ETC-BE working paper

Criteria and methods to identify Key Pollinator Areas (KPAs) and Buzz Lines

Authors:

Felix Deiss (BfN), Axel Ssymank (BfN), Hannah Burger (BfN), Heather Cohen (MLU), Alexander Harpke (UFZ), Martin Jung (IIASA), Sandro Pütz (BfN), Oliver Schweiger (UFZ), Piero Visconti (IIASA), Josef Settele (UFZ)

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Cover image: *Bombus vestalis*, *Aglais urticae*, *Helophilus pendulus*, *Macroglossum stellatarum*, *Helophilus trivittatus*, *Andrena fulva*, © Axel Ssymank and Hannah Burger (BfN)
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Summary

Europe's wild pollinators play an essential role for multiple ecosystem functions and services, including pollination of around 80% of wild flowering plants in Europe and a contribution of €15 billion annually to the market value of crops, ensuring human food security. Despite their ecological and economic importance, pollinators are experiencing severe declines, with every third pollinator species now in decline. The agricultural and forestry intensification, the loss of (semi-) natural habitats, and their degradation and fragmentation are amongst the primary drivers of pollinator declines. For flower visiting insects, the loss of flower-rich habitats with a high diversity in plant species is particularly detrimental. Habitat quality, connectivity, and complementarity are important to maintain pollinator diversity. In addition, climate change increasingly affects pollinator communities and drives colonisation of new habitats. To address this pollinator crisis, the revised EU Pollinators Initiative set the commitment to identify, and map Key Pollinator Areas (KPAs) and "Buzz Lines" (i.e. a network of ecological corridors for pollinators). This report develops criteria and methods for the identification of these two complementary conservation tools. KPAs represent the most important areas for the European Union's (EU) key pollinator taxa, namely bees (~2,000 species in Europe), hoverflies (~1,000 species), butterflies (~500 species) and moths (10,000 species). Their identification combines direct criteria based on species occurrence, such as the presence of threatened, rare, endemic, or keystone species and high species richness, with indirect criteria based on resources necessary for species survival, including habitat type, floral resources, nesting structures, and larval host plants. Based on these criteria we discuss the advantages and disadvantages of threshold-based and complementarity-based mapping approaches. Buzz Lines shall represent ecological corridors connecting KPAs and other areas of conservation importance. They shall provide habitat continuity at two spatial scales. On the one hand, they shall support long-distance connectivity for migration and range shifts driven by climate change. On the other hand, they shall represent corridors at the regional and local scale, enabling adult and larval habitat connectivity through habitat mosaics, stepping stones and linear structures such as hedgerows. We provide general criteria important for both KPAs and Buzz Lines, such as low pesticide exposure, high proportions of semi-natural habitats, continuous flowering phenology or minimal light pollution and highlight current data gaps that need to be addressed in up-coming projects. The report provides a starting point for the implementation of actions to establish KPAs and Buzz Lines (action 2.3/4.4) of the EU Pollinators Initiative and aims to help in the achievement of the targets set under Article 10 of the Nature Restoration Regulation to ensure the recovery of wild pollinators. We emphasise the great potential of such an approach for the EU-wide conservation of our pollinators, through active Member State engagement, stakeholder inclusion and cross-border cooperation.

1 Introduction

1.1 Pollinator Decline

The world is currently experiencing a triple planetary crisis, encompassing climate change, pollution, and biodiversity loss (United Nations 2022). The biodiversity crisis has resulted in a severe decline in numerous species populations, including insects (Hallmann et al. 2017; 2021, Habel et al. 2019, Seibold et al. 2019). Since insects represent the majority of pollinators in Europe (Leonhardt et al. 2013), they play a crucial role in the provision of ecosystem services and therefore directly ensure our food security (Gazzea et al. 2023, Ssymank et al. 2008). Collectively, pollinators provide a wide range of benefits to society including: more than €15 billion per year contribution to the market value of European crops; important contributions to human diets in terms of fruits, vegetables, and nuts with high nutritional value; pollination of around 78% of wild flowering plants, which ensure healthy ecosystem functioning and maintenance of wider biodiversity, as well as of culturally important flower-rich landscapes. The larvae of several deliver additional ecosystem services, such as water purification, decomposition of organic material, or biocontrol in crops. Furthermore, as many other insects, pollinator populations are an important asset in the food chain of birds, reptiles and fish feeding on insects.

Despite their ecological importance, according to the European Red List of Threatened Species, one in three species of bees, hoverflies, and butterflies are now in decline and every tenth butterfly and bee species is threatened with extinction. Pollinator decline largely depends on land-use changes affecting both habitat area and habitat quality. For flower visiting insects, the loss of flower-rich habitats with a high diversity in plant species is particularly detrimental. Habitat quality, connectivity, and complementarity are important to maintain pollinator diversity. Habitat connectivity reduces pollinator habitat isolation and allows migrations and (re-)colonisation of sites and for many pollinator species a suitable habitat mosaic of adult and larval habitats to be able to complete their life cycle. Habitat connectivity is also important for dispersal in response to climate change and to maintain gene flow among insect-pollinated plant populations.

Bees, hoverflies, butterflies, and moths represent key pollinator taxa in the European Union (EU). There is an urgent need for actions to ensure their protection and restoration. Therefore, the establishment of a political framework, with clearly defined targets in the EU Pollinators Initiative – A new deal for pollinators (2023/2720(RSP), European Commission 2023) and binding legislation through the Nature Restoration Regulation (EU 2024/1991, European Commission 2024) has been crucial. This document focuses on two conservation aspects, the identification of Key Pollinator Areas (KPAs) and Buzz Lines, and outlines associated requirements and possible approaches for their development. KPAs are most important areas for the EU's key pollinator taxa and Buzz Lines are thought as ecological corridors connecting KPAs and other areas of conservation importance to maintain habitat connectivity.

1.2 EU Policy context and legal context

EU Pollinator Initiative 2023 (2023/2720(RSP), European Commission 2023) – a framework of actions for halting the decline of pollinators sets the following commitments:

Priority I Action 2.3:

“The Commission will, jointly with Member States and the European Environment Agency, identify and map Key Pollinator Areas in the EU, which should become the focus of conservation and restoration efforts.”

Priority II Action 4.4:

“The Commission and Member States, with the support of the European Environment Agency, should devise a blueprint for a network of ecological corridors for pollinators – “Buzz Lines” – and develop a plan of measures for implementing it. The plan will build on the mapping of Key Pollinator Areas and the creation of new habitat areas through restoration. To support the implementation of the Buzz Lines network Member States should integrate pollinator conservation into spatial planning policies at national, regional, and local levels.”

Nature Restoration Regulation (EU 2024/1991, European Commission 2024) – sets binding targets for Member States

Article 10:

1. Member States shall, by putting in place in a timely manner appropriate and effective measures, improve pollinator diversity and reverse the decline of pollinator populations at the latest by 2030 and thereafter achieve an increasing trend of pollinator populations, measured at least every six years from 2030, until satisfactory levels are achieved, as set in accordance with Article 14(5).

Both KPAs and Buzz Lines, together with pollinator-friendly agricultural management are among the main measures to achieve the aims of Art 10(1) to improve pollinator abundance and reverse the decline of pollinator populations.

An agreed common understanding with a definition of Buzz Lines as well as a joint harmonised set of criteria are a good base for coordinated action and implementation among Member States.

1.3 Context and aim of the ETC BE Working Paper

As agreed in the first meeting of the EU Working Group on Pollinators (WGP) Task Force 2: Key Pollinator Areas and Buzz Lines, the aim of the ETC BE Task: “Support to the EU Pollinators Initiative – A New Deal for Pollinators” (Task 1.3.23.1) is to provide a first, preliminary draft on how to identify and map KPAs and Buzz Lines. This task is intended to facilitate the selection of appropriate measures and actions needed to reverse pollinator decline both under the actions of the EU Pollinators Initiative and under the Nature Restoration Regulation. It is important to note that this work is a starting point for more in-depth analysis and discussions to support the EU WGP with its Task Force 2.

2 Draft criteria and methods to identify Key Pollinator Areas (KPAs)

2.1 Why do we need KPAs?

2.1.1 Aims of KPAs

Among the primary drivers of the global decline in pollinator populations is habitat loss, due to the conversion of natural landscapes into intensive agricultural land and urban areas (Sánchez -Bayo and Wyckhuys 2019). This transformation leads to the loss of feeding and nesting resources and habitat fragmentation. Further contributing factors are pollution, the spread of invasive species and pathogens, and climate change (Sánchez-Bayo and Wyckhuys 2019). Therefore, protected and conserved areas with management adapted to the needs of pollinators are needed to safeguard pollinator diversity and their pollination services.

The current protected area network, however, is not capable of reversing this decline in pollinator populations, nor of achieving an increasing trend after 2030. In fact, globally, 76% of known insect species still do not meet minimum protected area target coverage and 2% are not represented at all (Chowdhury et al. 2023). Therefore, the EU Pollinator Initiative 2023 (2023/2720 (RSP)) provides a dedicated action for the identification of KPAs, which will make a significant contribution to the effective protection of pollinators.

By identifying and mapping KPAs, it will be possible to cross-analyse them with the current protected area network, determine gaps in conservation, adapt conservation and restoration measures and management plans, and possibly expand the protected area network if KPAs were identified outside of protected areas. KPAs should complement Natura 2000 networks and improve pollinator-specific protection. At the same time KPAs within Natura 2000 sites or overlapping with them can help to put a focus on pollinator-friendly management within the protected site. This could be an integral part of updating Natura 2000 integrated management plans.

2.1.2 General Overview: State of Knowledge on important areas for pollinator taxa

Important areas for individual pollinator taxa have already been identified in the past in some European States, but mostly on a national level and based on rare and endangered species. This previous work has provided important insights for the effective protection of key pollinator groups within the EU, and some examples are briefly outlined below.

Criteria used in the various previous approaches were mainly based on rare and/or endangered species (van Swaay & Warren 2003; van Swaay und Warren 2006; Vujić et al. 2016; Gallego-Zamorano et al. 2023), and species diversity (Gallego-Zamorano et al. 2023), or indirect approaches mainly based on availability of habitats relevant to pollinators (Maes et al. 2024). Standard criteria developed from the International Union for Conservation of Nature (IUCN) for Key Biodiversity Areas (KBAs, IUCN 2016) were also tested for pollinators (Nania et al. 2024), and Prime Butterfly Areas (PBAs) integrated into the High Nature Value (HNV) farmland approach (Paracchini et al. 2008).

The following criteria have previously been applied in a European context to identify areas of high conservation value for pollinator species and can support KPA criteria development:

Prime Butterfly Areas (PBAs) - (van Swaay & Warren 2003, 2006)

- Site selection based on rare and endangered butterfly species,
- Expert-driven approach,
- Identification on a European scale, based on the European Red List of butterflies,
- Species must trigger two of the criteria under Supplementary Material Table S1.

Prime Hoverfly Areas (PHAs) - (Vujić et al. 2016)

- Site selection based on rare and endangered hoverfly species,
- Expert-driven approach (developed criteria for species and area selection; passed these criteria over to experts who thereupon assigned the relevant areas; evaluation of these areas through complementary analyses – gap and irreplaceability analysis),
- Identification on a national scale for Serbia.

Important Butterfly and Moth Areas (IBMAs) - (Gallego-Zamorano et al. 2023)

- Site selection based on endangered species, endemic species, and species diversity of butterflies and moths,
- Data-driven assessment supported by expert knowledge (used data from the National Database Flora and Fauna over the last 10 years; aggregated the high-resolution recording data to a coarser resolution; then applied their criteria),
- Identification on a national scale for the Netherlands, resulted in 38 IBMAs across the Netherlands, but only for butterflies and moths,
- Species must trigger one of the criteria under Supplementary Material Table S2.

Important Pollinator Areas in Flanders – (Maes et al. 2024)

- Site selection based on a list of Annex I habitats important for pollinators considering the presence of pollinator-dependent plants that provide foraging resources for pollinators, while also considering the flowering period,
- Resulted in a list of top 5 European Habitats Directive (92/43/EEC, European Commission 1992) Annex I habitats per biotope group,
- Translated these habitats into codes of the Biological Valuation Map (BVM), only available on a regional level,
- Indirect approach not focusing on the pollinators but on the nectar/pollen availability through floral resources,
- An indirect approach would make it difficult to say something about the abundance and species richness of pollinators or about the presence of rare and endangered species,
- Further, it would only refer to imagoes, as most larvae are not feeding on pollen/nectar, and overlook other environmental variables.

Key Biodiversity Areas (KBAs) – e.g. Nania et al. (2024)

- Site selection can be based on any species except micro-organisms (IUCN 2016),
- Identified through the application of specific criteria on the global or regional level, of which one or more needs to be met (IUCN 2016)
- Data-driven approach (occurrence points) or expert knowledge (Brooks et al. 2019) to produce Area of Habitat (AOH) maps based on pollinator habitat maps,
- Two-step approach: First identification of potential KBAs based on biological criteria, then assessment of manageability based on accessibility, geographical features, and socioeconomic or cultural values,
- Well-established concept with worldwide application, e.g. Nania et al. (2024) identified KBAs based on 28 endemic or subendemic species/subspecies of bumblebees in Italy,
- However, methodology has some shortcomings in application, customised towards distribution data from IUCN, triggers of KBA criteria are known to be scale dependent, with different areas selected at different spatial grains (Farooq et al. 2023).

