The future is on their wings.

ZOO LIFE POLLINATORS - Zoos as local restoration and conservation hotspots in urban and peri-urban areas and citizen science ambassadors to reverse the decline of pollinators in anthropic spaces

DELIVERABLE – D3.1

Monitoring system for pollinators

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Goals of the Handbook

This pollinator monitoring handbook aims to provide clear, practical and scientific guidelines for carrying out high-quality monitoring of the three main groups of pollinating insects (*Apoidea, Lepidoptera,* and *Syrphidae*). The manual supports staff in establishing transects and survey plots, applying standardized data-collection methods, and developing basic skills to identify key species within these groups. Together with entomological monitoring, it includes phytosociological surveys and counts of **entomophilous floral units**, to analyse the qualitative and quantitative abundance of recorded pollinator populations, their interactions with plants, and to assess the condition and effectiveness of the ecological restoration measures implemented within the study areas.

1. Introduction & background

Zoological gardens in Europe welcome millions of visitors each year and are often located in urban and peri-urban areas. Traditionally, their mission has focused on promoting environmental awareness and encouraging the reduction of human impacts on nature. However, zoos have rarely contributed to raising awareness about local biodiversity and the ecosystem services that sustain everyday life.

This project, Zoo LIFE Pollinators, seeks to unlock the untapped potential of urban zoos to increase knowledge about the conservation status of insect pollinators and to create suitable conditions for their protection. A functional habitat capable of supporting a viable population of pollinator insects can be established on as little as half a hectare of land, making zoological parks particularly well suited to host and manage pollinator-friendly environments.
The project specifically addresses the decline of insect pollinators in urban and peri-urban areas by integrating habitat restoration, breeding and conservation activities, and public awareness actions within zoo spaces. By guiding visitors to discover and understand environments that support pollinators, the project represents a significant shift in recognizing zoos as ambassadors of biodiversity. This expanded role goes beyond traditional ex situ conservation, enabling zoos to actively contribute to in situ conservation within urban and peri urban landscapes.

Furthermore, the project contributes to the greening of urban and peri-urban areas and to halting the decline of pollinator insects. These actions will generate positive impacts on pollinator populations, local communities, and major European cities in which zoos are located. In this context, the project supports the implementation of the EU Biodiversity Strategy for 2030, particularly Pillar II which aims to reverse the decline of pollinators, as well as the EU Pollinators Initiative by improving knowledge of pollinator decline, strengthening conservation actions, and mobilizing society through strategic planning and cooperation at multiple levels.
Overall, the project contributes to protecting nature and reversing ecosystem degradation, positioning zoological gardens as key actors in urban and peri urban biodiversity conservation.

1.1 What is pollination?

The pollination is a fundamental process through which pollen is transferred from the male reproductive organ (the anther) to the female reproductive organ (the stigma) of flowering plants (**Angiosperms**). This transfer enables fertilization and seed production, representing a crucial step for sexual plant reproduction of angiosperms and for maintaining the genetic variability of plant population.

The classification of pollination primarily depends on the origin of the pollen and the position of the flowers involved:

- Autogamy (Self-Pollination): occurs when pollen from the anther fertilizes the stigma of the same flower or another flower on the same individual plant
- Allogamy (Cross-Pollination): occurs when a flower is fertilized by pollen from a different plant of the same species. This process requires an external vector and is a key driver of genetic diversity, enhancing the resilience and adaptive potential of plant populations.

Plants rely on different vectors to facilitate pollen transfer, as see below:



BIOTIC POLLINATION
- Depends on animal pollinators, which ensure a more targeted and often more efficient pollen transfer



ABIOTIC POLLINATION
- Utilizes non-living vectors such as wind or water; this strategy does not require complex floral attractants and typically depends on the production and passive dispersal of large quantities of pollen

Plants that adopt the biotic strategy often feature flowers with specialized morphologies, energy resources such as nectar, and visual or olfactory signals that guide pollinators toward the reward source. This mode of pollination is prevalent in many temperate and Mediterranean ecosystems and ensures greater precision in the reproductive process.

Among pollinators, we find an extremely diverse group, dominated by pollinator insects in temperate regions. Among these, bees (*Apoidea*) are the most well-known group and are generally considered the most efficient. Solitary bees, which include thousands of species differing in size, floral preferences, and nesting techniques, possess specialized structures for collecting pollen. This behaviour results in highly targeted pollen transfer, which is essential for the reproduction of many wild plant species.

In addition to bees, many other groups actively contribute to the pollination process. Hoverflies (*Diptera: Syrphidae*), although lacking specialized structures, visit a wide variety of flowers. Butterflies and Moths (*Lepidoptera*) also play a significant role: thanks to their elongated proboscis, they can reach nectar located deep within flowers and thus pollinate tubular blossoms that other insects cannot exploit.
Day-flying butterflies, which are more selective in choosing host plants and nectar sources, support the reproduction of numerous meadows and shrubland species, while moths, most active during twilight or nighttime hours, contribute to the pollination of plants that bloom or release scent during the night.

1.2 The insect pollinator's ecological role, agricultural relevance and contribution to biodiversity

The **mutualistic** relationship between pollinating insects and plants is the result of a long-term process of **co-evolution**. Pollinators visit plants in search of food sources, such as pollen or nectar, and plants in turn take advantage of this interaction to reproduce. The first direct evidence of insect pollination of angiosperms was reported from several pollen-collecting bees from the Middle Eocene (50 Ma) documented by fossilized pollen-collecting bees in Germany, strongly supported by their flower-visiting body shape, specialized pollen-feeding mouthparts, and **zoophilous pollen grains** attached to the body (Wappler et al., 2015).

The European context supports a rich diversity of wild pollinators, constituting a key ecological group, comprising over 2000 species of bees, nearly 500 species of butterflies, and almost 1,000 species of hoverflies, and thousands of species of moths, flies, wasps, beetles, and other insects (IPBES, 2016). Collectively, these

insects are estimated to be responsible for the pollination of most cultivated and wild plants (87.5%) of all flowering plants (Ollerton et al., 2011). While some pollinator species are particularly common visitors of crop flowers overall, different pollinator communities are important for the pollination of different crops (Garibaldi et al., 2013; Garratt et al., 2014).

Beyond direct plant reproduction, pollinators play a fundamental role in broader ecosystem functioning. They provide essential resources like food and shelter for a wide range of other organisms, including invertebrates, mammals, birds, and reptiles (Gutierrez-Ibanez et al., 2014).

