seeding nectar and pollen plants	semi-natural grassland	sharing	flower addition	n	y	vegetation	persistent
Agroforestry	arable, pasture	sharing	flower and nesting addition	y	y	vegetation	persistent

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Figure 4: Examples of implemented restoration measures. A) To provide undisturbed soil and floral resources for pollinators, a conventional wheat field was converted into an extensive, organic sheep pasture using local grassland seeds, (© A. Ouin). B) To provide nesting sites for many pollinators such as bees and wasps, semi-natural habitat can be diversified by creating open bare ground. In this case, a ~10×2m section of a slope was excavated to create a vertical and horizontal surface of bare soil in water buffers (© M. Močnik). C) To reverse succession and provide bare ground as nesting habitat for rare ground-nesting solitary bees sandy soils were ploughed and dug deeply. (© M. Rundlöf). D) To provide large amounts of flower resources in vineyards whilst allowing regular management, diverse perennial local plant species were added to every second interrow (© F. Fornoff). E) To enhance food resources for pollinators an organic barley field was undersown with regional flowering plants (© F. Fornoff?). F) To create nesting and forage habitats for many pollinator species in an intensive organic orchard,

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an insect house and row-end trees were added, old orchard trees were managed local flowers were preserved through mosaic mowing, and a water carrying ditch was maintained and bare ground was created (© N. Rosenberger).

Measures can differ depending on the habitat they are being implemented in. Semi-natural habitats may benefit from a certain measure, but it may not be practical for grassland or arable land due to its management. Likewise, land-sharing and land-sparing are two contrasting approaches to implement conservation measures into agricultural production (Grass et al. 2019). The purpose of land-sharing is to create landscapes where agricultural practices are designed to be more wildlife-friendly, often using low-intensity or traditional/innovative farming methods such as intercropping or undersowing. Further examples of this would be agroforestry, where trees are integrated with crops or livestock, providing habitats for birds and other species while producing food. Land-sparing involves setting aside land that is entirely for nature conservation. This could be an intensively managed high-yield field next to a protected natural habitat that is left undisturbed to conserve biodiversity, or on an even smaller spatial scale the conversion of parts of the field into a perennial flower strip. Table 2 contains a list of different restorations measures that could be implemented for pollinator restoration, including their different characteristics and benefits.

3. Monitoring

Sampling of the case study areas is important for provide the base information for long-term monitoring. Continuous sampling allows us to observe, track, and analyse the various pollinator restoration measures and to monitor overtime if their function is as expected, and to detect if any adjustment is required. The applied methods, including how the data is collected or analysed, vary depending on the questions being asked. Here we explain the sampling methods for monitoring the case study areas to address the natural scientific and social scientific objectives (Section 2.1).

3.1. NATURAL SCIENCE

3.1.1. POLLINATOR SURVEYS

To provide society with tools to reverse wild pollinator declines, including the restoration of pollinator habitats, the status and trends of pollinators in response to restoration measures need to be monitored. In Europe, there is a diversity of pollinators, including bees, butterflies, flies, carabids, wasps and more (Rader et al. 2016, Ollerton 2021). However, in accordance with the suggested European pollinator monitoring scheme (Potts et al. 2021), we suggest within the case study area network the following taxonomic groups should be monitored: (Hymenoptera: Apiformes), hoverflies (Diptera: Syrphidae) and butterflies (Lepidoptera: Rhopalocera). Assessment of their diversity and abundance on flowers (flower visitor monitoring) is a common method to describe their local population status and to depict community changes. RestPoll adapted a standard monitoring protocol originally developed in the pan-European STEP project (Status and Trend of Pollinator in EU; Holzschuh et al., 2016; Scheper et al., 2015). For details of the RestPoll monitoring protocol, please see Ouin et al., 2024.

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The flower-visitor monitoring should be conducted in at least two consecutive years and repeated three to five times per year within the vegetation period. We suggest using transects when sampling (i.e. 150m long and 2m (for bees and hoverflies) and 5m (for butterflies) wide transect) to be spatially explicit, and for an observation duration of 15 minutes to be temporally explicit. Within these spatial and temporal limits, all individuals of the three target groups are counted and identified at species level (when possible). As restoration measures target flowering and nesting resources, the protocol also includes the assessment of non-flower-visiting individuals, for example, hoverflies depositing eggs or bees nesting. The pollinator activity (flower visiting, flying, nesting etc.), and the respective resource type (e.g. flowering plant, vegetation, soil, or other nesting material) they are interacting with is noted to depict their habitat and resource use. Environmental variables that affect pollinator activity (e.g. weather conditions) to standardize samplings are recorded. Furthermore, flower abundance and diversity, vegetation density and ground cover are further assessed to capture the full picture of the pollinators' environments and allow for comparisons between sites.