2.2 Focus on key pollinator groups and the essential background on their ecology/ biology for KPAs

2.2.1 Wild bees (Apoidea)

Bees are present in all terrestrial habitats. They are herbivores that feed their larvae with a mixture of pollen and nectar or, rarely, plant oils. The availability of food from plants is thus one of the major factors limiting the development of the offspring and survival of adults (Biesmeijer et al. 2006, Scheper et al. 2014). Bees require large amounts of pollen to rear their offspring (often hundreds of flowers for one larva) and are thus directly affected by the decrease of available flowering plants and the loss of flower-rich habitats (Müller et al. 2006). Bees do not collect pollen on flowers randomly, many species demonstrate floral specificity (oligolectic) when harvesting pollen only on a limited number of plant taxa, and even polylectic bees often show a restricted range of pollen sources (Müller et al. 2008, Kuppler et al. 2023). Because of the various host plant choices of bee species, species-rich bee assemblages depend on the availability of high plant diversity.

Nesting resources for bees include the substrates within, or on which they nest, and the materials required for nest construction. Bees are highly diverse in their nesting ecology and comprise several distinct guilds (Harmon-Threatt 2020): miners, carpenters, masons, social nesters, and cuckoos. The majority of bee species nest underground in the soil (Antoine & Forrest 2021). It was demonstrated that the availability of both nesting substrates and construction materials were primary determinants of overall bee assemblage composition. Many bee species have short foraging distances (100-200 m) and rely on small scale habitat mosaics (habitat complexes) to obtain both food plants and nesting sites and material within their reach (larger sized bees have foraging distances of several hundred metres to two kilometres), which can affect their persistence (Zurbuchen et al. 2010). For example, fire, one of the dominant ecological perturbations in Mediterranean ecosystems, results in a marked turnover of nesting resources, resulting in large shifts in the relative proportions of nesting guilds. Important resources shown to affect bee nesting success include diameter of pre-existing holes for stem or cavity-nesting bees, and soil texture, hardness, slope and aspect of the ground for soil-nesting bees such as many halictid bees. On a landscape level, availability of open soil areas in grasslands are important prerequisites for underground-nesting bees and woody structures for cavity-nesting bees.

Overall, the quality of local habitat conditions for bee assemblages depends on a combination of the availability of floral resources and nesting sites, but also the surrounding landscape and its composition (Neumüller et al. 2020). Bees are able to move between different habitats within achievable flight distances. Beside these aspects, climatic conditions in a region determine the occurrence of bee species (Newbold et al. 2025, Outhwaite et al. 2022).

2.2.2 Hoverflies (Syrphidae)

Hoverflies are present in all terrestrial and most freshwater habitats (larvae of aquatic groups) including brackish water and are only absent in the marine environment (Rotheray & Gilbert 2011, Speight 2020, Speight & Castella 2024). Adults use both pollen and nectar from flowers. With a few exceptions, all hoverflies are pollinators, and even wind-pollinated plant species are visited. Additionally, evolution has allowed for changes from wind to insect pollination or the development of genetically different wind or insect-pollinated populations of the same plant species (e.g. in *Plantago* (Stelleman 1984)). Pollen feeding is essential for egg maturation and fecundity of hoverflies. Specialisation of hoverflies varies in flower visitation from almost generalist to oligolectic, linked to one plant genus or family, often flower preferences can be detected on flower type in combination with flower colour and average flower height (Ssymank 2001, 2002, 2003). Hoverflies have a trichromatic vision without red, but instead ultraviolet perception, including polarised light. Some species have been shown to be able to learn flower colour (Lunau 1988) and can have a high flower constancy with high pollination efficiency. Visiting time of flowers is generally lower than it is for honeybees, thus being quicker in transferring pollen to other flowers.

The larval biology of hoverflies is very diverse and includes aquatic saprophages and terrestrial saprophages with many species linked to dead wood, tree hole, or sap run habitats in forests, but also a large group of phytophagous species living in underground bulbs, rhizomes, and more rarely in leaves or even in fungi. Another large group are species with zoophagous larvae, often living on scale insects such as aphids, coccids etc., often combined with some migratory behaviour of the adults to be able to find suitable aphid colonies for egg laying. The number of generations varies from one per year to polyvoltine species having up to five or more generations per year, which can build up large populations with high annual fluctuations, while some of the rarer species have small and relatively stable sedentary populations, some even requiring several years for one life cycle. In contrast to larvae, adult hoverflies often use different habitats and need or prefer heterogenous habitat mosaics or spatially interlinked habitats on the landscape scale (Rotheray & Gilbert (2011) Ssymank (1991, 2001, 2002), Ssymank & Doczkal (2017), Assess to Plan (A2P) guidance (Lees et al. 2022)).

Adult hoverflies are also known to be important dispersers. A group of 30-40 hoverfly species, including *Syrphus vitripennis*, *Episyrphus balteatus* or *Scaeva selenitica* are long-distance migratory species with regular migrations over the Alps, and can therefore act as long-distance pollen dispersers, maintaining the genetic exchange between plant populations (Gatter et al. 1990, Reynolds et al. 2024). For example, an estimated 1-4 billion hoverflies carry millions of pollen-grains every year across the channel between the United Kingdom and Continental Europe (Wotton et al. 2019).

Hoverfly species assemblages are highly sensitive to anthropogenic pressures, to changes in habitat fragmentation, landscape mosaic and good indicators of habitat quality. With increasing pressures both species richness and abundance decline. Usually, the hoverfly species groups with zoophagous larvae and some of the less sensitive species with aquatic larvae remain in disturbed habitats, while more specialised saproxylic groups and the species with phytophagous larvae get lost.

2.2.3 Butterflies (Papilionoidea)

Butterflies are present in most terrestrial habitats, predominantly in open landscape types such as (calcareous) grasslands, heaths, scrubs, or mires, but they also occur in forest habitats. Most butterfly species that are associated with forest habitats are gap-system colonisers that inhabit complementary environments, such as clear cuts, transmission line corridors, fire breaks, or forest edges. Therefore, butterflies benefit from a diverse and small-scale landscape matrix, as well as from extensively managed habitats (Bottero et al. 2023), especially in dry grasslands and wetlands.

In general, habitat quality and habitat size appear to be more important for butterflies than habitat connectivity (Radchuk et al. 2012), highlighting the relevance of protecting, maintaining and enlarging existing protected areas. For specialist species, which are often of greatest conservation concern, larger habitat patches generally harbour more species than smaller ones, although it has been pointed out that clusters of small, suitable patches can be important too (Dover and Settele 2009). Due to that positive relationship between patch size and specialist density (Dover and Settele 2009) and the beneficial effects to other butterfly taxa, priority should be given for the protection of large, high-quality habitat patches. Moreover, butterflies are more likely to leave small patches compared to larger ones in a fragmented landscape (Schtickzelle and Baguette 2003), which would require even better habitat connectivity or a more continuous landscape.

Butterflies, like bees and hoverflies are highly sensitive to climate conditions and its changes over the last decades, and it has been suggested that microclimatic conditions including temperature variations have recently been more important in determining their distribution than landscape composition (Aguirre-Gutierrez et al. 2017). Depending on the environmental conditions, most species can produce several generations per year, with overwintering occurring species-specifically as eggs, larvae, pupae, or adults.

With 29 butterfly species listed in the Annexes of the Habitats Directive, butterflies are already well represented in EU legislation, making their improved conservation mandatory (van Swaay et al. 2012). The larvae of butterflies are generally herbivorous and often highly host specific, being associated with only a few, or a single plant species. Some members of the butterfly family *Lycaenidae* are zoophagous as larvae and feed on ant brood, i.e. the presence of the species is linked to the presence of certain ant species.

The majority of adult butterflies feed on nectar, but in contrast to hoverflies, not on pollen (at least not in Europe, some pollen feeding butterflies are known from the tropics). Most species are polylectic, although there are oligolectic exceptions. Butterflies have shown to be very effective pollinators of generalist plants on a per-visit basis, spending the longest time on an inflorescence and showing the highest proportions of stigmas pollinated compared to hoverflies or bumblebees (Ollerton et al. 2024). Further, butterflies travel long distances between inflorescences, rendering them important pollen dispersers between habitats (van Rossum and Triest 2010; Ollerton et al. 2024). Some butterfly species, such as *Vanessa atalanta* or *Vanessa cardui* even show migratory behaviours and therefore can act as long-distance pollen dispersers, maintaining the genetic exchange between plant populations.

2.2.4 Moths (Heterocera)

Moths are found in most terrestrial habitats with a focus on open landscape types such as (semi-natural) grasslands and in forest habitats, including species-rich ecotones such as field margins, water margins, forest edges or hedgerows (Fuentes-Montemayor et al. 2011, Coulthard et al. 2016). In general, forest habitats support higher moth species richness than meadow habitats (Merckx et al. 2019). Within forests, macromoths tend to be more abundant and species rich in younger forest habitats, whereas micromoth specialist species occur especially in old forest sites (Fuentes-Montemayor et al. 2022). In contrast to hoverflies, freshwater habitats are of minor importance, except for a few species in which the larvae live aquatically on top of water plants, such as water lilies.

Most moths are nocturnal, although numerous diurnal exceptions exist. As nocturnal species, they are strongly affected by light pollution, i.e. artificial light at night (ALAN), especially in the highly fragmented, urbanised, and densely populated landscape of Central Europe. Therefore, in order to implement effective conservation measures for moths, forest fragments should exceed five hectares in size and encompass habitats located more than 100 metres from the edge of the area (Slade et al. 2013). Further, these forest areas should contain a high tree diversity and high proportions of native tree species to best support moth abundance and species richness (Fuentes-Montemayor et al. 2012).

Although moths are by far the most species rich group among the four key pollinator taxa discussed, large knowledge gaps persist, particularly concerning microlepidoptera. These existing knowledge gaps, especially regarding distribution data, could make it difficult to cover this species-rich group in a representative way. However, a few species of moths are directly protected through the Habitats Directive (92/43/EEC).

In addition to fermenting fruits, tree sap, sweat, or water from puddles, adult moths of many families feed on nectar, thus making them important pollinators. Unlike hoverflies or bees, they do not eat the pollen, however, they do unintentionally carry it on their hairy bodies, making them very effective pollinators that have received too little attention in the past (Alison et al. 2022). Some studies suggest that the pollinator network of moths is more complex than that of butterflies and that moths pollinate some plant species that are not visited by diurnal pollinators (Walton et al. 2020). Presumably, the families of Sphingidae and Noctuidae represent the most important moth pollinators in Northern

America and Europe (Hahn & Brühl 2016). Like butterflies, they carry most of their pollen on the ventral side of the thorax, caput, and along the proboscis. However, species in the family Sphingidae, due to their hovering feeding behaviour akin to hummingbirds, primarily accumulate pollen along the proboscis. Due to their long proboscis, they are particularly relevant as pollinators for plants with long tubular flowers. While diurnal species as *Macroglossum stellatarum* rely more on visual signals in foraging (Balkenius et al. 2008), other species as *Manduca sexta* need simultaneous olfactory and visual signals to elicit feeding behaviours (Raguso and Willis 2005). Some moth species, such as *Macroglossum stellatarum* or *Hyles livornica* show migratory behaviours and therefore can act as long-distance pollen dispersers, maintaining the genetic exchange between plant populations.

2.3 Development of KPAs criteria

2.3.1 Proposed definition of KPAs

Definition: Key Pollinator Areas should represent the most important areas for the EU's key pollinator taxa (bees, hoverflies, butterflies, moths) which host (or hosted in the past) common, rare and endangered pollinating species, areas of high species richness, abundance and trait specificity, and complement the current protected area network in the most efficient way.

Terms and conditions for KPAs:

- *Size and expansion of KPAs:* KPAs "should be large enough to safeguard a viable population of a species, but at the same time, should be small enough to be conserved in their entirety" (Gallego-Zamorano et al. 2023).
    - This idea derives from the IBMA approach and is intended as a reminder to keep the identified areas as large as necessary but as small as possible. This should enable administrative authorities to designate and subsequently manage the areas as effectively as possible.
    - The lack of a maximum size criteria is also a frequent point of criticism of the KBA approach, as well as their spatial scale dependencies.
    - The more species are considered as trigger species for a KPA, the more KPAs can be identified, and the larger the KPA, the more species it will contain. However, in practice there is a need to be pragmatic and agree on priority species and define sites of reasonable size thresholds. Ideally, new KPAs are proposed to be complementary to key determinants of pollinator richness and abundance, including functional pollinator diversity (trait-based), floral resources and diversity and landscape contexts.
- *Buffer zones:* Pesticide amount in protected areas relates to the proportion of intensive agriculture in a two-kilometre perimeter, especially in the case of open habitats not sheltered by dense hedgerows or forests. This effect is particularly severe in countries that have many small and/or highly fragmented protected areas, as the edge effect is particularly high in these cases. Therefore, buffer zones of 100-200 metres up to two kilometres around existing protected areas were identified as critical support zones for pollinator populations. The needed dimension of buffer zones depends on the kind of pressure and on the specific type and structure of the buffer zone itself. In addition to pesticides and seed coatings, it is also necessary to consider the effect of light pollution on moths within protected areas or

urbanisation rates around protected areas/ the Natura 2000 network (Orsi and Le Clec'h 2023). Where possible, KPAs should be identified in a way that minimises their edge exposure to intensive agriculture and thus potential pesticide load. Here it is suggested to apply species-specific dispersal measures and criteria to scope for areas that would most likely contain stable and healthy pollinator populations, while avoiding hazards.