Entomophilous pollination is an indispensable ecosystem service with profound implications for humanity. From an agricultural perspective, it strongly influences both the quantity and quality of crop production. From an economic perspective, pollinators collectively provide a wide range of benefits to society. Gallai and colleagues (2009) estimated the global economic impact of this ecosystem service in 2005 at €153 billion, and €15 billion per year for European crops, ensuring healthy ecosystem functioning and economic stability (IPBES 2016, EU Pollinators Initiative).
Insect pollination not only increases yield but also enhances crop quality by influencing parameters such as fruit size, shape, and market grade (Garratt et al., 2013). This service is vital for many crops grown in Europe, such as apples, berries, watermelons, tomatoes, and oilseed crops, but also imported crops that form part of modern European diets, such as coconut, mangoes, soybeans, cocoa beans, and coffee.

Insect pollinators contribute fundamentally to global biodiversity by promoting floral diversity and sustaining the ecological processes that underpin terrestrial ecosystems. Their interactions with plants support the coexistence of diverse plant communities, allowing species with different ecological strategies to persist (Potts et al., 2016). Highly specialized relationships, such as those between certain orchids and their specific bee or moth pollinators, illustrate how mutualistic interactions maintain rare or **endemic species** (Tremblay et al., 2005). These interactions also enhance ecosystem resilience: plant communities enriched by diverse pollinator assemblages show greater stability and improved resistance to climatic extremes, pests, and diseases (Garibaldi et al., 2013). Moreover, many plant and pollinator species have undergone long-term coevolution, leading to the development of specialized floral traits such as colours, scents, or nectar guides that increase pollination efficiency (Schaefer & Ruxton, 2011). This coevolutionary dynamic contributes to ecosystem complexity and strengthens the network of biological interactions that support ecosystem health and functioning.

1.3 Main cause of general decline

Recent assessments of the conservation status of European pollinators show a marked deterioration in the condition of many key species, with significant implications for biodiversity and the associated ecosystem services. Data presented at the 2025 IUCN World Conservation Congress, held in Abu Dhabi, confirms an increased extinction risk.



WILD BEES

- Approximately 10% of the assessed species in Europe (172 species) are currently considered threatened with extinction, a substantial increase compared to the 77 species identified as threatened in 2014 (IUCN, 2025)
- The proportion of species previously classified as Data Deficient has been significantly reduced, from 57% to 14%, improving the accuracy and reliability of available assessments
- Bumblebees (15 threatened species, essential for pollinating legumes) and cellophane bees (14 endangered species) are particularly affected. (IUCN, 2025)
- The case of *Simpanurgus phyllopodus*, the only species of its genus in Europe and now listed as Critically Endangered, is especially emblematic



EUROPEAN BUTTERFLIES

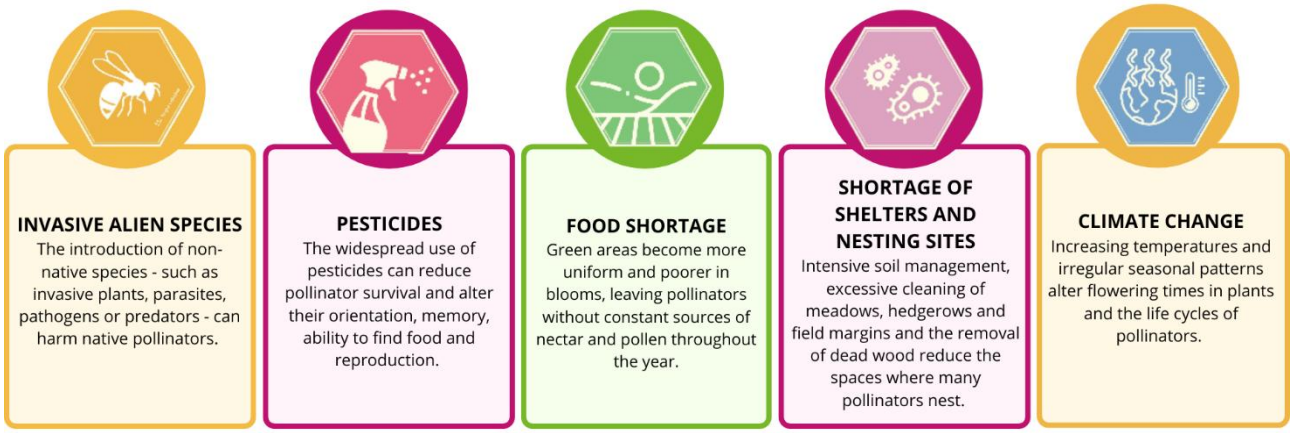
- 15% of the 442 assessed species are now considered threatened, nearly double the figure from 2010 (IUCN, 2025)
- Over 40% of Europe's endemic butterfly species are currently threatened or near threatened, and *Pieris wollastoni,* endemic to the island of Madeira, has been officially declared extinct



HOVERFLIES

- 37.2% of the species assessed are classified as threatened, and *Helophilus bottnicus* is considered regionally extinct (IUCN, 2022).
- Although these data proceed with the 2025 assessments, they remain a crucial reference for understanding the pressures affecting non-bee pollinators.

The decline of insect pollinators is primarily attributed to:



Overall, the evidence from 2025 underscores the urgent need for integrated conservation strategies that combine habitat protection, the reduction of anthropogenic pressures, and adaptation to climate change, to reverse the decline trajectories of European pollinators and ensure ecosystem resilience.

1.4 The European Regulatory Framework

The European regulatory framework for the protection of wild pollinators is based on a comprehensive set of Directives, Regulations, and Initiatives (Tab. 1).

A key milestone in this field was the Habitats Directive of 1992, which over thirty years ago introduced a new approach to nature conservation and led to the creation of Natura 2000, the largest ecological network in the world. Through this Directive, Europe protects 233 habitat types and 1,389 animal and plant species; among

them, many wild pollinating insects benefit indirectly from the preservation of the habitats on which they depend (ISPRA, 2019).

A more specific framework for pollinator protection was established with the EU Pollinators Initiative, launched in 2018 and updated in 2023 with the "New Deal for Pollinators". This initiative aims to counter the decline of wild pollinators by improving scientific knowledge, safeguarding habitats, and reducing pressures from pesticides, pollution, and land-use change.

In 2024, the "Nature Restoration Law" was adopted, representing one of the most significant measures to reverse biodiversity loss. The regulation seeks to restore degraded ecosystems (terrestrial, marine, agricultural, forest, and urban) to preserve essential ecosystem services, including pollination, with consequently positive environmental and economic impacts. Article 10 specifically requires Member States to halt the decline of pollinators by 2030 and to ensure a subsequent positive trend in their populations, assessed at least every six years.

To meet these goals, Member States must monitor pollinator populations using a methodology defined by the European Commission. On 19 September 2025, a delegated regulation was adopted establishing a science-based method to:

- Collect annual data on the abundance and diversity of pollinator species.
- Analysis of trends in their populations.
- Assess the effectiveness of restoration measures implemented across Member States.