Rapid assessment

Rapid assessment methods enable laypersons without prior experience in pollinator sampling and identification to contribute to the project. This will be developed during the project, using feedback from local stakeholders as their involvement during and beyond the project promotes continued reassessment of restoration success and the inclusion of further restoration measure types and participants. Of course, rapid assessment methods are more limited than larger empirical studies conducted by scientists. However, using these methods allows more immediate feedback to stakeholders on their restoration efforts so that they can stay engaged with the process when scientific resource are limited (e.g. lack of funding, manpower, etc.)

3.1.2. Pollination services monitoring

Restoration of pollination services to crops and wild plant species alike facing pollination deficits is an important objective in addition to broader conservation goals. Pollination deficits occur when flowers receive insufficient or incompatible pollen receipt to fertilize ovules that a plant can develop into seeds. Pollination deficits can directly affect yield, a crucial concern for farmers and impact seed set of wild plant species in restored areas (Reilly et al. 2024, Siopa et al. 2024). Building on farmer interests, it is important to involve them in measuring pollination deficit in crop plants and restored wild plants they desire. Providing stakeholders with stakeholder-friendly pollination monitoring methods that are easy to implement will facilitate their collaboration.

A stakeholder friendly protocol that compares flowering-plants that exclude pollinators and open pollinated flowers can help estimate the pollinator dependence for crop plants and focal wild plant species (Fig. 5, Rosenberger et al., *in preparation*). This will establish a common basis of expected pollination deficits based on plant species mating system, which can then inform stakeholders of which plants are most vulnerable or

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most likely to benefit from co-designed restoration measures. Although different plant species and pollinator communities occur between sites, the pollination monitoring protocol emphasizes comparison between common crops and wild plant species used at Living Lab sites. Sampling methods will be developed through experimental testing during the duration of the RestPoll project, and then translated into rapid assessment methods which stakeholders can employ independently.

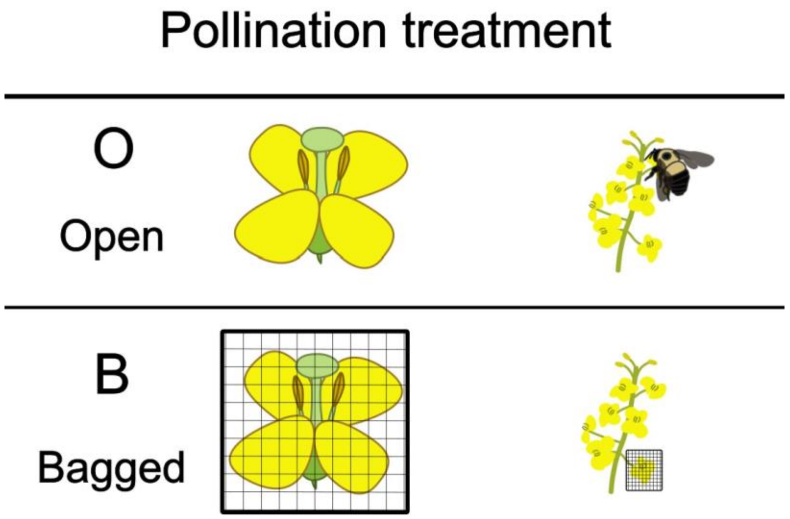

Figure 5: Example of pollination experimental treatments applied to individual flowers are Open (O) or Bagged (B). Example from Rosenberger et al., *in preparation*.

Rapid assessment
Rapid assessment of the pollination dependence of crops or important wild plants, allows land managers or other stakeholders without prior experience to assess which plants are currently receiving enough pollen deposition for successful reproduction and which plants are lacking in services from pollinators. A method that is easy to implement and results in quick results, which provides land managers with immediate and relevant information that can be used to further improve the restoration measures.