- *Management effectiveness:* Pollinator friendly conservation measures and management plans are crucial. Current gaps in conservation needs are yet to be comprehensively assessed.
    - In the case where several sub-areas in a region are suitable for designation as a KPA, areas should be assessed in regard to their governance and ownership, with public ownership given priority to simplify the implementation of management measures, although privately owned land can also be effective in implementation.
    - Stakeholder consultations and identification of long-term and practical management interventions are paramount to ensure agricultural land is managed in a pollinator-friendly way.
- *Restoration of sites:* Most KPAs will be sites that harbour species-rich pollinator communities, but there could be cases where a degraded site is identified as a KPA, followed by a call for its restoration. This may occur if that site played a vital role in the past or will gain importance under future global change, is strategically located, or hosts complementary pollinator assemblages. Additionally, last remnant populations of species that are highly threatened by extinction or are local endemics might require site restoration, or even population introduction at new sites under the EU Nature Restoration Regulation.
- *Protected area network:* Many KPAs will overlap with the Natura 2000 network, but can be also located outside protected areas, for example, in other effective area-based conservation measures (OECMs, Alves-Pinto et al. 2021) or to some extent in unprotected areas. As part of the EU Biodiversity Strategy for 2030, a commitment has been made to expand protected areas to 30% of the EU's surface, including 10% under strict protection. In this context, KPAs may play an important role. However, in the case of strictly protected areas (e.g., wilderness areas), which are often left to develop naturally and consequently tend to evolve into forests across much of Europe over the long term, it remains unclear to what extent they can contribute to or qualify as KPAs. Especially xylobiontic groups, for example in hoverfly species with saprophagous larvae in dead wood and ancient trees may clearly benefit from wilderness areas.
- *Habitat types and resources:* Most pollinator species depend on specific habitats (e.g. European Nature Information System (EUNIS) habitat types or habitat complexes) and floral resource requirements, and the identification of KPAs, whether through conservation or restoration should ideally consider the complementary occurrence of resource availability.

2.3.2 Approaches to identify KPAs

Direct/ indirect approaches:

In order to identify KPAs, direct (focusing on species) and indirect (focusing on habitats and the availability of resources) approaches can be used (Table 1 and 2). We suggest combining both direct, based on occurrence of pollinator species or groups of species characterised by specific traits, and indirect approaches based on habitat conditions that indirectly support distinct species or groups of species (Figure 1).

Data-driven approaches using monitoring data or distribution data available in high resolution e.g. in Red Lists or databases are most promising to accurately identify KPAs. However, there is a lack of data for many pollinator species because of low monitoring efforts in the past (except for butterflies, see data availability below). In these cases, indirect approaches can provide a suitable complement. Further, if data-driven approaches are not possible, expert knowledge can help to fill knowledge gaps. However, they should not be relied on exclusively and should be complemented with intensified monitoring prior to KPA designation. Data availability will soon increase upon the start of EU-wide monitoring schemes (e.g. EU PoMS). However, the planned standard transects of the core monitoring will contribute little to KPA selection, while specific additional monitoring, for example of Habitats Directive Annex I habitats in the additional monitoring, or monitoring with extended methods could deliver valuable new datasets for KPAs. Criteria need to be selected based on the current data availability to be operational. First assessments of potential areas can be later fine-tuned according to a developing database and additional criteria; the criteria outlined in this report describe approaches based on best available data to date. In addition to biological factors, the manageability of areas, influenced by accessibility, geographical suitability, and cultural aspects should also be considered.

Threshold-based approach:

Analogous to KBAs, it is necessary to have information which should cover the whole country, e.g. through occurrence points or expert knowledge (Brooks et al. 2019) and produce AOH maps for single species, which reduce the range of a species to the actual available habitat. Species must trigger one or a set of the criteria listed below (similar to the KBA approach). However, such threshold-based approaches will need to carefully consider the appropriate unit of analysis (Farooq et al. 2023), as KBA identification can be highly scale-dependent; the larger the unit of analysis, the more likely a given unit is to be identified as a target area. This limitation is true for most approaches based on thresholds for occurrences or population size. Further, the more species considered in such approaches, the more potential areas are received, raising the question of later feasibility. Additionally, none of these approaches are able to consider spatial design criteria, e.g. connectivity and fragmentation of habitat patches (these need to be addressed by the Buzz Lines), co-occurrence of pollinator-friendly habitats, or area contiguity. Nor are they able to consider the resilience of these sites to climate change and exposure to pollinator-related pressures (e.g. light pollution, pesticides). Finally, similar approaches in the past, except for KBA, exclusively relied on the aggregate metrics of species richness, rarity or endemism, which risks overlooking many areas of importance to biodiversity that are irreplaceable or complementary.

Complementarity approach:

Complementarity measures the extent to which an area, or a set of areas contribute to protecting under-protected biodiversity features (e.g. habitats, species, functional pollinator diversity (trait-based)) to an existing area or set of areas (Margules & Pressey 2000). Complementarity-based approaches have been documented to be superior to threshold-based approaches in terms of identifying areas that most efficiently achieve a given set of conservation objectives (Pressey & Nicholls 1989; Justus & Sarkar 2002; Cowling et al. 2003; Game et al. 2013; Ribeiro et al. 2017), and they can be applied with the same data necessary for threshold-based approaches, while remaining robust to different spatial grains. Further, they can flexibly integrate a range of different datasets of non-biological nature (e.g. landscape elements or climate resilience). Based on a set of features, spatial optimisation algorithms such as Zonation or Marxan can be used to select sites that together cover the most complementary number of species with minimal redundancy. In other words, areas are selected that support biodiversity features that are unrepresented in other existing or selected areas (Williams et al. 2006). Complementarity-based approaches are furthermore able to assess sites based on KBA criterion E (irreplaceability), capture species-specific threats (such as Red List criteria) and rarity as explicit criteria driving a solution, as well as providing a quantification of how close a selected site is from a set conservation target (Kukkala and Moilanen 2013). Further, these methods can be used to identify areas with high restoration opportunity for pollinating species in ‘what-if’ scenarios, i.e. where would be of the greatest benefit for restoring semi-natural grassland, given existing and future pollinator distributions. Finally, algorithmic solutions allow the flexible integration of costs, penalties and constraints (such as existing governance types, pollution exposure or land-use intensity) as part of the scoping.

Trait-based multispecies groups approach (identification of groups):

Multispecies groups that likely benefit from the same kinds of conservation activities performed either in the same places or involving the same conservation agencies and actors. Species can be grouped according to traits of biology, distribution, habitats, and major threats. In general, the management groups identified in A2P documents of the latest EU Red Lists for pollinators can be suitable groups, as they use the best available expertise. For hoverflies, experts identified the most valuable groupings (traits) as those relating to larval feeding types and their associated microhabitats (Lees et al. 2022). For bees A2P documents was published by Reverte et al. 2026, identifying groups based on lecty, nesting, sociality, and habitat type. For other EU pollinator groups A2P documents are planned or already under way.

2.3.3 Criteria based on pollinator occurrence and diversity in an area (direct approach)

Table 1. Criteria for KPA identification based on pollinator occurrence and diversity in an area (direct approach)

Species Occurrence Criteria	Description	Identification
Threatened pollinators	Threatened, Red-Listed species	Threatened on European, national or regional level (based on European or National Red Lists), Red List status Critically Endangered (CR), Endangered (EN), Vulnerable (VU), possibly also Near Threatened (NT) and for restoration Extinct (EX)
Rare pollinators	Species with a very low range or area of the population (often highly specialised species with specific habitat requirements)	Species occupying less than 1% of the area of a Member State. This can be species with a concentrated occurrence, for example on a mountain summit, but also species with naturally very low and dispersed populations, for example glacial relict species in bogs
Endemic or subendemic pollinators	Range-restricted species for which countries/regions/local administrations might have a special responsibility, because a large proportion of their global/EU population is present there	As identified in the EU/IUCN Red Lists and in TaxoFly and Orbit. Focusing on sites containing ≥1% of the global or ≥10% of the national species population
Keystone species	Species that have a disproportionally large impact on the ecosystem relative to their abundance: i.e. functionally important pollinators as species important for crop pollination, particularly effective pollinators, important for the functioning of ecosystems, long-distance migrating pollinators, visit diverse flower spectrum	Functionally important pollinators, e.g. crop pollinators, long distance migrators

Species Occurrence Criteria	Description	Identification
Umbrella/Flagship species	Species which indirectly lead to the protection of other species/ charismatic species which help to justify conservation measures	Umbrella species: Ideally including representatives from all 4 pollinator groups and all trait-based multispecies-groups Flagship species: Charismatic, often large and colourful species, often well-known in public
Specialised pollinators	Highly specialised pollinators, with close plant-pollinator relationships	Identification based on ecology/biology of species, expert knowledge
Pollinators with high conservation priority	Assurance that no pollinator species is further declining	Exceptionally threatened pollinators according to EU and/or National Red Lists
Species richness	Species rich assemblages can pollinate a high diversity of plants and support diverse ecosystems	High number of species within a defined habitat or exceptional number of species
Abundance	High abundance of pollinators in an area which can pollinate a high number of plant individuals, thus provide great ecosystem services	High number of individuals within a defined habitat, exceptional individual numbers, or high densities, might mainly include common species
Trait-based multispecies groups	Assemblages of species with similar traits or similar resource requirements. The protection of one species within the group might then lead to the protection of the whole group (umbrella effect)	Occurrence of assemblages of species with similar traits/requirements, recommendation to use the A2P identifies pollinator groups or subgroups if necessary
Species inventory complementary	Increases diversity and overall representativeness	Species that are most complementary to the ones in existing protected areas, thus ensuring that no species is left behind. Relevant and cost-efficient especially if the number of targeted KPAs is limited.

Note: Using the proportion of already legally protected pollinators in Annex IV of the Habitats Directive as a criterion is not possible simply because pollinator groups have not been considered at all in the Annexes of the Habitats Directive (bees, hoverflies) or are only to a very limited part covered (butterflies, moths).

2.3.4 Criteria based on resource availability in an area (indirect approach)

Table 2. Criteria for KPA identification based on resource availability in an area (indirect approach)

Resource availability criteria	Description	Identification
Habitat type	Important habitat types for pollinators e.g. calcareous grasslands	Existing lists of important habitat types of HD-guidelines, typical pollinator species of Annex I habitats (Ssymank et al. 2021, 2022), projects such as HabCon, PollHab
Floral resources	Areas with a high nectar/pollen availability through floral resources	Flower richness, important foraging resources, presence of all major flower types, considering number and spectrum of flowering peaks/ flowering periods
Larvae host-plant resources	Availability of host plants, many larvae depend on a specific host plant species	Distribution of specific plant species or plant species groups
Other feeding resources	Resources for saprophagous species e.g. dead wood, Resources for zoophagous species e.g. aphids; Resources for aquatic saprophagous species	General diversity, diverse and small-scale landscape matrix
Taxa-specific resources	Some members of the butterfly family Lycaenidae or hoverflies of the genus *Microdon* feed on ant brood and are therefore dependent of the presence of specific ant species, other hoverfly species are myrmecophilous feeding on ant-tended root-aphids	Distribution/ presence of associated ant species in certain habitats
Nesting resources, other larval resources	Nesting habitats can differ to foraging habitats, microhabitat occurrence, microhabitat diversity and density for larvae	Presence of vertical walls, bare ground, woody structures for bees; Dead wood, sap runs or small waterbodies for hoverflies
Resources for trait-based multispecies groups	Management or conservation measures adapted to species with similar traits, e.g. conservation of specific feeding resources	Assemblages of species with similar traits, e.g. specialisation on same group of host plants

Resource availability criteria	Description	Identification
Resource/structure complementarity	With the aim to increase species diversity	Resources, structures, habitats that are complementary to the ones in existing protected areas
Ecotones and landscape mosaics	With the aim to increase pollinator diversity, both as orientation and migration corridors as well as for pollinator species linked to double habitat requirements with larval feeding resources in the forest and flower resources in the forest margin and adjacent open habitats	Structure of forest borders, length and width of contact lines, landscape indices etc. Several important habitat complexes will be described in the EUNIS revision of habitat complexes (due in 2026).

2.3.5 Schematic Overview of criteria

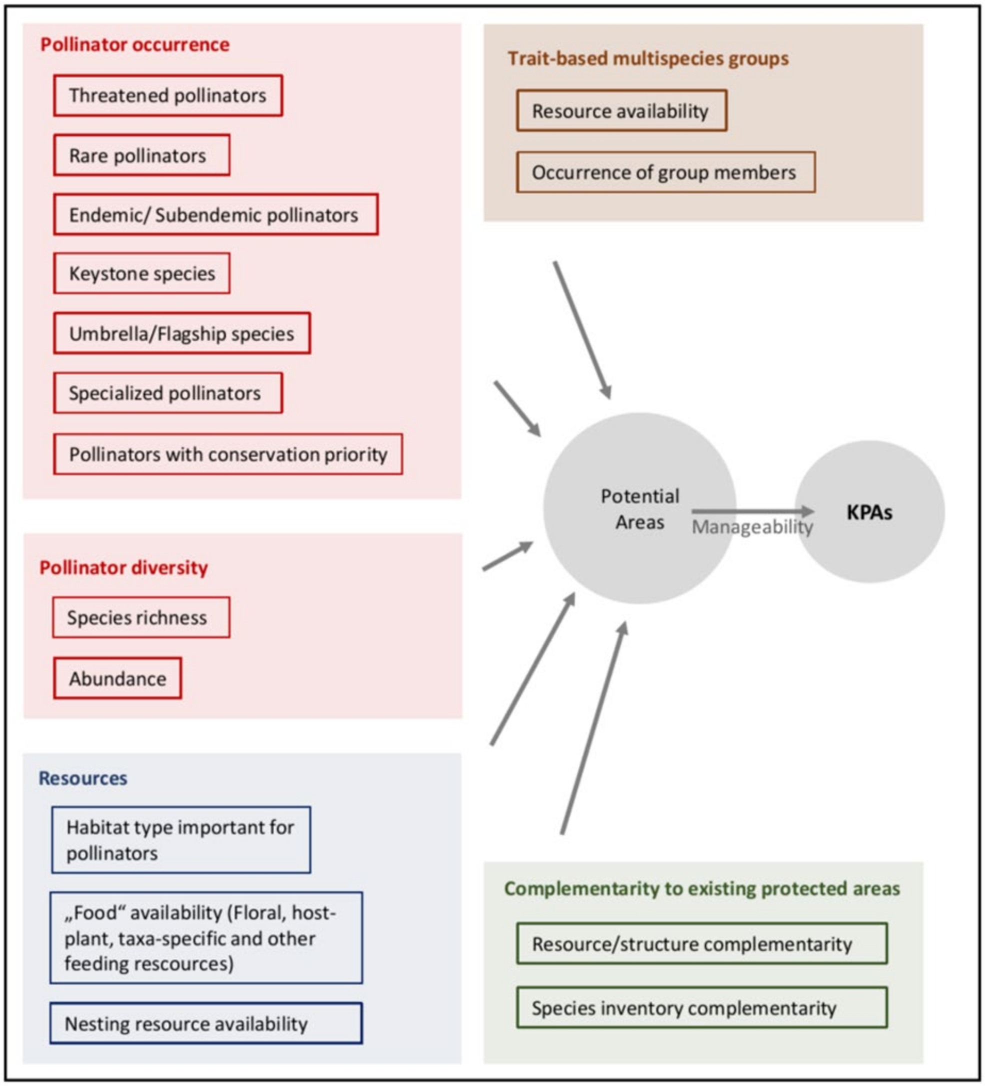

Figure 1. Schematic overview of criteria that can be used to identify KPAs.