This **harmonized monitoring system**, known as the EU Pollinator Monitoring Scheme (EU-PoMS), is set to become the key tool for evaluating and strengthening European policies aimed at protecting pollinators.

Tab.1: The main European regulatory framework.

Year	Action	Title	General objectives	Actions	Links
1992	Directive	92/43/CEE Habitat Directive	Conservation of natural habitats and wild species	Natura 2000 network: management plans and habitat protection	Eea.europa.eu
2009	Directive	2009/147/CE Birds Directive	Protection of wild birds and their habitats, indirect benefits for pollinators	Habitat management, designation of protected areas	Eea.europa.eu
2009	Regulation	Reg. (CE) n. 1107/2009 Plant protection products	Protecting bees and pollinators from the harmful effects of pesticides	Assessment of bee toxicity; restrictions on the use of active substances	Food.ec.europa.eu
2018	EU Initiative	EU Pollinators Initiative	Halting the pollinator decline in the EU	Knowledge, conservation and awareness	Environment.ec.europa.eu

2020	Strategy	EU Biodiversity Strategy 2030	Restore biodiversity and ecosystems by 2030	Habitat targets, pesticide reduction, sustainable agriculture	Europarl.europa.eu
2020 - 2025	Horizon / LIFE	SPRING project	European monitoring system (EU PoMS)	Citizen Science, research	Safeguard-pollinators.eu
2020 - 2026	Horizon	STING & STING + projects	Technical support	Training, data collection and analysis	Knowledge4policy.ec.europa.eu
2023	EU Initiative (review)	"A New Deal for Pollinators" COM (2023) 35	Strenghtening the Pollinators' Initiative: reverse the decline by 2030	New measures on pesticides, monitoring, public participation	Environment.ec.europa.eu
2024	Regulation	Reg. (EU) 2024/… Nature Restoration Law	Reverse the decline of biodiversity and pollinators by 2030	National restoration plans, monitoring	Consilium.europa.eu
2025	Regulation	Delegate Reg. (UE) 2025/2188	Define a harmonized monitoring methodology	Training, data collection and analysis	EUR Lex

2. Target pollinators

2.1 Wild bees (*Hymenoptera Apoidea*)

The term “wild bees” refers to social (including eusocial and semi-social species) or solitary bees that are not managed by humans. This definition is context-specific and cannot generally be applied to species, as most bee species managed by humans, except for the European honey bee (*Apis mellifera L.*) in Europe, also occur in wild populations (Klein et al., 2018).

Bees represent the most diverse and abundant group among the three major pollinator taxa (*Apoidea*, *Lepidoptera*, and *Syrphidae*). According to the most recent checklist, Europe hosts 2,138 bee species (Ghisbain, Rosa et al., 2023). The highest species diversity is found in Mediterranean countries, with Greece, Spain, and Italy being the three most species-rich countries for bees (Reverté et al., 2023) (Fig.1).

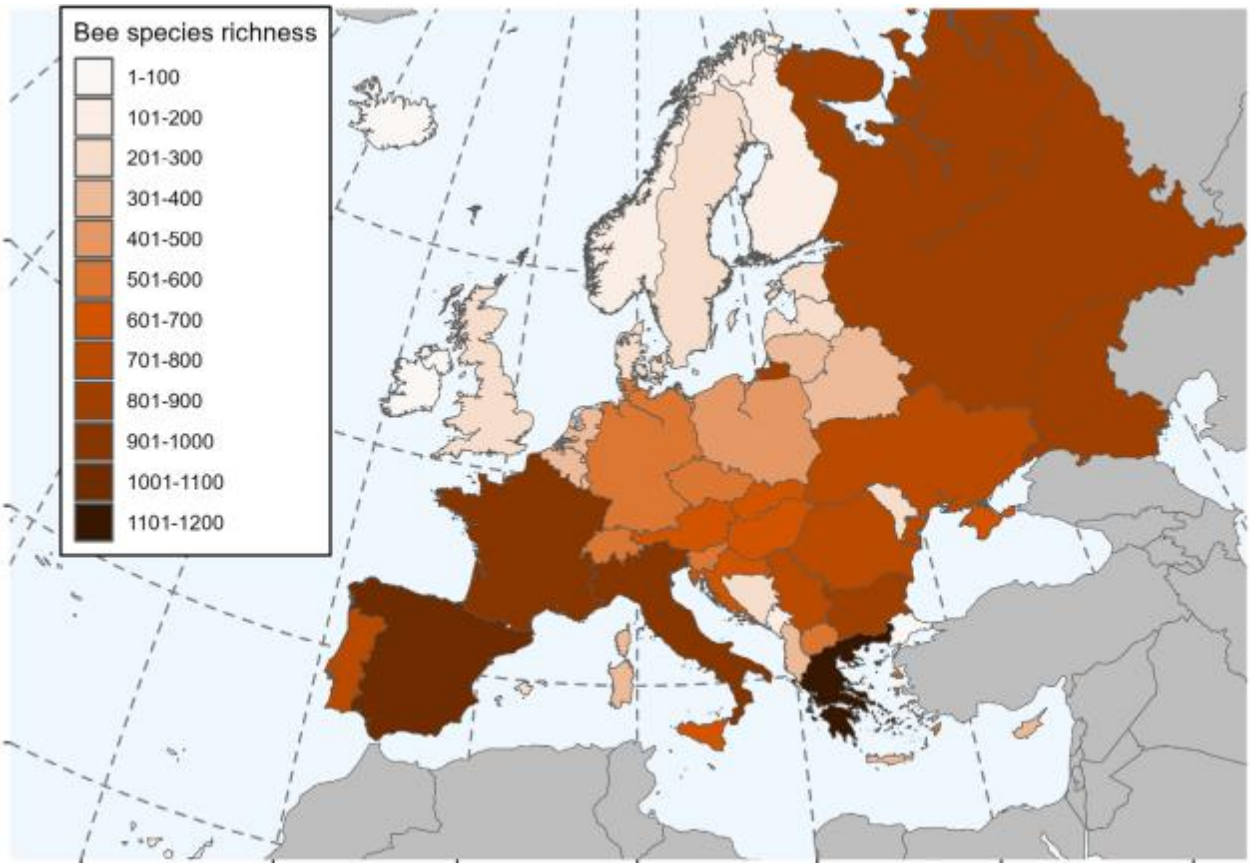
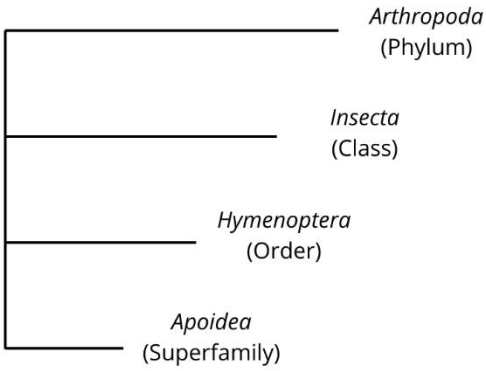


Fig.1: National records of European specie; source: National records of 3000 European bees and hoverfly species' S. Reverté et al., 2023

2.1.1 Classification

The bees are classified as below:





The bee species hosted in Europe are divided into six families and two groups (Tab. 2):

- Long-tongued bees: *Apidae* and *Megachilidae*
- Short-tongued bees: *Andrenidae*, *Colletidae*, *Halictidae* and *Melittidae*

The most prominent and diverse family of bees is the *Apidae* (561 species), which includes the honey bee and the bumblebees (*Bombus* spp.), while the least diverse family is the *Melittidae* with only 37 species. (Nieto et al., 2014).