3.2. SOCIAL SCIENCE

To ensure the feasibility and adoption of pollinator restoration actions, a working relationship with the stakeholders implementing such measures is crucial. Using the network of case study areas, a network of Living Labs (LL) should be established. LLs can be used as the primary means for stakeholder engagement and analysis of stakeholders' perspectives across all participatory activities and demonstrate best practices for pollinator restoration measures. Across Europe, LLs are used as a key platform for experimentation ensuring joint learning and research focusing on locality specific ecosystem services enabling solutions that fit with local needs and concerns (European Commission, 2022; Bouma, 2022). For example, engagement of stakeholders in building pollinator-habitat connectivity, e.g. through hedgerows as storm breakers or

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polycultures like agroforestry, leading to co-benefits that buffer climate change, drought and flooding disasters will be monitored through workshops within the LLs. Methodological guidelines for the establishment and monitoring of LLs were developed, bearing in mind the diverse environmental and institutional conditions across landscapes.

Following the established protocol, the LLs should be established and monitored using three phases of innovation development: exploration, experimentation, evaluation (Evans et al., 2017). The exploration phase is used to identify the current state and will identify the problem related to pollinator restoration and its potential solutions in the LL to measure potential impacts and effects of the experimentation phase. In this stage, the objectives of the individual LLs will also be determined, whether it is focusing on the success of implementation of co-design measured, evaluating people's perspectives, calculating the co-benefits and economic valuation thereof, determining synergies or trade-offs of policies and/or evaluating the market valuation of pollination through evaluating the willingness to pay by consumers or develop a certification scheme for labelling. The experimental stage will put these proposed solutions to the test by developing and experimenting with innovative restoration measures. The main goal of this phase is to understand user reactions and attitudes to and enabling environment for the proposed pollinator restoration measures. Moreover, the economic feasibility of the practices will be examined to help stakeholders in their decision-making process. The evaluation stage of the LLs consists of evaluating the implemented measure and illustrating potential impact and added value created by the measure. This multi-step and multi-year monitoring of the LLs will help to evaluate the effectiveness of the participatory activities within these areas and the success of co-designed restoration measures. In the RestPoll project, the network of LLs will include sites that have been previously co-created from ongoing activities and sites that are newly established. For more information regarding establishing and monitoring the LLs, please see Basaran et al., 2024.

4. Methods for meta-analysis of co-designed measures

Using the data collected from the evaluation and sampling of the network of case study areas and living labs, it is possible to analyse not just the local but also the regional effects using a meta-analysis approach. Using the single case study areas and living labs as single data units, the level of co-design or impact on the socio-economic benefits of restoration can be disentangled and compared. 4.1 Methods for case study area meta-analysis

Determining the influence of co-design on the effectiveness of restoration measures is challenging. Even in case study areas where co-designed restoration measures have been implemented alongside restoration measures that were designed without stakeholder involvement, it is generally not meaningful to directly compare the two types of measures. Because co-design generally considers stakeholder preferences that, for example, are influenced by the ease with which measures can be implemented in

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farm businesses, the two types of measures will differ in more aspects than just co-design. This means that it will no longer be possible to disentangle the effects of increased ownership and commitment that co-design is expected to produce, and the effects of the different actual measures.

Addressing this question using data from different case study areas is even more challenging, because such data come from areas with different environmental conditions (e.g. landscape complexity, soil type) and different farming systems, and examine different restoration measures that were developed using different levels of co-design. All these variables, including the level of co-design, have been known to affect the effects that restoration measures have on pollinators (Batary et al., 2011; Scheper et al., 2013). To disentangle the influence of the potentially moderating effects of such variables, we suggest using a meta-analysis approach in which each case-study area represents a single data unit. For each case study area, the level of co-design will be assessed using a standardized questionnaire and expressed on a continuous scale that ranges from "no co-design" to "high co-design". This information will include determining how many and which stakeholders were involved in deciding the restoration measures and sites (Ploeg et al., *in preparation*). Additionally, for each case study area, data is collected on other key variables expected to influence restoration effectiveness, such as the restoration measures, landscape complexity, and the farming system.

Using meta-analysis, these explanatory variables will be linked to restoration effect size (e.g. the difference in pollinator abundance or richness between restoration sites and control sites). Currently the number of RestPoll case study areas is relatively small for meta-analyses with multiple predictor variables, we therefore plan to grow the RestPoll network through collaborations with future projects and additional data from previous projects that have examined pollinator restoration measures. Fortunately, because of the recent interest in pollinators and concerns about their decline, many past and ongoing projects have produced data that can be used for this (e.g. the EU H2020 SHOWCASE and SAFEGUARD, along with national projects). This approach therefore offers the best chance that an effect of co-design will be picked up, if it exists.