2.3.6 Recommendations and challenges for KPA mapping

KPAs should specifically address protection gaps for pollinators, extending beyond the current Natura 2000 network and other protected areas. Natura 2000 provides a valuable starting point but is insufficient in offering targeted protection for pollinators. It is essential to incorporate local-level knowledge and site-specific data to identify areas of high potential importance that are currently outside established protection networks. There are challenges in determining whether to maintain existing ecosystems or to actively manage and restore degraded areas in order to achieve satisfactory pollinator levels. It is also necessary to assess the extent to which restoration is required and whether it should be prioritised.

To achieve this, it is crucial to carefully design the process following these steps:

- Identify the appropriate data sources,
- Determine how the maps will be produced,
- Prioritise which areas should be addressed first,
- Define key focus areas and understand the pressures impacting them,
- Develop approaches to address these pressures effectively.

This process must result in a concrete and practical tool to support decision-making for pollinator restoration and protection at both national and transnational levels.

Suggested roadmap for KPA-mapping:

(based on Settele et al. 2025)

Prior to identifying and mapping KPAs, it is important to clarify the goals of conservation efforts. The focus could be on pollination function, specific species, or habitats (including intermediate or transitional ones). Attention must also be given to the role of both temporary and permanent habitats, with complementarity across landscapes being a critical principle for effective planning. Emphasis should also be placed on red-listed species and the use of habitat maps as key inputs for identifying KPAs. However, it is recommended to avoid focusing on rare species solely, as this could misdirect limited resources. Instead, species with higher abundance and faster recovery potential should also be considered to maximise restoration impact, and to balance species conservation with ecosystem service delivery. There is also a high need to incorporate risk assessment and future scenarios to account for potential changes and threats to pollinator habitats or emerging options.

Throughout the process, an active involvement of Member States is necessary to ensure their engagement, validation, and ownership. As this is a top-down initiative, securing national-level participation is essential for successful implementation. The selection and delineation of KPAs must carefully consider sampling methods and spatial resolution to avoid bias and ensure reliable outcomes. In this context, care should be taken to ensure that single Member States do not have to bear a large share of the responsibility due to their higher diversity in species or many endemic species. Instead, all Member States should contribute to the establishment of a coherent KPA network with a defined minimum target for every Member State. However, based on scientific grounds KPA density will differ among Member States.

For data collection**,** a hybrid approach for generating input data for the KPA scoping is suggested. Accurate atlas data should be used if available. If observational data is scarce, biased or outdated, Species Distribution Models (SDMs) and/or expert-based approaches, e.g. based on availability of habitat and other resources, would be preferable. Algorithmic selection methods are recommended to support data-driven decision-making.

For KPA mapping, a blended modelling approach is recommended depending on the specific data situation, combining:

- SDMs,
- Species richness and abundance estimates,
- Occupancy models,
- Opportunistic data from citizen science and expert networks,
- Continuous integration of climate and land-use pressures.

A structured, systematic approach to conservation mapping is necessary. Species-level data is often the starting point for identifying KPAs. However, challenges remain for data-deficient species and regions. For these species, the focus should extend to habitat-level assessments. For example, threatened and rare species are often associated with specialised or rare habitats and can be addressed through their habitat preferences.

Member States should be encouraged to conduct their own KPA-studies and to specifically address knowledge gaps with targeted mapping and monitoring programs, which will allow the refinement of future KPA selection.

For mapping of KPAs, the use of both threshold-based and complementarity-based approaches is suggested. Both could be also used in parallel, as in KBAs that use irreplaceability analysis as criterion E and threshold-based criteria (A-D). In particular, the principle of complementarity is important to ensure overall species richness and habitat diversity are adequately captured.

When establishing criteria for mapping KPAs, general guidelines on setting thresholds should be provided, rather than prescriptive and universally applied thresholds for all taxa and countries. For example, in the Netherlands, thresholds for IBMAs were defined at a level that ensures that a reasonable number of sites are identified and that sites are well distributed across the country. This approach not only supports conservation objectives, but also ensures that people throughout the country have access to and can benefit from natural areas.

For identifying and prioritising KPAs, a tiered approach focusing on both the quality and prioritisation of areas is suggested. In some cases, or for certain species groups, historical importance may be less relevant than an area's potential to support pollinators. This potential is determined not only by current degradation levels but also by the feasibility and cost of ecological restoration. Historical continuity plays an important role for less mobile pollinators, both in ancient forests (for example, saproxylic groups of hoverflies) and in many open habitats. In such cases, recolonization is slow or may even be impossible due to the absence of viable source populations within the surrounding intensively managed landscape. This makes historical continuity particularly important in landscapes with a low coverage of (semi)natural biotopes and habitats. Taxon-specific factors also need to be considered. For example, the area of habitat is more important than connectivity for butterflies. In general, prioritisation and restoration plans should be dynamic and adaptable, recognising that KPAs may change over time in response to ecological shifts and landscape dynamics.

Ranking sites can support prioritisations and may assist Member States in coordinating their strategies to safeguard pollinators, planning conservation measures at site level, and determining the appropriate form of legal protection for these areas. It is advisable to apply a range of thresholds that can subsequently be used to rank sites. For example, Category 1 would include the sites identified using the most stringent thresholds, Category 2; those using less stringent thresholds, and so on. This approach would generate not only a map of sites and the criteria that trigger their designation, but also a clear ranking of their relative importance. Areas classified as being of 'good habitat quality' should provide a diverse range of flowering plants, suitable nesting opportunities, and adequate microhabitat diversity and density for pollinator larvae. However, KPAs may take various forms, including areas currently in good condition, areas with high restoration potential, and even urban environments. Restoration areas could contribute to the objectives set out under the NRR and would consequently fall under the legal requirement of non-deterioration of restored areas.

When KPAs are identified based on models and expert opinion, rather than extensive field data, ground-truthing of proposed KPAs is essential. It must be confirmed whether these areas actually host the species that trigger KPA status, and their habitat condition should be assessed to determine whether and which restoration measures are required. This could be carried out, among other approaches, through large-scale nature conservation projects at national or regional level, with EU co-funding where applicable, such as the L'Instrument Financier pour l'Environnement (LIFE) Programme and through citizen science initiatives.

This roadmap describes the process of KPA mapping but it remains unclear what will happen to the sites once they are designated - either as protected areas or simply as mapped locations for planning purposes without formal legal status. The number of KPAs identified will largely depend on the level of ambition of each Member State. While KPAs may be crucial for safeguarding pollinators, broader country-wide measures beyond the KPAs will be necessary to halt and reverse pollinator decline.

2.4 State of knowledge for criteria assessment

2.4.1 General overview

Europe supports a rich diversity of wild pollinators, including an estimated 2,051 species of bees, 482 species of butterflies, nearly 1,000 species of hoverflies, and thousands of species of moths, flies, wasps, beetles, and other insects (Potts et al. 2024). There is well established evidence that many European pollinator species are in decline and require targeted pollinator-friendly conservation measures both within and beyond protected areas.

2.4.2 Data availability

Data availability differs among taxa, as does the level of knowledge on Red List status, trends, taxonomy and ecology (Table 3). Red Lists for the four key pollinator taxa are currently available, or will soon be, at the EU level. At the national level up-to-date Red Lists are mainly available for north-western countries but remain scarce in southern Europe. Some distribution data are also available. In addition, monitoring schemes for butterflies have been established in many European countries, with over 10 countries participating in the Assessing Butterflies in Europe (ABLE) project, covering all 27 EU Member States. Similar schemes for the three other key pollinator taxa are expected to be implemented soon. Model-based estimates of pollinator species ranges across Europe, such as those derived from species distribution modelling, will also soon be made publicly available through the NaturaConnect project[1] and the PollHab project[2].

However, significant gaps exist in many Member States. While continental-scale data for bees are generally sufficient, substantial gaps exist at regional and local levels, particularly in southern Europe. National species lists and habitat quality assessments urgently require updating and further development. The absence of national Red Lists for bees, in particular, limits the ability to accurately prioritise species and habitats. Substantial data gaps also exist for hoverflies and moths, both at regional and national scale and typical pollinator species for several rare Annex I habitats of the HD remain unknown (for example in Germany Ssymank et al. 2021, 2022) and require additional targeted research and monitoring.

Citizen science initiatives (e.g. European Butterfly Monitoring Scheme (eBMS)) involving contributions from expert volunteers are valuable for filling data gaps. Ground-truthing and validation with national experts and local stakeholders are essential to ensure the reliability of the data.

Data sources for the identification of KPAs:

- Monitoring data (e.g. eBMS),
- European and National Red Lists,
- Orbit,
- Taxo-Fly,
- Citizen Science projects (e.g. iNaturalist, Observation.org or iSpotnature.org are operating at a global level, integrating data from many national and even regional Citizen Science projects (e.g. Bioblitz)),
- Utilisation of specimens from museum collections,
- Databases (often national/ regional solutions, e.g. NDFF in the Netherlands, in Germany often on the federal state level, EU-wide solutions are urgently needed),
- Scientific (peer-reviewed) literature,
- Species listed in the Habitats Directive and Bern Convention (butterflies and moths only): include range, distribution and population data from sites in standard data forms and from Art. 17 HD reporting,
- For host and floral plants, standardised vegetation surveys from the European Vegetation Archive (EVA) https://euroveg.org/eva-database/databases (access can be requested) as well as national floristic mapping schemes and atlases,
- Other global, tangential databases with broad pollinator relevance, such as a project on a crop pollination database (CropPol) (Allen-Perkins et al. 2022).

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[1] https://cordis.europa.eu/project/id/101060429

[2] https://www.bc-europe.eu/webpage.php?name=pollhab

Important databases for distribution data:

- European database of plant pollinator networks (EuPPollNet, Lanuza et al. 2025). This work spans 23 European countries and includes data on 34% of the European species of bees, 26% of butterflies and 33% of hoverflies. However, the number of species and plant pollinator relations is still very limited and only covers a small percentage of published or known data,
- National and expert databases (sometimes with limited access),
- IUCN Hoverfly Specialist Group, Red List data (where available),
- Joint database and results of SAFEGUARD; ORBIT and TaxoFly (Database publication in preparation) for bees and hoverflies with an expected species coverage of well over 90% for both groups,
- Planned release of high-resolution modelled species distribution data for all insects with sufficient coverage (from NaturaConnect),
- Estimated distribution of EUNIS habitat types at high resolution (100m) across Europe from NaturaConnect (Si-Moussi et al. 2025),
- Vegetation-based EUNIS maps (Chytry et al. 2020) and maps of Potential Natural Vegetation of Europe (Jung 2025),
- Museum collections (only a small proportion are digitised, but a lot of work is currently being done on this).

Table 3. *Overview of the knowledge and data availability for the four pollinator taxa.*

	Wild Bees	**Hoverflies**	**Butterflies**	**Moths**
EU Red List	Michez et al. 2026	Vujic et al. 2023	Van Swaay et al. 2025	In preparation
National Red Lists (L, M, H)	L	L	H (33 of 42 European countries)	L
Taxonomic Knowledge, European Pollinator Identification Coursed (EPIC)	M-H (Orbit) EPIC-bee	M-H (Taxo-Fly) EPIC-hoverfly	H EPIC-butterfly	L
Distribution/Data	M	M	H	L
Main pollinating species	M	M	L	L-M
Habitat knowledge (adults)	M	M	H	M
Habitats Larvae	M	M	H	M

State of knowledge: L: Low, M: Medium (with regionally high differences), H: High

2.4.3 Wild bees

The 2026 update of the IUCN European Red List of Bees (Michez et al. 2026) categorises 10.4% of the assessed species (1,928 species) as threatened (1.3% Critically Endangered (CR), 4.7% Endangered (EN), 2.9% Vulnerable (VU)), having an elevated risk of extinction in the near future, and 9.4% are assessed as Near Threatened (NT). Additionally, 14% of the species are classified as data deficient and could not be assessed. Depending on the treatment of these species, the proportion of threatened species ranges from 8.9% to 23.3%. Other national Red Lists in Europe indicate up to 40% of invertebrate pollinator species, especially bees and butterflies, are threatened (IPBES, 2016). The newly released Red List is accompanied by a planning document (A2P, Reverté et al. 2026) that recommends conservation actions for the threatened European bee species.