Tab. 2: Bee classification

Family	Representative species	Number of species (Europe)	Sociality	Nesting	Distintive morphological feature
Andrenidae	*Andrena sp.* (mining bee)	455	Solitary, sometimes aggregations	Ground, preferring sandy or loose soils	Pollen-carrying hairs (scopa) on hind legs
Apidae	*Apis mellifera* (western honeybee)	561	Variable; eusocial (*Apis*, *Bombus*) and solitary	Cavities, trees, structures, or ground	Corbicula (pollen basket) on hind legs
Megachilidae	*Megachile rotundata* (alfalfa leafcutting bee)	441	Solitary	Cavities or soil; nests lined with leaves/resin/mu	Ventral scopa (on abdomen)
Halictidae	*Halictus rubicundus* (orange-legged furrow bee)	307	Solitary or primitively social	Ground, usually loose or sandy soils	Often metallic coloration; small, slender body
Colletidae	*Colletes succinctus* (common colletes)	141	Solitary	Ground or cavities; cells lined with waterproof secretions	Smooth, shiny body; often setose lining for cells
Melittidae	*Macropis nuda* (oil-collecting bee)	37	Solitary	Ground, often sandy soils; many oligoleptic habits	Morphology adapted to specific plants (specialized pollination)

2.1.2 Morphology

In common with all insects, the bees can be divided into three sections: head, thorax (Mesosoma), and abdomen (Metasoma) (Fig.2).

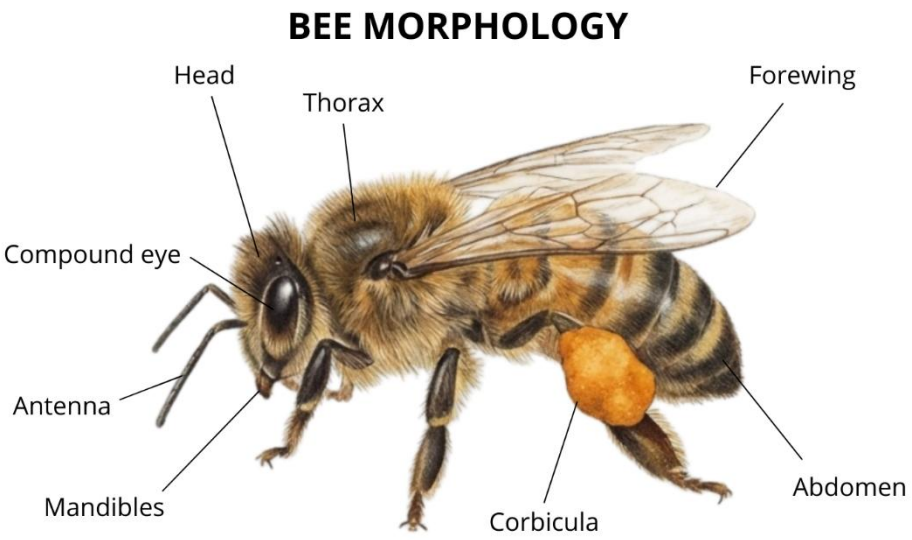


Fig. 2: Bee morphology



THE HEAD

- Like the other insects, has compound eyes called "ocelli", which contribute to light perception and orientation
- The antennae, consisting of 12 segments in females and 13 in males, function as key sensory organs involved in olfaction, mechanoreception, and intraspecific communication
- The mouthparts are of the chewing–lapping type, with robust mandibles used for manipulating nesting materials and a specialized proboscis (glossa) adapted for nectar uptake



THE THORAX (MESOSOMA)

- It's the center of locomotion
- It bears three pairs of legs, often modified for pollen collection
- Many solitary bees carry pollen using dense brushes of hairs (scopa) located on the hind legs or ventral abdomen, while some social bees (e.g. *Apis* and *Bombus*) possess structures known as the corbicula or pollen basket
- Bees have two pairs of membranous wings particularly important in the identification, with the forewings and hindwings coupled during flight by a series of small hooks (hamuli)



THE ABDOMEN (METASOMA)

- It contains the main internal organs, including those of the digestive and reproductive systems
- In social species, such as honeybees, the abdomen also bears wax glands used in nest construction
- The sting, present only in females, is a modified ovipositor and serves primarily for defense; in many solitary bees it is reduced and rarely used

If you want to know more about bee morphology check out this link:
https://pollinatoracademy.eu/knowledge-center/bee-anatomy-search-tool1

2.1.3 Life cycle

In most insects, including bees, the life cycle is composed of four distinct stages (holometabolous)**: egg, larva, pupa (or nymph), and adult (imago)** (Fig.3).