4.1. METHODS FOR LIVING LAB META-ANALYSIS

The meta-analysis of the impact of restoration practices from the socio-economic perspective will be based on the evaluation of the Living-Labs. In fact, developing a set of indicators that will inform the knowledge flow and the social learning dynamics should be identified according to an adapted social-ecological systems framework (Ostrom, 2009). The indicators for the RestPoll project will be organised into the following sets of variables:

- Resource systems (Case study areas), i.e., Size, location, facilities, location, ecosystem history, system boundaries, etc.)
- Resource units (Pollinators), i.e., mobility of pollinators, growth or replacement rate, interaction among pollinators, value of pollinators, distinctive characteristics, spatial and temporal distribution)

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- Governance systems (Pollinator governance system), i.e., government organization, nongovernment organization, network structure, property rights system, operational choice rules, monitoring and sanctioning rules)
- Users (land owners and managers, farmers), i.e., number of actors, socioeconomic attributes, leadership/entrepreneurship, norms, social capital, technologies used)
- Interactions (Pollinator restoration interactions), i.e., harvesting levels, information sharing, deliberation process, conflicts, investment activities, lobbying activities, etc.)
- Outcomes (Pollinator restoration outcomes), i.e., socioeconomic performance measures, ecological performance measures, externalities to other Social-Ecological Systems (SESs).

For the selection of these indicators, it is advised to establish a dedicated steering group, which is comprised of project participants ranging from socio-economists to ecologists. This interdisciplinary group will play a pivotal role in deliberating and selecting the most pertinent indicators essential for effective monitoring of the LL's dynamics and outcomes. By drawing upon the collective expertise and insights of diverse stakeholders, including those deeply versed in social and ecological sciences, the steering group aims to ensure a comprehensive selection process that reflects the multifaceted nature of the LL initiative. Through collaborative discussions and informed decision-making, the steering group will pave the way for robust monitoring mechanisms that align with the goals of fostering innovation and sustainable development within the Living Labs. To accomplish this, the steering group will engage with all LL leaders and potentially local stakeholders to pre-identify indicators based on the purpose of their work and according to the specific needs and requirements of their LL. The pre-selection of these indicators will be discussed with the steering group and validated during the first LL workshop to be used as monitoring measurement indicators. Moreover, the selection of all indicators by the different LLs will serve as proxies for developing more generalized indicators (downscaled variables) for monitoring among the different LLs, facilitating the overall monitoring of the project and comparison among the different LLs (For more information see Basara et al. 2024).

5. Outlook and Applicability

5.1. PROJECT OUTPUTS

A restoration project like RestPoll captures perceptions of local, national, and global stakeholders to understand levers and barriers to adopting co-designed, pollinator-friendly management practices. This information should be collected using interviews, surveys, workshops, and focus groups, which enables farmer-to-farmer, farmer-to-researcher, or farmer-to-policymaker knowledge exchange. Integrating local and traditional knowledge into tools- and methods, which can be selected from workshops and surveys, is important to help develop novel instruments and tools that help support decision-making and are applicable to different local situations. To evaluate the co-

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benefits of restoration, it is important to collect and analyse data on the use of agrochemicals and its effect on pollinators, soil and water quality, which will be implemented into bio-economic models including data on the use of pesticides and fertilizers for providing decision tools for land managers and professionals in human health. These health-related decision tools can then be integrated into toolboxes to mitigate the combined effects of pollution, climate change, natural disasters, and habitat destruction. A toolbox can build an inventory of the existing measures that can be supported or promoted by policies and supports a comprehensive assessment which can highlights best practices of policy implementation, including opportunities for managing trade-offs and integrating pollinator restoration with other societal goals, like carbon sequestration, nutrient management, and biodiversity conservation (Box 3). With such a toolbox, land managers and researchers can assess the evidence of successful restoration measures and gain technical knowledge on the effectiveness of management practices promoting target organisms like pollinators, evaluate the willingness to pay by consumers, and develop a certification scheme for labelling.