2.4.4 Hoverflies

The latest EU Red List of hoverflies (Vujic et al. 2023) shows that, of approximately 890 assessed European species, 36.4% are threatened; 5% CR, 23.3% EN, and 8.1% VU, with an additional approximately 8% classified as NT. This means that just over half of all EU hoverfly species, 51.6% are considered of Least Concern (LC) (51.6%). In addition to a full analysis of threats according to IUCN criteria, the Red List is complemented with an extended analysis of traits and species groups, as well as recommended management actions to address their threats. This information can be used for comprehensive multi-species management and planning, covering most threatened species, rather than relying on single-species action plans (A2P document, Lees et al. 2022). The IUCN Hoverfly Specialist Group supports this work and can provide guidance on various aspects of hoverfly conservation, including the improvement of national restoration plans.

2.4.5 Butterflies

Butterflies are well-known and represent the best sampled taxa of pollinators. They have a long history of sampling and good data availability for European countries such as the UK, the Netherlands and Switzerland, with more recent expansion to other European countries. The most recent Red List of Butterflies of continental Europe shows that 50% of butterfly species have declining populations (excluding data deficient species), and 15% are classified as threatened (van Swaay et al. 2025). National Red Lists for butterflies indicate that, on average, 27% of butterfly species are considered threatened across the 24 EU countries with Red Lists at the time of the study (Maes et al. 2019). There is, however, considerable variation between countries, ranging from a low proportion of threatened species in the Mediterranean- only 3% in Spain and 6% in Italy - to much higher percentages in north-western Europe, with 55% in the Netherlands and 49% in Belgium. The IUCN SSC Butterfly and Moth Specialist Group contribute to the conservation assessment of butterflies and large monitoring efforts through the eBMS and its expansion through the ABLE project[3] help to track those changes constantly.

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[3] https://www.bc-europe.eu/webpage.php?name=able-project

2.4.6 Moths

Less information is generally available on the trends for moths, although studies suggest similar declines in abundance as in butterflies. One national study in Britain found that the population of the common garden tiger moth *Arctia caja* had decreased between 1968 and 1999 (Conrad et al. 2006). However, recent evidence suggests that moth biomass may be fluctuating without a clear trend, implying that a few species might doing well (Macgregor et al. 2019). There is no current European Red List for moths and there are huge differences in knowledge regarding Red List status, trends, taxonomy and ecology between macro- and microlepidoptera, with substantial knowledge gaps for microlepidoptera. The IUCN SSC Butterfly and Moth Specialist Group is involved in the assessment and conservation of these species.

3 Preliminary draft criteria and methods to identify Buzz Lines

3.1 Why do we need Buzz Lines?

- Landscape fragmentation is a severe problem affecting the dispersal of many pollinator species with negative impacts on their populations, disrupting ecological food webs (Albrecht et al. 2014).
- Buzz Lines aim to connect Key Pollinator Areas (KPAs) for long-distance dispersing pollinators such as Syrphidae and Lepidoptera species and support important long-distance dispersal events for all pollinator species.
- Long-distance connectivity is critically important, as mass migrations of pollinating insects are rapidly declining; largely due to inadequate nectar resources along migration routes, pesticide exposure, and reduced population densities (Gatter et al. 1990, Reynolds et al. 2024).
- Many pollinator species are expected to shift their geographic distributions in response to climate change, for example, by expanding their northern range limits or by moving to higher altitudes. Successful dispersal and colonisation of new habitats depend on adequate habitat structures and habitat quality as well as landscape connectivity.
- Buzz Lines also aim to sufficiently connect habitats on a small scale and make them accessible for recolonisation, which is particularly important for pollinators that require habitat mosaics, distinct habitat complexes, or metapopulation dynamics characterised by fluctuating subpopulations.
- Buzz Lines will facilitate metapopulation structures and connect imaginal and larval habitats for complete life cycles of pollinators.
- Pollinators with limited mobility are especially dependent on small-scale habitat connectivity, typically within spatial ranges of several hundred metres to two kilometres.
- Due to the positive correlation between pollinator size and foraging distance, small species in particular could be affected by habitat isolation (Steffan-Dewenter & Tscharntke 1999).
- Habitat corridors that connect otherwise isolated habitat patches positively affect the pollen transfer between these patches, as shown both for bee and butterfly species (Townsend & Levey 2005).
- Buzz Lines can maximise pollination services in agricultural ecosystems and other surrounding areas.
- Healthier and connected pollinator species populations are directly linked to sustainable agricultural productivity.
- Independent of the scale, it should be noted that even green infrastructure is not to be equated with continuity in landscape connection for pollinators. For example, forests or high hedges (>3m) can also represent uncrossable obstacles for butterflies, which can lead to a change in their flight direction (Cant et al. 2005). The same is true for natural landscape features such as water bodies or mountain ranges (Schleimer & Frantz 2025). Buzz Lines must therefore be carefully designed to meet the ecological and behavioural needs of pollinator species.

3.1.1 Proposed definition and aims of Buzz Lines

The definition of ‘Buzz Lines’ is proposed as landscape elements or structures that provide spatial and functional habitat continuity between KPAs, while also reducing local habitat fragmentation within KPAs. Buzz Lines form a landscape network of linear structures, habitat mosaics and stepping stones that enable pollinators to move between habitats and landscapes. In doing so, they help to strengthen ecological connectivity and enhance pollination services in surrounding local areas.

Buzz Lines must address connectivity on two different spatial levels:

1. Long distance connectivity supporting migration, range shifts, long-distance genetic transfer, and pollen transport and/or,

2. Regional to local habitat connectivity, which is important for pollinator species that depend on habitat mosaics, or exhibit metapopulation dynamics with fluctuating sub-populations.

3.1.2 Buzz Lines within and outside protected areas

The Natura 2000 network provides a valuable starting point for nature conservation but is currently insufficient in offering targeted protection for pollinators, partly because key pollinator taxa as bees and hoverflies are not listed in the annexes of the Habitats Directive (92/43/EEC). Additionally, within protected areas, including the Natura 2000 Network, habitat connectivity at the site to local levels is often inadequate. Management and restoration practices in the framework of Buzz Lines should therefore be adapted to enhance small-scale habitat connectivity. While high-value Annex I habitat patches may be partially preserved, the surrounding 'white spots'-areas, are often not integrated into conservation planning and are frequently overlooked. This gap is critical, as many fragmented pollinator populations within these patches are declining due to habitat degradation and the loss of key species. In some cases, populations have already dropped below minimum viable levels, compromising the stability of wider metapopulations. Integrating targeted habitat restoration and pollinator-friendly management within Natura 2000 sites can significantly enhance connectivity between suitable habitats, thereby supporting the recovery and long-term viability of pollinator populations.

Relation to other planning of habitat/ biotope connectivity:

- Habitats and Bird Directives (92/43/EEC and 2009/147/EC, for example Art. 3 and 10 of the HD on habitat connectivity or habitat connectivity for migratory birds),
- Habitat Condition Guideline for the assessment of Structures and Functions Parameter of Habitats (Annex I HD) including typical (pollinator) species (European Commission 2025),
- Establish a coherent Trans-European Nature Network as set out in the EU Biodiversity Strategy for 2030,
- Expansion of the current network of protected areas should encompass habitats critical for viable pollinator populations, contributing to the EU Biodiversity Strategy for 2030 target of legally protecting a minimum of 30% of the EU’s land area and strictly protecting at least 10% of the EU’s protected areas. Nature Restoration Regulation (NRR): Restoration is required both to achieve the necessary area to meet Favourable Reference Area (FRA) for habitats and

to restore existing habitats to good condition, as well as to comply with regulations for individual species,

- Initiatives/ existing guidelines on habitat connectivity, for example Kettunen-Andrew et al. (2007),
- National biotope connectivity planning – examples and legal national regulations,
- Large-scale existing habitat connectivity and planning – such as European Green Belt (Wang and Svenning 2025), river valley restorations or national programmes to promote habitat connectivity as in Germany (Fuchs et al. 2010),
- Additional criteria to assess suitability of existing biotope connectivity concepts as contributing to Buzz Lines,
- Management adapted to the needs of insects/pollinators,
- Network of temporal habitats of high quality (e.g. species-rich perennial flower strips),
- Measures in agricultural areas, permeability of agricultural ecosystems,
- Links to the EU's Common Agricultural Policy (CAP) Strategic Plans.

3.1.3 Implementation and management of Buzz Lines:

- Reduction of threats to pollinator connectivity at all scales - creation of new habitats,
- Restoration of existing habitats not in good condition,
- Conservation of existing habitats, especially of flower-rich and plant species-rich habitats,
- Conservation of ecotones and zonations, for example restoration of linear structures like forest margins (natural and seminatural), riverbanks with adjacent alluvial plains (EUNIS habitat complexes revision in preparation),
- Facilitation of an increased permeability of the landscape,
- Securing a high density of stepping stones,
- Pollinator populations should be supported by decreasing pressures (e.g. pesticides, nitrogen deposition, land abandonment, agricultural intensification, etc),
- Measures regarding land management should be taken at different spatial scales driving local/regional/national/EU decision-making processes.

3.2 Focus on key pollinator groups and the essential background on the ecology/ biology for Buzz Lines

3.2.1 General overview

	Wild Bees	Hoverflies	Butterflies	Moths
Species number in Europe	ca. 2,000	ca. 1,000	ca. 500	ca. 10,000
Common flight distances of non-migratory species (usual foraging distances)	Typically, 100-200m, larger species up to 2km	Typically, 100 m-500m, up to 2km	Very diverse, from <100m to several kilometres	As far as known: Very diverse, from <100m to several kilometres
Flight distances for dispersal (dispersal capacities)	Maximum foraging distance six to seven times larger than mean foraging distances. Larger bees have disproportionately larger foraging distances than smaller bees.	Typically, 20-50km (100km) for zoophagous groups	On average a few hundred metres, up to >10km	On average a few hundred metres, up to >10km
Maximum migration distances for migratory species	L	More than 2,500 km for migratory species	More than 5,000 km for *Vanessa cardui*, migrating between Africa (Atlas Mountains) and Europe	More than 1,000 km for migratory species
Migratory behaviour knowledge	L	M	M	L
Medium distance dispersal (number of species, proportion)	L	ca. 40% of species (mainly zoophagous groups)	L	L
Number of species with long distance directed migration	None	ca. 40 species (3-4%)	Few species	Few species

	Wild Bees	**Hoverflies**	**Butterflies**	**Moths**
Pollen use	Collection for larval food	Males & female adults (egg ripening)	Feed on nectar, carry pollen unintentionally	Feed on nectar, but also carry pollen and are partly important pollinators
Nectar use	Adults and larvae	Adults	Adults	Adults
Flower visiting preferences	M	M	M	M
Other reasons for migration/ dispersal	Response to climate change	Larval prey, Overwintering, Response to climate change	Overwintering	L
Different habitat requirements for adults and larvae with spatially interconnected habitats/ habitat mosaics	Nesting and food resources within a habitat or habitat mosaic; only larger sized bees can effectively use food habitats in larger distance	Majority of all species: Especially groups with zoophagous, aquatic and terrestrial saprophagous larvae, partially also for phytophagous larvae	True for most species	L; might be the case for most species

State of knowledge: L: Low; M: Medium

3.2.2 Wild bees

Bees are central place foragers, meaning their nesting and foraging habitats are spatially separated, and they return to their nest multiple times a day to provision their brood cells. In general, bees depend highly on flower-rich habitats with diverse nesting structures. Bee species vary in their associations with nesting-habitat attributes (ground-nesting bees: e.g. soil type, compaction, slope, ground surface features; aboveground-nesting bees: e.g. cavities, dead wood, vertical stems) and the majority are ground-nesting bees. Different bee species show different flower choice behaviours (specialisations for different taxonomic groups of plants) and collect large amounts of pollen for larval development. Larval provision consists of pollen and nectar, whereas adults mainly consume nectar as an energy supply.

Nesting and foraging resources can be within a habitat complex or habitat mosaics. Bees are mobile and able to move between different habitats within achievable flight distances. Foraging areas can shift depending on flower availability within a bee's lifetime. In particular, species with narrow diet or nesting preferences have obligate requirements on the habitat structures. Species with long flight periods (social, bivoltine) depend on continuous floral aspects in their foraging area.

The distance between nesting and foraging sites largely determines the bees' reproductive success; the further apart the sites are, the higher energetic and reproductive costs. Most bee species have short foraging distances (100-200m) to effectively provision offspring with sufficient food. The proximity to floral resources can vary among species, with larger species such as bumblebees having longer foraging distances (2 km). Maximum foraging distances are six to seven times larger than mean foraging distances. Larger bees have disproportionately larger foraging distances than smaller bees.

Habitat connectivity is important for bees to allow them to switch between complementary habitat types to avoid temporary declines in feeding sources. It has also been shown that bee communities can recover from disturbance events if a stable community is present in the surrounding area. Small habitat patches can be important as refuge habitats (for example, following mowing or grazing events) or as stepping stones, enabling bees to disperse through an otherwise unsuitable landscape matrix. In response to climate change, many bee species shift their northern boundary. Adequate habitats and connectivity are important to facilitate successful dispersal along a temperature gradient.