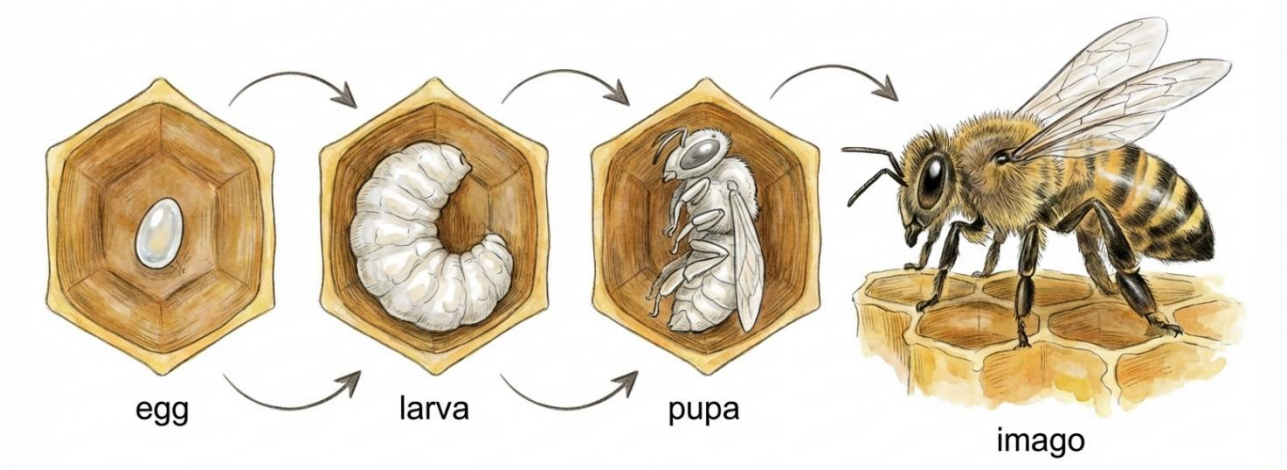


Fig.3: Bee's life cycle

However, within bees, there is considerable variation, not only in social organization (ranging from solitary → communal → eusocial), but also in the timing and structure of nesting and reproduction. The classical colony growth model (Macevicz & Oster,1976) for social insects describes an optimal resource allocation strategy characterized by the sequential production of workers during the early phases of the flight season, while the production of sexual individuals (males and future queens) toward its end. This reproductive strategy maximizes colony fitness.

In eusocial species, such as bumblebees (*Apidae*), and in communal species, including many sweat bees (*Halictidae*), nesting cycles typically follow well-defined phases of activity. During active phases, the reproductive female and/or nestmates collect resources, build nest, and provision brood cells; these phases alternate with periods of inactivity, when the nest remains closed (Mitesser et al., 2006).

Solitary species, including carpenter bees (*Xylocopa* spp.*)* and mason bees (*Osmia* spp.), show strategies that differ markedly from those of social taxa. Adult female lives independently, without cooperation with conspecifics. Depending on the species, nests may be built in soil, pre-existing cavities, in rock crevices, or using glandular secretions produced by the female, often forming resinous or plastic-like materials.

The female typically lays from a few to several dozen eggs: each deposited in a separate larval cell provisioned in advance with food resources required for larval development. After several weeks, the larvae complete its growth and pupates; the pupal stage remains inactive within the cell for several months.

Adult emergence occurs over a species-specific period that may range from early spring to late summer, depending on environmental conditions and life-cycle phenology.

An alternative reproductive strategy is cleptoparasites. So-called "cuckoo bees" lay their eggs in the nests of other bee species, exploiting the eusocial behaviour or parental care of their hosts. This strategy allows cleptoparasitic species to reproduce while avoiding the energetic costs associated with nest construction and brood rearing, providing a significant evolutionary advantage under certain ecological conditions (Dozier et al., 2023).

2.1.4 Bees or Wasp

The 5 characteristics that help to distinguish some bee genera to wasp are showed in the picture below (Fig.4).

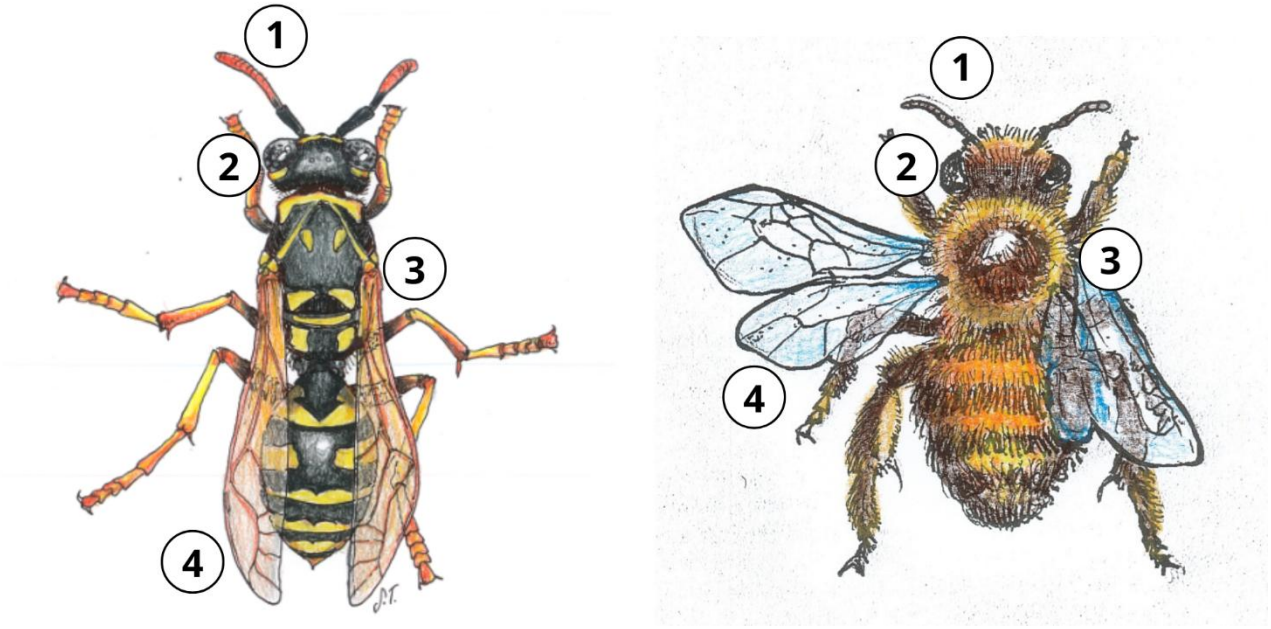


Fig.4: Different characteristic between wasp and bee

1. Bees have straight **eye** contours
2. Bees never fold their **wings**
3. Female social and solitary bees have structures on their **hind legs** or **abdomen** to collect pollen. Except for some parasite bee (*Nomada* spp.) that doesn't have structures to collect pollen
4. Some wasps can have **bulky heads** or enlarged eyes
5. Wasps can have **legs with thick spines** and **constrictions on their abdomen.**

2.2 Hoverflies (*Diptera Syrphidae*)

Hoverflies, often referred to as "*the most beautiful flies in the world*" (Parvu, 2011), represent one of the largest and most diverse families within the order Diptera.

Hoverflies are well known as important flower visitors and effective pollinators in both natural and agricultural ecosystems, Sarthou and Speight (2005) describe these insects as good indicators of the ecosystem quality. They are also known for **Batesian mimicry**; a phenomenon in which a non-venomous insect (*Syrphidae*) mimics, in its morphology, coloration, or behaviour, another potentially dangerous insect (*Hymenoptera*).

The family name derives from the English term "*hovering*", referring to their characteristic suspended flight, made possible by the reduction of the second pair of wings into halteres. From a taxonomic perspective, wing venation, particularly the presence of the **spurious vein** (Fig.5), is the primary diagnostic character distinguishing *Syrphidae* from other dipteran families.