Box 3: Info box on the RestPoll Toolbox, which includes decision support tools and good-practice guidelines for implementing pollinator restoration measures

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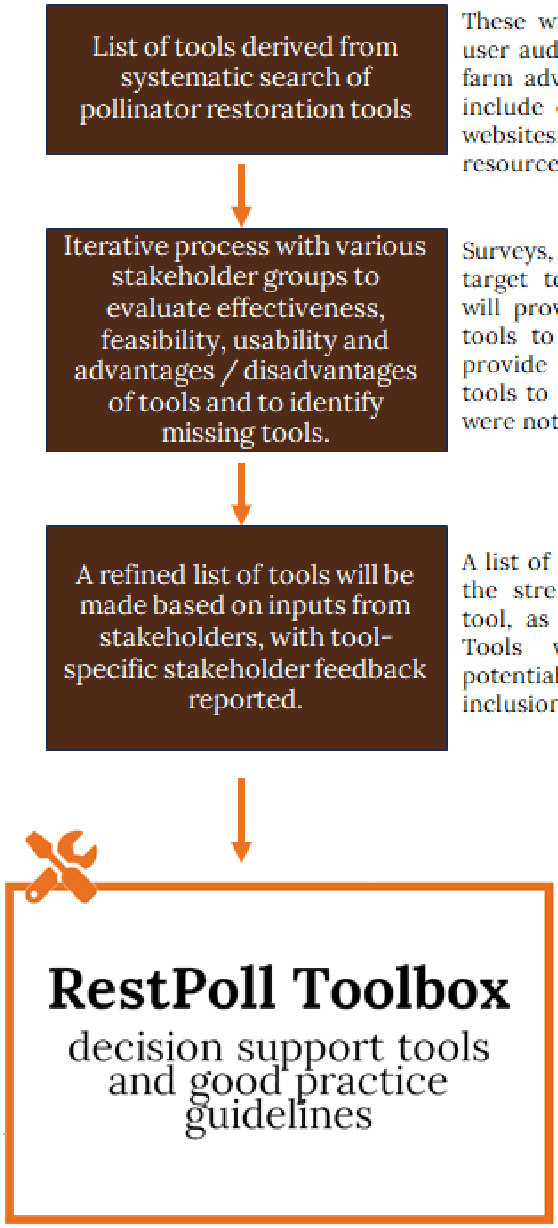

These will be organised into target tool-user audiences (e.g. farmers, researchers, farm advisors, policy makers). Tools may include computer software, applications, websites, networks, protocols and other resources.

Surveys, interviews and workshops with target tool-user audiences listed above will provide us with feedback on which tools to include in toolbox, as well as provide an opportunity for additional tools to be highlighted and included that were not included previously.

A list of tools will provide information on the strengths and weaknesses of each tool, as informed by stakeholder input. Tools with positive feedback from potential users will be shortlisted for inclusion in the RestPoll toolbox.

The RestPoll toolbox will be hosted on an online platform with easily navigable tabs for specific stakeholders (e.g. farmers) to find the tools most appropriate for them. Descriptions of and, where available, instructions on how to use tools will be provided alongside the link to the tool itself. The tool box will be made available on established platforms, such as European Commission's HIVE and FAO's International Pollinators Initiative website

5.1.1. Collaborations and outreach

Collaboration between projects, groups, and initiatives is important as it can enhance innovation, resource sharing, and overall success of projects. As there are other pan-European projects with similar goals, it is important to collaborate with them as this will help accelerate our goals and create synergies. This can be done through planning joint sessions, whether it be in the form of a meeting or workshop, to explore areas of mutual interest and brainstorm innovative solutions. Likewise sharing tools and resources, including information or knowledge created and gained during the projects, will help in avoiding redundancy and optimize efficiency. Integration across projects, whether it be cross-projects teams/members or implementing taskforces between the projects, will also support knowledge sharing of information, specific skills, or methodology.

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Collaborating or interacting with policymakers has bidirectional benefits. For policymakers it is important to understand what are needs and limitations at the practical level. This will enable the policymaker to adapt policies and related legislation. Of course, this has to be considered in the actual political context, and the opportunities and limitations that that political context entails. For other stakeholders the exchange will help illuminate the needs and limitations that are given by other relevant policy domains and/or by political objectives. It will also help to identify synergies with other projects or initiatives that are not directly in the scope of the stakeholders.

Interaction thus may lead to a context in which decisions and outcomes may be established in a more efficient manner, and with more effectiveness. This is most effective when the interaction involves all stages of innovation/development of the LLs on the one hand, as well as the various stages of policy development, implementation, and evaluation on the other hand. This can be done by public engagement or attending local meetings or hearings or simply involving the policymakers directly in the development and execution of the LLs.