Important landscape elements for bees are:

- Flower-rich meadows, extensively managed grassland (e.g. calcareous grasslands), areas with ruderal vegetation,
- Woody structures (woodland edges, hedges, dead wood, single trees) as nesting resources for cavity-nesting bees; flowering trees and shrubs as main feeding sources in spring. Woodland edges can buffer unfavourable temperature peaks. However, the importance of woody landscape elements for bees varies, e.g. forests can also function as barriers that obstruct the movement and dispersal of bees,
- Field margins and roadsides can act as corridors that enhance species mobility but are often highly degraded. Extensively managed edge structures and dirt paths are important bee habitats,

- Embankments close to rivers or roads: flowering vegetation along rivers are important foraging habitats and often provide nesting structures,
- Vertical earth banks or clay walls are important nesting sites for ground-nesting bees,
- Permanent and perennial landscape elements are particularly important as nesting sites,
- Species-rich perennial flower strips on arable land can provide additional food resources and can function as connecting corridors and stepping stones, and
- Structure-rich agricultural landscapes.

3.2.3 Hoverflies

Hoverflies are flower visitors that feed on both nectar and pollen, the latter is needed for egg-ripening and to guarantee offspring. They are highly dependent on flower-rich habitats, with a variety of flowers depending on type, colour, height, and in some species specialisations on different taxonomic groups of plants. Larval resources vary greatly in hoverflies, ranging from phytophagous, fungivorous, zoophagous, terrestrial, and aquatic saprophagous to commensals and parasites in Hymenopteran nests (Lees et al. 2022, Rotheray & Gilbert 2011). Additionally, the availability of suitable larval habitat has a strong influence on hoverfly species richness (Speight & Castella 2024).

The mobility of hoverflies between different resources varies from 10 to 20 metres around an ant nest, and regular flight distances of 50 to 200 metres for many localised species, to hundreds of kilometres for dismigration flights and to several thousand kilometres for a few true long-distance migratory species (Gatter et al. 1990, Reynolds et al. 2024, Wotton et al. 2019). Landscape mosaic or heterogeneity, connectivity of habitats, and microhabitat presence are important for hoverfly species richness and abundance. Localised species tend to be linked to very specific habitats or microhabitats (Ssymank 1991, 2001, 2002, 2003).

Habitat connectivity is crucial for hoverflies because adults and larvae require different resources to complete their life cycle and maintain viable populations (Ssymank 1991, 1993). Larval habitats must occur within the typical flight range of adult foraging sites, particularly areas with abundant floral resources. In addition, adults often move between habitats on a daily basis to fulfil different behavioural needs, including seeking shelter, roosting overnight, visiting flowers, mating, or egg-laying. Species with aphidophagous larvae and those possessing greater migratory capacities are generally able to tolerate higher levels of disturbance and habitat fragmentation than highly localised species with small populations. Habitat connectivity is also particularly important for specialists living near their thermal limits: Under ongoing climate warming, specialists of cold environments, such as periglacial fields, may need to shift to higher altitudes. Conversely, specialists of xeric grasslands or other hot, open habitats may rely on adjacent forests or woodland edges as refuges during the hottest parts of the day.

Additionally, landscape patches with high flower densities can serve as important “refuelling” sites for more mobile migratory species, enabling them to replenish energy reserves during longer movements across the landscape.

Important landscape elements and microhabitats for hoverflies are:

- Flower and species-rich habitats in combination with larval habitats: species-rich grasslands, forest and water-fringe vegetation (both running and standing water), tall herb stands, zonation and habitat mosaics especially with woody vegetation,
- Larval habitats for saproxylic species such as trunk cavities, rot holes in the canopy, root holes especially in living trees (habitat or biotope trees), sap runs (specific larval habitat for several genera), standing and lying dead wood of larger dimensions, waterlogged deadwood (trees laying partially in water) in riverbanks,
- Larval habitats for species associated with ant nests (ant nest density, specific ant species), both for zoophagous larvae living on ant brood (*Microdon*), as well as for species with root aphid-eating larvae (*Philhelius*, *Chrysotoxum*, *Doros* etc.),
- Larval habitats for zoophagous species living mainly on scale insects, from species with a broad range of prey to more specialised species, for example only living in aphid galls on a single plant species,
- Larval habitats for phytophagous species with high plant species richness (genus *Cheilosia* mainly in central and northern Europe), and particularly in southern Europe for genera *Merodon* and *Eumerus*; a diversity of bulb plants, plants with rhizomes, and a limited number of species in rosettes, leaves, or other aboveground plant organs usually specialised monophagous or in a group of related plant species, and fungi in forests,
- Plant population and patch size is important for many species. Especially mono- to oligophagous hoverfly species and hoverflies with phytophagous species need a certain minimum size of the food plant population to be able to colonize it and to build up viable hoverfly populations,
- Larval habitats for aquatic larvae: shallow water zones, banks or riparian zones with emergent plant vegetation, various types of water bodies from tiny microhabitats (Phytotelmata) or waterholes in wetlands, to alluvial locations, ponds and lakes, across the whole range from dystrophic, oligo-, meso- to eutrophic waterbodies,
- Provide a broad range of different flower types and colours that can be used by different hoverfly species according to their adult flower preferences,
- Extended flowering phenology with abundant flower resources also in late summer and autumn,
- Climate change has significant effects on hoverfly populations and range shifts as well as changes in altitudinal distribution, including modifications in life cycle (number of possible generations per year, northern limit of adult overwintering for some species). Indirect effects on hoverfly populations and their distribution will occur due to plant composition changes and in consequence also changes in flower availability,
- For migratory hoverflies migration routes and especially bottle necks such as certain mountain passes (for example Col du Bretolet between Switzerland and France, Randecker Maar in Germany) are crucial for long distance connectivity.

Details on species groups for actions to restore hoverfly populations or conserve hoverflies can be found in the IUCN A2P document for the EU Red List of Hoverflies (Lees et al. 2022). Many of the currently described EUNIS habitat complexes (revision under way by EEA and ETC BE) are of specific importance for hoverflies and other pollinator groups.

3.2.4 Butterflies

Butterflies inhabit many diverse terrestrial habitats but show a strong association with open and semi-open landscape types, such as (calcareous) grasslands, heaths, scrubs, and mires. Many species benefit from diverse, small-scale landscape mosaics and extensively managed habitats, which provide a combination of nectar resources, larval host plants, and suitable microclimatic conditions (Bottero et al. 2023). In general, habitat quality and habitat size appear to be the most important factors for butterfly populations (Radchuk et al. 2012), underlining the need to support large and high-quality habitats such as Key Pollinator Areas. Most adult butterflies are polylectic nectar feeders, with some oligolectic exceptions, whereas larvae are generally herbivorous and often highly host-specific, depending on a limited number of larval food plants. As larval mobility is very limited, dispersal possibilities in butterflies are mainly dependent on the adult stage. Approximately 75% of butterfly species persist in predominantly closed populations, with dispersal often insufficient to fully compensate for habitat fragmentation (Thomas 1984). As habitat fragmentation reduces species richness and abundance, and alters foraging behaviour; it is important to support habitat connectivity and provide corridors for dispersal (Zschokke et al. 2000).

The influence of the landscape matrix on butterfly assemblages typically operates at spatial scales of several hundred metres to a few kilometres. Bergman et al. (2004) suggested that an area within a radius of approximately five kilometres is most appropriate for assessing landscape effects on butterfly communities. Species that are vagrant, widely distributed, or multivoltine and overwinter as pupae or adults tend to be less vulnerable to fragmentation (Essens et al. 2017). The colonisation of new habitat patches depends primarily on the isolation of source populations and on the number of individuals at the initial site (Simcox et al. 2025). Corridors with high habitat quality support population persistence and are particularly important for specialist species, which have more specific habitat requirements (Habel et al. 2020). In general, habitat connectivity has shown to have exceptionally positive effects on ecologically specialised, sedentary, and endangered butterfly species (Habel et al. 2021). These corridors providing habitat connectivity do not necessarily have to be continuous, but can also represent stepping stones between suitable habitats (Dover & Settele 2009). Even urban and peri-urban green spaces can contribute to habitat networks and act as refugia or corridors, provided that the urban matrix is managed to maintain sufficient permeability (Ancillotto et al. 2024).

The effectiveness of habitat connectivity strongly depends on the landscape elements within the matrix and species-specific habitat associations. For many open landscape butterflies landscape elements such as small forest patches or hedgerows taller than three metres can represent barriers (Cant et al. 2005) and forests, high hedges, water bodies, and mountain ranges may induce flight direction changes or boundary avoidance behaviour (Cant et al. 2005; Schleimer & Frantz 2025). Therefore, woodland-dominated matrices generally restrict dispersal more than open or mixed terrain (Nowicki et al. 2014, Simcox et al. 2025), with butterflies frequently performing U-turns at habitat boundaries, whereas boundary crossings occur more often in continuous habitat networks (Schtickzelle & Baguette 2003, Franzen et al. 2024). In this context, linear open landscape structures, including field margin strips and grassy banks have proven effective as connectivity features for butterflies (Sutcliffe et al. 2003; Threadgill et al. 2021). This is especially true for generalist species, while specialists are less likely to leave corridors and enter unsuitable matrix habitats, reflecting their narrower ecological tolerances (Dover & Settele 2009; Habel et al. 2020). While many butterflies are associated with open habitats, some species occupy forest environments, with many of them being gap-system colonisers, inhabiting forest edges, clear-cuts, fire breaks, or transmission line corridors and some few canopy species. These transmission line corridors can provide important habitats for both early and late-successional species and may connect open habitats without negatively affecting forest-associated butterflies (Oki et al. 2021).

Dispersal capacity in butterflies is dynamic and can change over time, even within species. Larger species generally show higher dispersal abilities (Sekar 2012) and individuals from the edge of the species distribution have shown a higher capacity and motivation to disperse, improving their chances of finding new habitat patches (Dederichs et al. 2024). Further, rapid evolutionary shifts towards increased mobility have been documented for *Phengaris arion* generations in the UK (Simcox et al. 2025), suggesting some flexibility in adapting to landscape changes. For their dispersal, both visual and olfactory cues play a role in guiding their movement towards suitable habitats (Öckinger & van Dyck 2012), which should be accounted for in the design of connecting corridors.

Climate change further increases the importance of habitat connectivity, which enables butterflies to shift their distributions towards higher latitudes or altitudes in response to changing climatic conditions. Species richness is generally positively associated with higher mean temperatures and precipitation, as well as with higher elevations and a more heterogeneous landscape matrix (Habel et al. 2021). With respect to weather variability, populations located at the margin of a species' range tend to be more sensitive to environmental fluctuations than those in the centre of the range (Mills et al. 2017). Emigration rates may increase during warm summers and in response to drought-induced habitat degradation. In contrast, cooler summers, larger habitat patches, higher population densities, and abundant floral resources tend to reduce the likelihood of emigration (Simcox et al. 2025).

Effective butterfly conservation requires maintaining both short- and long-distance connectivity. Short- and intermediate-distance connectivity supports daily movements between microhabitats, larval host plants, and nectar resources; while long-distance connectivity facilitates range shifts and migration, particularly in response to climate change. Butterfly species exhibit a wide range of dispersal strategies, from highly migratory species such as *Vanessa cardui* to extremely sedentary species with very limited dispersal, such as *Cupido minimus* (Dover & Settele 2009). In some species, regular long-distance movements of several kilometres have been recorded (e.g. *Boloria aquilonaris*; Baguette 2003), underscoring the need for connectivity across multiple spatial scales.

3.2.5 Moths

Moths represent the most species-rich taxonomic group addressed in this report, yet their ecological requirements remain the least studied, partly due to their predominantly nocturnal lifestyle. They occur across most terrestrial habitats, with many species associated with open landscapes such as grasslands or heaths, as well as forest environments, including ecotones as forest edges and hedgerows. In contrast to butterflies, forest habitats may support even higher moth species richness than meadows (Merckx et al. 2019). Younger forests tend to host greater abundance and diversity of macromoths, whereas older woodlands support a higher number of specialists micromoth species (Fuentes-Montemayor et al. 2022). At smaller spatial scales, the presence of suitable habitat patches appears to be more important for moth communities than patch size or the degree of isolation (Merckx et al. 2019). Accordingly, local habitat quality, such as vegetation structure and the availability of nectar resources, has the strongest influence on moth density and species richness, as demonstrated in semi-natural grasslands (Pöyry et al. 2009, Alison et al. 2017). However, moth abundance and diversity also increase with greater woodland connectivity (Fuentes-Montemayor et al. 2012, 2022). Connectivity features often simultaneously function as high-quality habitats, thereby providing a dual benefit for moth populations.

In the context of habitat connectivity, it is important to consider the different requirements of forest-associated and open-landscape moth species. In intensively managed agricultural landscapes, woody hedgerows have been shown to increase moth abundance, with abundance increasing as distance to the hedgerows decreases (Coulthard et al. 2016). Additionally, hedgerow trees and wide field margins can positively influence macromoth species richness (Merckx et al. 2012). Such linear landscape elements provide shelter, favourable microclimatic conditions, larval food plants, and floral resources, thereby functioning both as corridors and as suitable habitat (Merckx et al. 2009b, Boutin et al. 2011, Coulthard et al. 2016). At the landscape scale, the proportion of forest cover and the total length of hedgerows within a 250m radius are key determinants of forest-associated macromoth abundance and diversity, whereas meadow management appears to play a comparatively minor role (Kühne et al. 2022). Ideally, forest fragments should exceed five hectares and contain interior forest areas located more than 100 metres from habitat edges to sustain stable populations of forest specialists (Slade et al. 2013). However, in fragmented landscapes, solitary trees and small woodland patches can function as stepping stones, when embedded within hedgerow networks or otherwise permeable landscape matrices (Slade et al. 2013). These positive effects are particularly pronounced for shrub- and tree-feeding species (Merckx et al. 2012).