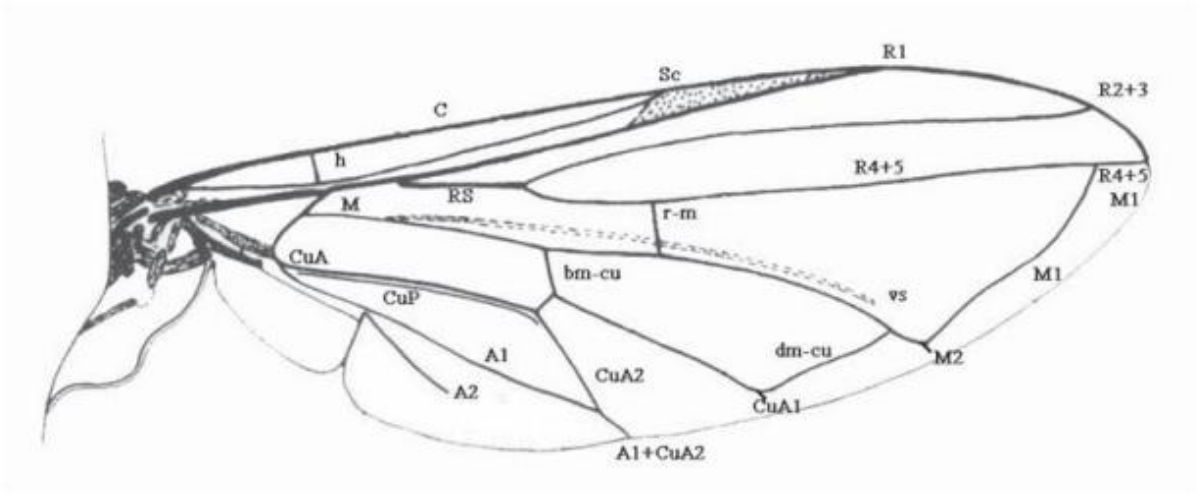


Fig.5: Spurious vein; source: Stubbs A.E., Falk S., 2002

According to the most recent European checklist, 913 species are currently recorded across Europe, with a high level of endemic alpine diversity concentrated in mountainous regions of France, Italy, Switzerland, and Germany (Fig. 6).

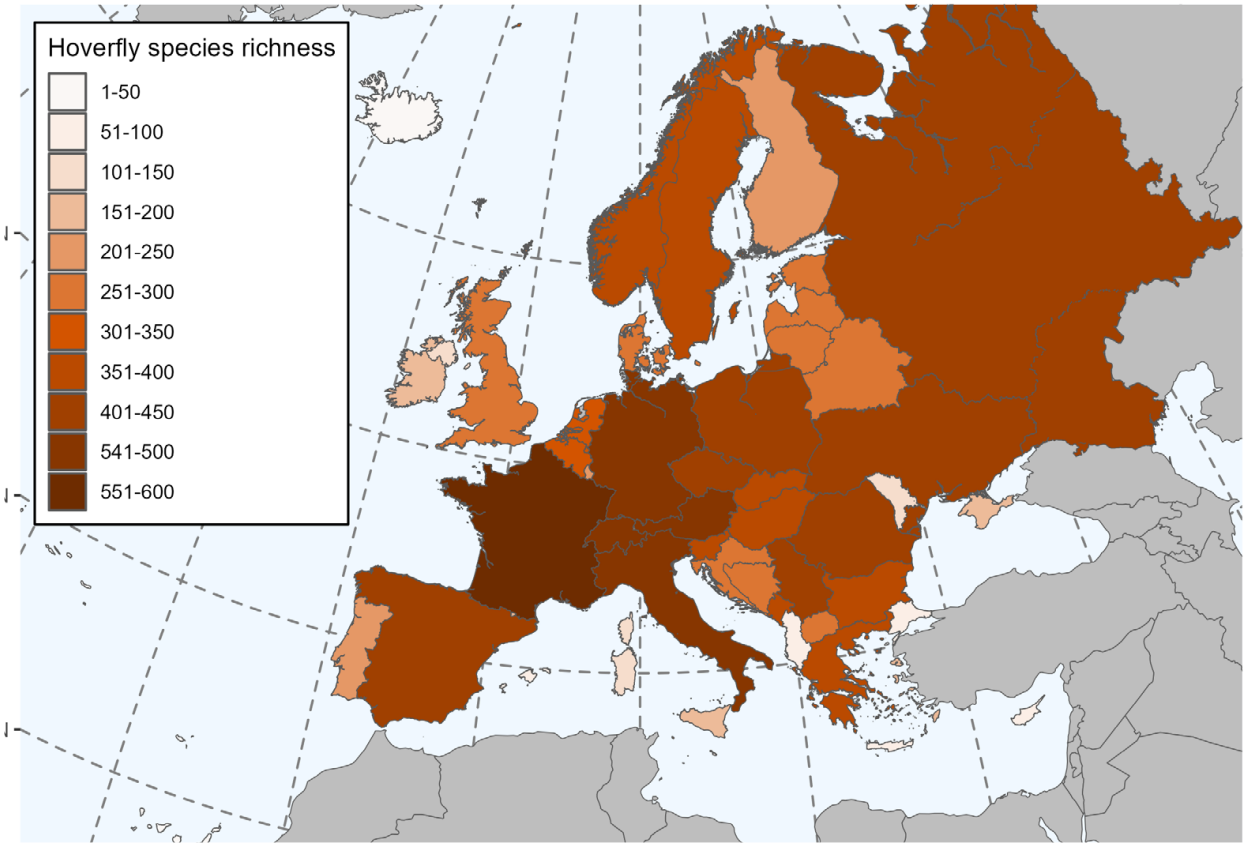
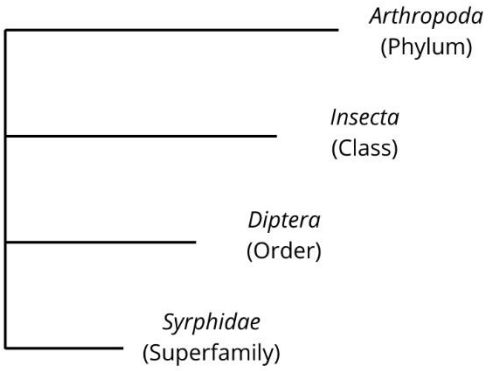


Fig.6: National records of European species; source: National records of 3,000 European bee and hoverfly species; Reverté et al., *2023*

2.2.1 Classification

The Hoverflies are classified as below:





Hoverflies exhibit numerous specific characters but few generic characters and for this their systematic classification has proven particularly complex over time. Only in recent years has a widely accepted subdivision been achieved, based mainly on larval characters, dividing the family into four subfamilies: *Eristalinae* (62% of the described hoverfly fauna), *Syrphinae* (29%), *Microdontinae* (7%), and *Pipizinae* (3%) (Burgio et al., 2015) (Tab.3).