Building collaborations with other organizations, such as NGOs can help collectively advocate for policy changes or contribute to policy discussions.

5.1.2. Conclusion

The RestPoll project's innovative approach to pollinator restoration, rooted in co-design and transdisciplinary collaboration in living labs, presents a promising model that can be adapted and applied to other countries with varying ecological, socio-economic and agricultural contexts and systems worldwide. While the project focuses on European landscapes, the principles of participatory restoration, stakeholder engagement, and adaptive co-management are universally applicable and can also be used towards future research aims or other restoration goals. As different countries face similar challenges in pollinator decline due to habitat loss, pesticide use, and climate change, the case study area network established by RestPoll can serve as a blueprint and starting point for international restoration initiatives. By tailoring the co-designed restoration measures to local needs and conditions, researchers in other regions can leverage the lessons learned from this pan-European effort to develop resilient, sustainable solutions for pollinator restoration. Ultimately, the project's success in fostering collaboration among scientists, policymakers, and land managers can drive a global movement towards more inclusive and effective restoration practices, contributing significantly to reversing biodiversity loss and ensuring ecosystem health on a broader scale.

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7. Appendix 1

Descriptions of each case study area in each country and partners are listed below. Information about the general location of the case study area, related to local landscape context (e.g. crop types, restoration measures are included in the columns.

Country	Federal_state	Coordinate of cases study area region	Number of farms in case study area	Case study area is within protected areas	Main land use types [Arable crop/forage, Pasture, Livestock,	Main type and presence of insect pollinated crops at farm [only, some, non]	Main type and presence of restoration measures [many, some]	Stakeholder grous in Living Lab

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					Fruit/speciality crop]			
Germany	Baden-Württemberg	47.69, 7.59	7	n	Arable crop/forage, Pasture, Livestock, Fruit orchards	Rapeseed [some], Apple [some]	Perennial flower strip [many], Soil mounts and bare ground [some], Flower undersowing [some], pesticide reduction [some], organic farming [some], Insekt houses [many], woody plant addition [some], management of SNH [some], old grass strips [some], intercropping [many]	NGOs, Researchers, Ministiries, Farmers
Germany	Germany			n	Arable farmland			
Hungary	Heves	47.59, 20.53		y	Arable farmland	Some: Sunflower, vetch, goat's rue, alfalfa		
Spain	Catalonia	41.57, 0.66	20	n	Fruit orchards and arable land	Apple [only]		
Italy	Puglia	41.20, 16.41	1	n	olive orchards	wild herbs (marigold, mauve, chicory, daisy, charlock,...), cherry tree, almond tree		
Latvia	Latvia	57.20, 27.03	9	y	Extensive grasslands (pasture, livestock)	semi-natural grassland habitats [pollinated crops are farm-specific] [some]		
France	Occitanie	43.39, 0.66	3000	y	Arable crop/forage, Pasture, Livestock, Mixed farmland with extensive grassland Livestock = mainly cattle and sheep	sunflower [some] oilseed rape [some] alfalfa and other [some] semi-natural grassland habitats[some]		
UK	Kent		NA	n	Fruit orchards	semi-natural grassland habitats [pollinated crops are farm-specific] only		

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UK	Somerset		Not identified	y	Mixed farmland	semi-natural grassland habitats [pollinated crops are farm-specific]
Denmark	Møn	54.97, 12.39	Not identified		Extensive grasslands	
Germany	Saxony-Anhalt		not identified	n	Arabel farmland	Oilseed rape
Switzerland	Valais	46.21, 7.30	not identified	n	Mixed farmland	some, apple, apricot, pear, strawberry raspberry, OSR,
Greece	Eastern Macedonia-Thrace		1	y	Fruit orchards, arable crops	Kiwi, some
Ukraine	Khotyn			y	Protected&Public space	
Ireland	Kildare	53.07, -6.79	40	n	10 Arable farm, 10 dairy pasture, 10 livestock pasture, 10 mixed farms	Beans, OSR
Germany	Baden-Württemberg & Thüringen			*y*	*Extensive grasslands*	
Netherlands	Boshommel L. Geuldal	50.84, 5.87	30	y	Mixed farmland	Apple, Pear
Sweden	Skåne	55.85, 13.55	24 (arable) + 16 (pasture) + 2 (fruit)	y	Arable crop, Pasture, Fruit crop	Apple (some), Oilseed rape (some)

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