For open landscape species, hedgerows do not universally facilitate movement and may also constrain dispersal, depending on species-specific behaviour. For example, moths have been observed to increasingly orient their flight paths parallel to hedgerows the closer they get to them. This behaviour suggests that hedgerows may function as dispersal corridors, but also indicates lower permeability compared with open fields (Dover and Fry 2001, Coulthard et al. 2016). This context-dependence is also reflected in agri-environment scheme (AES) evaluations, where hedgerow management alone did not lead to measurable increases in micro- or macromoth abundance or species richness (Fuentes-Montemayor et al. 2011). Instead, Fuentes-Montemayor et al. (2011) found that AES-managed field margins, semi-natural grasslands, and water margins within a 250-metre radius had positive effects on both moth abundance and diversity. Less mobile species appear to benefit particularly from wide field margins (Merckx et al. 2009a). Grassland management further modulates these responses. Macromoth species richness is primarily influenced by mowing frequency, whereas micromoth assemblages are more sensitive to the timing of the first cut and vegetation composition (Kühne et al. 2022). The availability of semi-natural grasslands and scrub habitats at small spatial scales in general influences macro- and micromoth abundance, as well as micromoth species richness (Fuentes-Montemayor et al. 2011). The effectiveness of these measures appears to operate at relatively limited spatial scales, with significant effects on macromoth populations observed within distances of approximately 800 metres (Merckx et al. 2012).

In contrast, urbanisation negatively affects moth populations, particularly macromoth species, and operates at landscape scales of around one km (Fuentes-Montemayor et al. 2011). The major contributing factor is ALAN, which disproportionately disrupts larger moth species due to their higher dispersal abilities (Nieminen et al. 1999). Illuminated urban areas and street networks are therefore of particular concern, as they may simultaneously function as both attractants and barriers. The use of amber LEDs with a colour temperature of 1800 K can help to mitigate these pressures significantly (Ludreschl et al. 2026). In the surrounding landscape matrix, higher tree species richness and a greater proportion of native trees have been shown to support moth abundance and species richness (Fuentes-Montemayor et al. 2012). In the context of climate change, these landscape elements provide a range of microclimatic conditions that enable temperature avoidance behaviour and help mitigate climate-related stressors (Hill et al. 2021), which are often particularly pronounced in urban areas.

In response to climate change, maintaining both short- and long-distance connectivity corridors is essential for effective moth conservation. Short-range movements are largely facilitated by linear landscape features such as hedgerows and field margins, allowing species to switch between microclimatic conditions or different altitudes. At the same time, several moth species undertake regular long-distance migrations, including *Macroglossum stellatarum*, *Hyles livornica*, and *Autographa gamma* (Hawkes et al. 2024). For long-distance connectivity, the protection of known migration corridors and bottlenecks, such as the Pass of Bujaruelo in the Pyrenees, is therefore crucial (Hawkes et al. 2024). Migration behaviour varies among species and is, for example, linked to feeding ecology, with oligophagous and polyphagous species migrating more frequently than monophagous species (Nieminen et al. 1999), underscoring the need to maintain connectivity across multiple spatial scales.

3.3 Development of a set of criteria and methods to identify Buzz Lines

3.3.1 Analysis of existing criteria for habitat connectivity and state of the art of habitat/ biotope networks for pollinators

Planned and existing protected area systems are often considered not only as “stand-alone” reserves in intensively used landscapes, but also as core zones in a coherent ecological network supplemented by interlinking habitat corridors that allow for exchange and migration of species. While under the Habitats Directive there were already provisions of Art. 3 and Art. 10 referring to landscape elements, the implementation of habitat connectivity was slow or seen only as a recommendation, despite the fact that an Art. 10 guideline (Kettunen-Andrew et al. 2007) was drafted and that workshop outcomes early in the Natura 2000 implementation phase clearly stated that there are many habitats and species where the favourable condition can only be reached by applying habitat connectivity (BfN 2005).

However, in several Member States, for example in The Netherlands and Germany, detailed criteria were elaborated at a national scale to establish, plan, or implement habitat corridors or green corridors.

Such planning of habitat connectivity usually distinguishes three different elements:

- The core zones as protected areas (KPAs for pollinators),
- The connecting lines or stepping stones (Buzz Lines for pollinators),
- The (wider) landscape matrix.

For conservation to be effective, all three components must meet certain minimum criteria; for example, the landscape matrix must have a minimum level of permeability.

Applying these widely accepted concepts and existing criteria to pollinator conservation requires evaluation to determine their applicability and effectiveness. It is also essential to identify whether additional or modified criteria are necessary to establish ecologically meaningful and operational Buzz Lines for pollinators. Consequently, a more systematic and rigorous analysis of current criteria is necessary.

Planning for habitat connectivity often uses habitat corridors for certain groups of habitats and species related to them such as:

- Corridors for species dependent on forests and mixed landscapes with a high proportion of woody landscape elements such as hedgerows etc. and a sufficient proportion of microhabitats for saproxylic invertebrates,
- Corridors for wetlands and wetland species,
- Corridors for dry open habitats and thermophilus species.

In principle, these habitat and species migration corridors can serve as 'Buzz Lines' for pollinators. However, additional, pollinator-specific criteria are required to ensure their effectiveness. Some of these criteria must be regionally adapted. For instance, in the Mediterranean region, a substantial proportion of hoverfly species depend on bulbous plants as larval hosts. Therefore, in these typically dry corridors, minimum thresholds for both the diversity and abundance of bulb species must be integrated into corridor design.

Pollinators with saproxylophagous larvae depend on a diversity of and minimum density of microhabitats of dead wood and ancient trees, such as rot holes, sap runs, dead wood partially immersed in water etc.

At the European level, in addition to Buzz Lines between Natura 2000 sites, large landscape corridors such as the European Green Belt, or main migration paths in river valleys for thermophilus pollinator species will also be relevant.

Buzz Lines should therefore represent pollinator-friendly corridors at both local and transnational scales.

Independent of the spatial scale, there are some general criteria for Buzz Lines, which should apply at all levels:

- Small or no negative impact of pesticides, fungicides, seed-coatings, or other toxic substances, i.e. a very low or no substantial proportion of intensively used agricultural land, especially no arable fields; some may need to be restored or developed by alternative/organic farming,

- High proportion of seminatural to natural habitats, preferably in small scale mosaics,
- Continuous flowering phenology at the landscape level (close to the (semi) natural situation),
- Connecting flower-rich and diverse pollinator habitats,
- Low or no light pollution especially for nocturnal pollinators,
- Accessibility and quality of hilltopping places as mating places for certain pollinator species (Hoverfly species and other fly and butterfly groups),
- Ensuring alignment with local, regional, and national policies,
- Designing dynamic, adaptable maps rather than static corridor plans, recognising that Buzz Lines may change over time due to ecological shifts and landscape dynamics.

3.3.2 Criteria for long-distance connectivity at the landscape level

Enabling long-distance connectivity between KPAs and protected areas to build a future EU-wide ecological corridor network. This long-distance connectivity is important for regular annual migrations, to ensure gene flow among populations and to allow range shifts due to climate change.

Relevant features to promote long-distance connectivity are:

- Migration corridors along rivers or valleys,
- Mountain passes as known insect migration paths,
- High proportion of habitats with late flowering herbs or tall herbs with high flower density,
- Complete altitudinal zonations in mountain areas to encompass a large range of microclimatic conditions to allow for daily local migrations of pollinators, and to buffer changes due to climate warming,
- Minimal artificial light at night (for moths) and general aerial infrastructure for flying species (Sordello et al. 2025),
- Cross-border cooperation to ensure species movement and ecosystem connectivity across Europe,
- Addressing pressures from the transportation network, which may function as both barriers and potential corridors,
- With regard to the transportation network, the integration of transmission line corridors into the Buzz Line network could be a promising approach. These transmission line corridors have shown to be important habitats for pollinators and serve as corridors between habitat patches (Berg et al. 2013; Hill and Bartomeus 2016; Oki et al. 2021; Munill et al. 2024); simultaneously, they provide suitable habitats for other species (Askins et al. 2012),
- Transmission line corridors can be of high value especially in countries with high forest cover in regard to complementing the existing protected area network and can be comparable to semi-natural grasslands habitats (Hill and Bartomeus 2016),
- Given that these corridors require active management regardless, the development and implementation of cost-effective, pollinator-friendly management strategies is both feasible and practical. Several promising case studies and examples already demonstrate the potential of such approaches (EuropaWire 2023).

3.3.3 Criteria for short-distance connectivity at the local to regional level

Enabling short-distance connectivity within KPAs and protected areas to connect larval and adult habitats and metapopulations.

Relevant features to promote short-distance connectivity are:

- Presence of small-scale mosaics of adult and larval habitats of pollinators (at a scale of 100-200 m),
- Presence of continuous flower supply for adult pollinators,
- Plant species richness including needs for specialised pollinators of all four main pollinator groups,
- Presence of ecotones such as forest margins with fringing herbs, riverbank zonation, wetland zonation around lakes or bogs,
- Presence of habitat complexes rich in microhabitats for all specific requirements of different pollinator groups.

3.4 State of knowledge and data gaps for the main pollinator groups

3.4.1 Cross-taxon synthesis: methods, models, and monitoring

Dispersal is variable, context-dependent, and evolves. Across all groups, dispersal is shaped by trade-offs, behaviour, and landscape context; in butterflies, this has been demonstrated to the point of linking genotypes to demography in metapopulations. Comparable genetic and eco-evolutionary links remain scarcely documented in bees, hoverflies, and most moths.

From structural to functional connectivity. Corridor presence and 3D habitat structure improve colonisation probabilities for bees and likely for moths; hoverflies and some bees can maintain high connectivity even in cities if stepping-stone resources exist. Thus, resource phenology, stage-structure, and behaviour must be built into connectivity models.

Metapopulation evidence is uneven. Butterflies provide textbook metapopulations; robust equivalents are rarer for bees, hoverflies, and moths and also population level studies are rarer. Applying incidence function models with landscape resistance surfaces, coupled to SDMs and genomic data, is promising but requires long-term occupancy and colonist-quality data that are currently uncommon outside a few focal systems.

Monitoring and design. Emerging guidance calls for bee monitoring that explicitly measures demography (recruitment, survival) and movement, and for integration of physiology with field ecology to mechanistically predict dispersal under warming and drought. For hoverflies, combining aerial radar/ isotope tools with ground-based demography would link migratory fluxes to local population persistence. For hoverflies time based quantitative transect observations can be used, more effective is time-based grid mapping of grid sizes of 10 x10 m^2 in parallel transects both with additional data on habitats and flowering phenology (Ssymank 2001, 2002) while a complete monitoring of hoverflies will need in addition to observer dependent methods the use of Malaise traps to efficiently detect also smaller species (Ssymank & Doczkal 2017, Ssymank et al. 2018). For butterflies, transect walks have shown to be very effective for assessing species assemblages and abundance and Butterfly Monitoring Schemes (such as the eBMS) are running in all EU Member States. For moths, prioritising behaviourally explicit movement (e.g., hilltopping) and ALAN effects should reduce structural–functional mismatches in connectivity planning.

3.4.2 Wild bees

Current state of knowledge

Mobility. Bee movement spans a few hundred metres to several kilometres, scaling strongly with body size, nesting mode, and sociality. Mark–recapture and genetic studies show that small solitary species typically move hundreds of metres, while large bumblebees can routinely exceed a few kilometres. Movement is resource-driven and highly seasonal, with floral and nesting resource phenology structuring path choice and step length. However, distances between nesting sites and floral resources largely determines the bees' reproductive success and many species have short foraging distances of 100-200 m due to energetic and reproductive costs. Landscape experiments demonstrate that structural connectivity (e.g., corridors) can increase colonisation rates into new or managed habitat, implying limited but ecologically meaningful dispersal that is sensitive to matrix permeability.

Connectivity. Functional connectivity for bees is often "resource connectivity"; patches linked by continuous bloom or nesting substrates (habitat mosaics) in effective foraging distances rather than simple Euclidean proximity. Edge structure and corridor presence increase effective connectivity and colonisation, particularly for cavity-nesters and species with shorter flight ranges. Urbanisation negatively influences dispersal via impervious cover and altered 3D connectivity, highlighting matrix effects at multiple scales. Landscape genetic syntheses report frequent isolation-by-resistance, rather than isolation-by-distance; with roads, intensive cropland, and urban cores acting as movement barriers for many species, but semi-natural or flower-rich landscape elements such as hedgerows, flower strips, and riparian corridors can partially mitigate this resistance.

Metapopulation dynamics. True, classical metapopulations (frequent local extinctions balanced by recolonizations in discrete patches) are documented far less often for bees than for butterflies, but emerging demographic and genetic work shows patch turnover in specialist species (e.g., oligolectic or habitat-restricted taxa) and in fragmented systems managed with rotational disturbance. Conceptual and methodological pieces argue for bringing population ecology "back" to wild bees via repeated occupancy, capture–recapture, and genomic monitoring to detect patch dynamics and rescue effects.

Priority data gaps

1. *Direct movement data for solitary bees.* Most flight-range estimates rely on allometry or foraging radii; high-resolution tracking (harmonic radar, Radio-Frequency Identification (RFID), tags) is rare across the major functional groups.

2. *Matrix-dependent dispersal kernels.* Species and context-specific kernels parameterised by matrix type (e.g., urban, intensive agriculture) are still lacking to feed connectivity and metapopulation models.
3. *Colonisation–extinction datasets.* Few multi-year occupancy datasets exist for bees at patch networks; corridor/edge experiments are promising but geographically uncommon.
4. *Linking physiology to movement.* Thermal limits, energetic budgets, and stress biomarkers rarely inform dispersal/ settlement probabilities despite clear mechanistic potential.
5. *Genomic inference standardisation.* Landscape genomics show structure, but standardised sampling frames and cross-species panels are needed for comparative inference about connectivity.