Tab.3: Hoverfly classification

Subfamily	Representative species	Approx. number of species (Europe)	Adult Traits	Notes
Syrphinae	*Episyrphus balteatus*	~250–260	Often brightly coloured; strong mimicry of bees and wasps	Major contributors to pollination services and biological control
Eristalinae	*Eristalis tenax*	~550–560	High morphological variability; includes the so-called "drone flies"	Frequent flower visitors; important generalist pollinators
Microdontinae	*Microdon mutabilis*	~60	Morphologically atypical; adults often resemble ants rather than hymenopterans	Rarely observed on flowers; limited role in pollination
Pipizinae	*Pipiza noctiluca*	~25	Small, inconspicuous adults with weak or absent mimicry	Minor contribution to pollination services

2.2.2 Morphology

In common with all insects, the Hoverflies can be divided into three sections: head, thorax and abdomen (Fig.7).

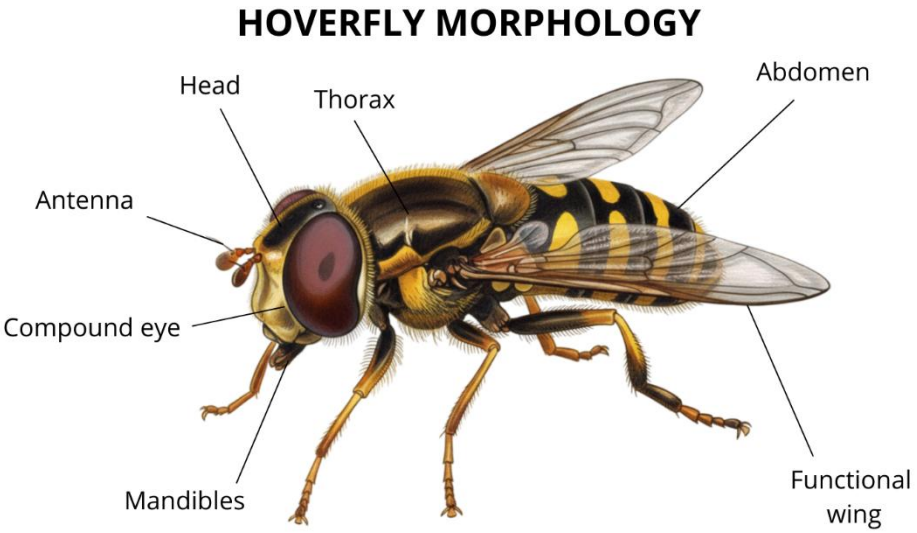


Fig.7: Hoverfly morphology



THE HEAD

- As in other insects, the head bears a pair of compound eyes, which are usually uniformly colored but may exhibit species-specific patterns
- Sexual dimorphism is evident in eye arrangement: in males the eyes are holoptic, touching or nearly touching at the top of the head, whereas in females they are dichoptic, separated by a distinct frons
- The compound eyes play a key role in light perception and spatial orientation
- The antennae of adults consist of three segments (scape, pedicel, and flagellomere); in most taxa, the flagellomere bears an arista, whose presence and morphology may vary among genera
- The mouthparts are of the lapping–sucking type, forming a proboscis with a well-developed labellum adapted for nectar uptake
- The facial profile represents an important diagnostic character and is frequently used in dichotomous identification keys



THE THORAX

- It is the center of locomotion and bears the wings and legs
- Hoverflies possess a single pair of functional wings adapted for flight, while the second pair is reduced to halteres, which function as gyroscopic organs for balance
- Wing venation is a key taxonomic character and is widely used to distinguish Syrphidae from other dipteran families
- Three pairs of legs are present; their morphology, including the presence of specialized structures, when considered in combination with wing venation, can assist in species or genus-level identification.



THE ABDOMEN

- It contains the principal internal organs, including those of the digestive and reproductive systems
- Its shape and surface characteristics are variable and taxonomically informative: it may be petiolate (constricted), flattened, or distinctly pubescent
- Abdominal morphology is therefore an important diagnostic character in species identification
- Abdominal coloration may be influenced by environmental factors, such as larval developmental temperature, and can therefore vary considerably within the same species

If you want to know more about hoverfly morphology check out this link:
https://pollinatoracademy.eu/knowledge-center/hoverfly-anatomy-search-tool

2.2.3 Life cycle

Hoverflies, like all insects of the order *Diptera*, have complete metamorphosis (holometabolous) with four distinct life stages: **egg, larva, pupa, and adult** (Fig.8).

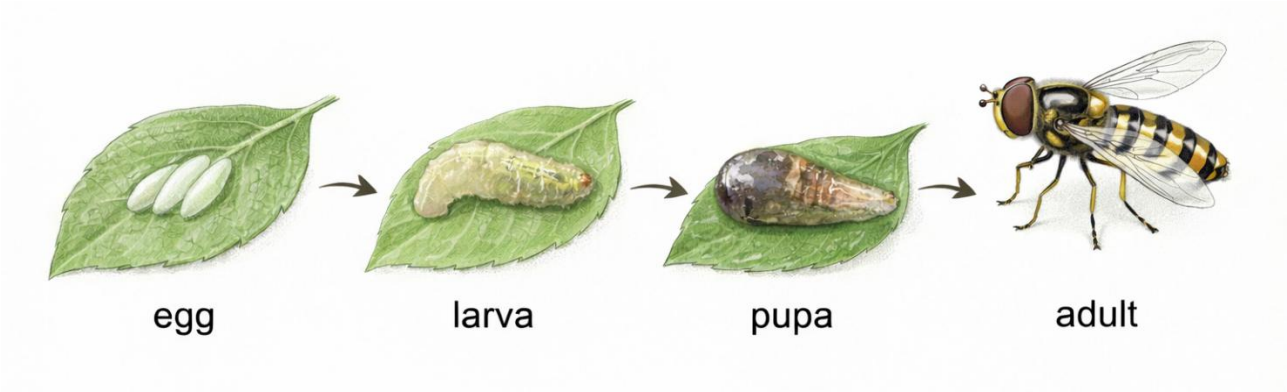


Fig.8: hoverfly's life cycle

Among these stages, the larval phase exhibits the greatest diversity in morphology and feeding strategies, reflecting strong ecological specialization across species (Rotheray & Gilbert, 2011). These differences are closely linked to species-specific habitat requirements and ecological niches.