3.4.3 Hoverflies

Current state of knowledge

Mobility. Syrphids include both migratory and sedentary species. Long-distance, seasonal, migrations move billions of individuals and deliver substantial pollination and biocontrol services across regions; radar and isoscape work in Britain and the EU has quantified north–south fluxes and trophic transfers. For non-migratory taxa, daily movements and gap-crossing are typically in the order of tens to hundreds of metres, with documented rates up to ~2 km/day for some species; field boundaries and inhospitable matrices reduce movement. Undirected dismigration is occurring in many Syrphidae species with aphidophagous larvae over distances of 50-100 km in search of aphid colonies for egg-laying or moving to flower rich vegetation patches. Several species of hoverflies show hill-topping behaviour both in open landscapes and in forest areas.

Connectivity is stage-dependent: Landscapes that couple floral resources for adults with larval microhabitats maintain functional linkages. Some long-distance migratory species need abundant nectar resources as generalist foragers in late flowering biotope patches along their migration routes (mostly species with aphidophagous and some aquatic saprophagous species). The majority of hoverfly species need connectivity at the regional to local level between their larval habitats and suitable floral resources (both nectar and pollen). These species usually require certain floral resources based on flower type, colour, height preferences and phenology, varying over the year, some species being oligolectic specialised on certain plant genera or families. Urban studies show that even nonmigratory species can maintain high genetic connectivity across green-space networks, implying high permeability when stepping stones exist. Conversely, simplified farmland and strong linear barriers reduce movement and assemblage richness.

Metapopulation processes. Evidence for classic metapopulations is limited; for migratory species, population dynamics may be better represented by seasonal source–sink meta-communities spanning continental scales for migratory species. For sedentary taxa in patchy woodlands or wetlands, occupancy is responsive to patch area, history, availability and density of microhabitats for larvae and connectivity, but long-term colonisation–extinction series remain scarce.

Priority data gaps

1. *Quantifying dispersal kernels for non-migratory species.* Beyond a handful of taxa, daily/seasonal movement distributions and barrier/edge responses are poorly parameterised.
2. *Linking radar/isotope migration metrics to demography.* We can measure fluxes aloft, but we rarely connect them to breeding success or local persistence at ground level.
3. *Knowledge on larval biology and larval food requirements.* While larvae of aphidophagous species are relatively well known, there are fundamental knowledge gaps in phytophagous species and their relation to host plants (*Cheilosia, Eumerus, Merodon*) as well as in several saproxylic groups
4. *Larval habitat connectivity.* Stage-structured connectivity models are needed to couple adult floral networks with larval resource webs across landscapes.
5. *Availability of floral resources at the landscape level and its variation throughout the year linked to vegetation classification.* Symphenological knowledge on a wide range of vegetation units will allow to predict the availability of important floral resources in a landscape (Ssymank 2001)
6. *Pollen carrying capacity and pollination efficiency.* Pollen carrying capacity over short distances in a given habitat and longer distances during migration is only partly known and pollination efficiency is dependent on pollen load, flower visiting frequency, pollinator behaviour etc., where only part of the important traits of hoverflies is known for a broader set of species.
7. *Metapopulation evidence.* Repeated occupancy and genetic time series across patch networks are needed to detect rescue effects and turnover, especially in managed agroecosystems.

3.4.4 Butterflies

Current state of knowledge

Mobility. Butterflies are the classic model for dispersal heterogeneity: even within species, individuals differ along dispersal–fecundity trade-offs, with “dispersive” morphs often paying costs in survival or reproduction. Movement is shaped by resource tracking, topography (e.g., hilltopping), and weather.

Connectivity. Decades of work in fragmented grasslands—most famously the Glanville fritillary system—demonstrate that connectivity among habitat patches governs colonisation, gene flow, and adaptation to fragmentation. Landscape structure (patch size, quality, and isolation) predicts turnover; functional connectivity metrics and Incidence Function Models (IFMs) are now routinely coupled to SDMs and genomic data. Population synchrony analyses indicate local dispersal at short distances and environment-driven dynamics at broader scales.

Metapopulation dynamics. Butterflies provide the clearest classical metapopulation evidence: thousands of habitat patches with recurrent local extinctions and recolonizations, eco-evolutionary feedback (e.g., selection on dispersal), and genomic consequences (selection at loci associated with movement and performance). At landscape scales, rescue effects and colonist quality drive persistence; molecular variation can predict population growth and extinction risk at the patch level.

Priority data gaps

1. *From models to management rules.* IFM-derived thresholds (e.g., minimum patch size/connectivity) are rarely translated into generalisable, region-specific prescriptions under climate change.
2. *Behaviourally explicit connectivity.* We need movement models that encode behaviours like hilltopping, puddling, and resource-switching to avoid misestimating corridor value.
3. *Joint demographic–genomic monitoring.* Many systems lack synchronised time series to quantify how gene flow, selection, and demography co-determine persistence under rapid environmental change.
4. *Under-studied taxa/regions.* Most robust datasets are temperate and European, whereas tropical, mountainous, and arid systems remain data-poor. Butterfly Monitoring Schemes are currently running in all EU Member States, although across different time series; with good (spatial) data availability in the UK, Ireland, The Netherlands, Belgium, Luxembourg, Switzerland, Germany and Southern Sweden, and poorer availability in Eastern Europe and the Mediterranean region. Even within countries there are strong differences between regions/ Federal States or landscape classes, which means that general statements are often difficult (Inference from the distribution of study systems in the cited literature).

3.4.5 Moths

Current state of knowledge

Mobility. Moths span resident, short-range, and long-distance migratory strategies, but compared to butterflies, fine-scale movement ecology is less understood. Recent work highlights behavioural mechanisms- e.g., hilltopping in day-flying arctiines that reconfigure effective connectivity by separating mating sites from larval resource patches, producing two-stage movement (to mating hubs, then to oviposition sites).

Connectivity. Light pollution, hedgerow networks, and topographic funnels likely alter movement and gene flow, but quantitative, species-level resistance surfaces are sparse. Where studied, corridor elements and semi-natural field margins increase occurrence and may aid recolonization after local extinction, similar to butterflies, yet the evidence base is patchy and taxonomically narrow.

Metapopulation processes. Classical metapopulations are documented for a few habitat specialists (e.g., bog fritillary–like systems in butterflies have analogues among some moths), but long-term colonisation–extinction series are rare. Disturbance regimes (e.g., rotational grazing, scrub dynamics) likely create dynamic patch networks where patch location/quality shifts over time—a scenario under which metapopulation persistence depends on the speed and direction of “moving habitat.” Theory and early empirical tests suggest mobile disturbance can hinder or help persistence depending on how far “new” patches appear relative to dispersal distances.

Priority data gaps

1. *High-resolution movement tracks.* Harmonic radar/RFID studies lag behind butterflies; most inferences are from trap captures or occupancy. This limits parameterisation of stage-structured connectivity (mating vs larval sites).
2. *Landscape genetics.* Few species have dense Single Nucleotide Polymorphism (SNP) datasets to map resistance and identify barriers or corridors at management-relevant scales (general gap across moth literature relative to butterflies).
3. *Light-at-night effects on metapopulations.* Quantitative tests are lacking on how ALAN re-routes movement and alters the colonisation–extinction balance (gap inferred from scarcity of ALAN-linked metapopulation studies in current syntheses).

3.4.6 Practical implications for conservation planning

1. *Design for the right scale.* Use species-specific (or guild-specific) dispersal kernels when designing and installing patches and corridors; for bees and sedentary hoverflies, stepping stones at 250–1000 m spacing are often necessary, whereas migratory hoverflies demand continental-scale flyways.
2. *Link adult and larval resources.* Ensure stage-structured connectivity by co-locating or linking adult foraging corridors with breeding substrates (aphid resources, detrital microhabitats, host plants, dead wood, bare soil).
3. *Maintain patch quality and size.* For butterflies (and likely many moth specialists), larger, high-quality patches reduce local extinction; connectivity boosts recolonisation, but habitat quality is more important than connectivity—together determining persistence per IFM predictions.
4. *Manage the matrix.* Reduce resistance (e.g., mow regimes aligned with bloom, hedgerow retention, night-lighting controls, low levels of pesticides and seed-coatings) to convert structural proximity into functional connectivity.
5. *Commit to long-term, repeated surveys and changes in population genetics.* Occupancy dynamics, synchrony analyses, and genomic time series are essential to detect metapopulation processes and to evaluate management.

4 References

The literature on the four main pollinator groups is quite extensive and dispersed, encompassing several thousand papers on the distribution, ecology, and biology of European species. Here, only an initial selection of studies is presented, focusing on KPAs and providing key background information on the ecology, biology, threats and declines relevant for developing criteria for KPA identification. For a full scoping of KPAs, a more comprehensive review of the literature is required, including country-specific management contexts and evidence. Papers on Buzz Lines, average flight distances, foraging distances, habitat use, habitat connectivity and spatial use of habitat mosaics are limited, and larger knowledge gaps remain in all these basic fields of ecology to some extent.

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Abbreviations

ABLE project	Project for Assessing Butterflies in Europe
AES	Agri-environment scheme
ALAN	Artificial light at night
AOH	Area of Habitat
A2P	Assess to Plan
BVM	Biological Valuation Map
CR	Critically Endangered (Category of IUCN Red List)
CropPol project	Project to build a dynamic, open and global database on crop pollination
eBMS	European Butterfly Monitoring Scheme
EEA	European Environment Agency
EN	Endangered (Category of IUCN Red List)
EPIC-bee/hoverfly/butterfly	European Pollinator Identification Courses
ETC-BE	European Topic Centre Biodiversity and Ecosystems
EU	European Union
EUNIS	European Nature Information System
EUPPollNet	European database of plant pollinator networks
EU PoMS	EU Pollinator Monitoring Scheme
EVA	European Vegetation Archive
EX	Extinct (Category of IUCN Red List)
HabCon project	Project to analyse methods used to assess specific structures and functions with their typical species across Member States and to develop a Habitat Condition Guideline
HD	Habitats Directive (EU 92/43/EEC)
HNV	High Nature Value
IBMAs	Important Butterfly and Moth Areas
IFMs	Incidence Function Models
IPBES	The Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services
IUCN	International Union for Conservation of Nature
KBAs	Key Biodiversity Areas
KEN	Pollination Knowledge Exchange Network
KPAs	Key Pollinator Areas

LC	Least Concern (Category of IUCN Red List)
LIFE Programme	L’Instrument Financier pour l’Environnement Programme
NDFF	Dutch National Database of Flora and Fauna
NRR	Nature Restoration Regulation (EU 2024/1991)
NaturaConnect project	Project to build an ecological network of conserved areas across Europe
NT	Near Threatened (Category of IUCN Red List)
OECMs	Other Effective Area-based Conservation Measures
Orbit project	Project to build taxonomic resources for European bees
PBAs	Prime Butterfly Areas
PHAs	Prime Hoverfly Areas
PollHab project	Project to identify pollinators typical of habitats protected under the Habitats Directive
RFID	Radio-Frequency Identification
SAFEGUARD project	Project to safeguard European wild pollinators
SDMs	Species Distribution Models
SNP	Single Nucleotide Polymorphism
SPRING project	Project with the aim of Strengthening Pollinator Recovery through Indicators and monitorinG
TaxoFly project	Project to build taxonomic resources for European hoverflies
UK	United Kingdom
VU	Vulnerable (Category of IUCN Red List)
WGP	Working Group on Pollinators

Supplementary Material

S1. Criteria for the identification of Prime Butterfly Areas

Source: adapted from van Swaay and Warren 2006.

Criteria	Description
Biogeography	The world range of the species is restricted to Europe
Conservation	The species is threatened according to the Red Data Book of European Butterflies
Legislation	The species is listed in Appendix II of the Bern Convention and/or the EU Habitats and Species Directive

Minimum Threshold: Fulfilment of at least two criteria

S2. Criteria for the identification of Important Butterfly and Moth Areas (IBMAs)

Source: adapted from Gallego-Zamorano et al. 2023.

	Criteria	Description
Threatened species	Site* contains one or more globally threatened species	Site known, thought or inferred to contain >=1% of the global population AND/OR >=10% of the national population OR the 5 "best sites" for that species nationally, whichever is most appropriate
	Site contains one or more regionally threatened species	Site known, thought or inferred to contain >=10% of the national population, OR the 5 "best sites" for that species nationally, whichever is most appropriate
	Site contains one or more highly restricted endemic species that are potentially threatened	Site known, thought or inferred to contain >=1% of the global population AND/OR >=10% of the national population, OR the 5 "best sites" for that species nationally, whichever is most appropriate
	Site contains one or more range-restricted endemic species that are potentially threatened	Site known, thought or inferred to contain >=1% of the global population AND/OR >=10% of the national population, OR the 5 "best sites" for that species nationally, whichever is most appropriate
Species richness	Site contains a high number of species within a defined habitat	For each habitat type: up to 10% of the national resource can be selected within the whole national Important Butterfly and Moth Area network OR the 5 "best sites" nationally, whichever is the most appropriate

	Criteria	Description
	Site contains a high number of species of high conservation importance	Site known to contain >=3% of the selected national list of species of conservation importance OR the 15 richest sites nationally, whichever is most appropriate
	Site contains an exceptional number of species	Site known to contain >=40% of the selected national list of all species OR the 15 richest sites nationally, whichever is most appropriate

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