Depending on the species, the life cycle may be completed once, twice, or several times per year. Accordingly, species are classified as univoltine, bivoltine, or multivoltine. Migratory species are typically included among multivoltine taxa, as migration allows them to exploit seasonal resources across different regions.

Based on the feeding strategy of the larval stage, hoverfly larvae can be broadly categorized as follows:

- Phytophagous, feeding on living plant tissues
- Predatory, mainly consuming aphids and other soft-bodied arthropods
- Aquatic saprophagous, feeding on microorganisms in aquatic or semi-aquatic environments
- Saproxylic, associated with decaying wood and tree cavities
- Coprophagous, developing in dung or manure
- Myrmecophilous, developing within ant nests and feeding on ant brood



Syrphinae

- Composed predominantly of aphidophagous species
- Larvae are free-living predators that develop externally on plants, where they feed on aphids and other soft-bodied arthropods (Rotheray & Gilbert, 2011)
- Many larvae exhibit cryptic coloration, which enhances protection from visually oriented predators during foraging activities
- Adults are among the most effective dipteran pollinators, frequently visiting a wide range of flowering plants for pollen and nectar
- Several species display seasonal migratory behavior, moving toward southern Europe to overwinter or reproduce, thereby contributing to long-distance pollen transfer and landscape-scale pollination services (Aubert et al., 1976; Sutherland et al., 2016)



Eristalinae

- Represents one of the most ecologically diverse subfamilies of *Syrphidae*
- Larval stages occupy a wide array of microhabitats and exhibit diverse feeding strategies
- Many species have saprophagous larvae that feed on microbial communities, such as yeasts and bacteria, associated with decomposing organic matter, including tree sap, decaying wood, compost, and organic sediments in ponds and streams (Rotheray, 1993)
- Other taxa include phytophagous or semi-aquatic larvae, reflecting high ecological plasticity



Microdontinae

- Highly specialized subfamily with a unique ecological strategy
- Larvae are obligatory myrmecophiles, developing inside ant nests where they feed on ant eggs and pupae (Howard et al., 1990; Witek et al., 2014)
- This association with ants involves morphological and chemical mimicry that allows larvae to evade host defenses
- Due to their specialized life cycle, *Microdontinae* are typically rare and localized.
- Although adults may visit flowers, their contribution to pollination is considered limited compared to other syrphid subfamilies.



Pipizinae

- The Larvae of the *Pipizinae* are aphidophagous, often showing a high degree of specialization toward aphid groups
- Several species are known to prey on gall-forming aphids, including those inducing leaf and petiole galls on poplar trees (*Populus spp.*), as documented by Kurir (1963)

2.2.4 Hoverfly or bee

The 4 main characteristics that help to distinguish Hoverfly from Wild bee are showed in the picture below (Fig.9).

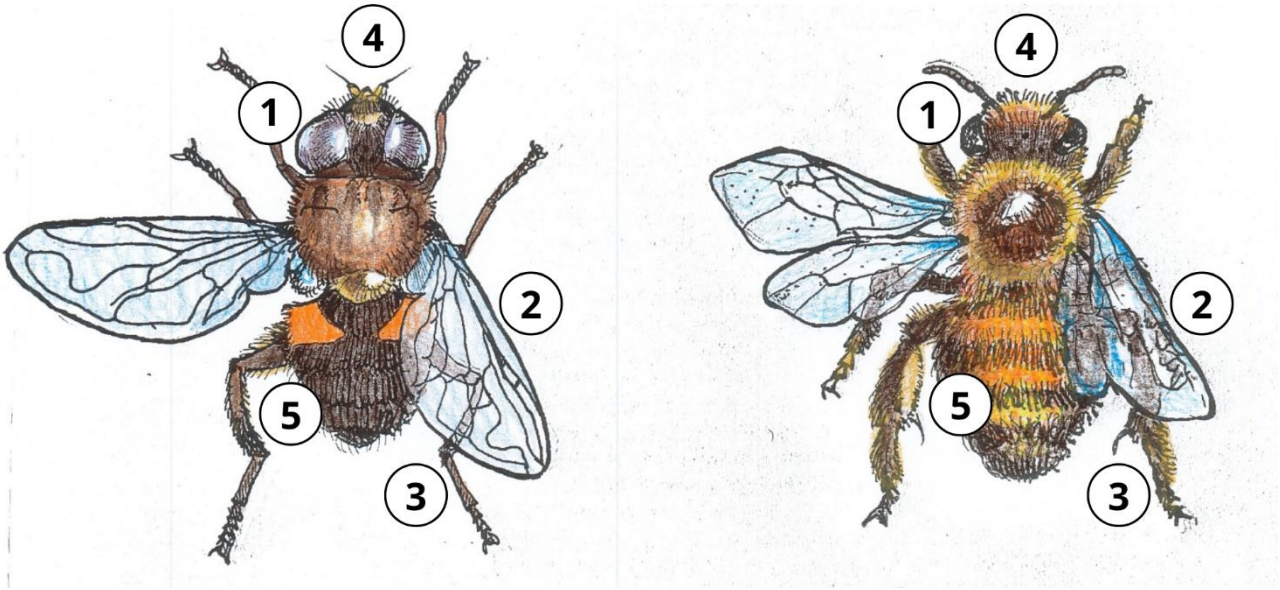


Fig. 9: Different characteristic between hoverfly and bee

1. Hoverflies have short **antennae** (3 segments)
2. Hoverflies have larger **eyes** that cover the width of the head
3. Hoverflies have **abdomen** with different shape (petiolate, flat, pubescent…), mainly colored yellow

and dark pattern

4. Hoverflies have only one pair of functional **wings**

2.3 Butterflies (*Lepidoptera, Rhopalocera*)

Butterflies constitute one of the best-known groups of insects and have become important models to study speciation, community ecology, biogeography, climate change, and insect-plant interactions (Wiemers et. al., 2018). Butterflies are a large group of insects, belonging to the order "*Lepidoptera*", which means "scaly wing".They are characterized by their large, scale-covered, flattened, and modified wings, often coloured, and are known to be the most attractive for public in the three pollinators group. Their beautiful and delicate wing colours enhance the aesthetic value of environment.
Butterflies make up a tiny fraction (about 10%) of the order *Lepidoptera*, the rest of which is primarily composed of moths. This generic term encompasses many species that mostly fly at night.

According to the latest IUCN assessment, Europe hosts as many as 482 species of butterflies, 37 of which (8,5%) are threatened and nearly 30% of them are endemic to the region. Italy, Spain and France are the three most species-rich countries, with particularly high numbers of endemic species are found in the Alps and the Pyrenees. Other important concentrations of endemics are found in mountainous areas in Spain (e.g. Sierra Nevada and Cantabrian Mountains) and in Italy (the Apennines) (Fig. 10).

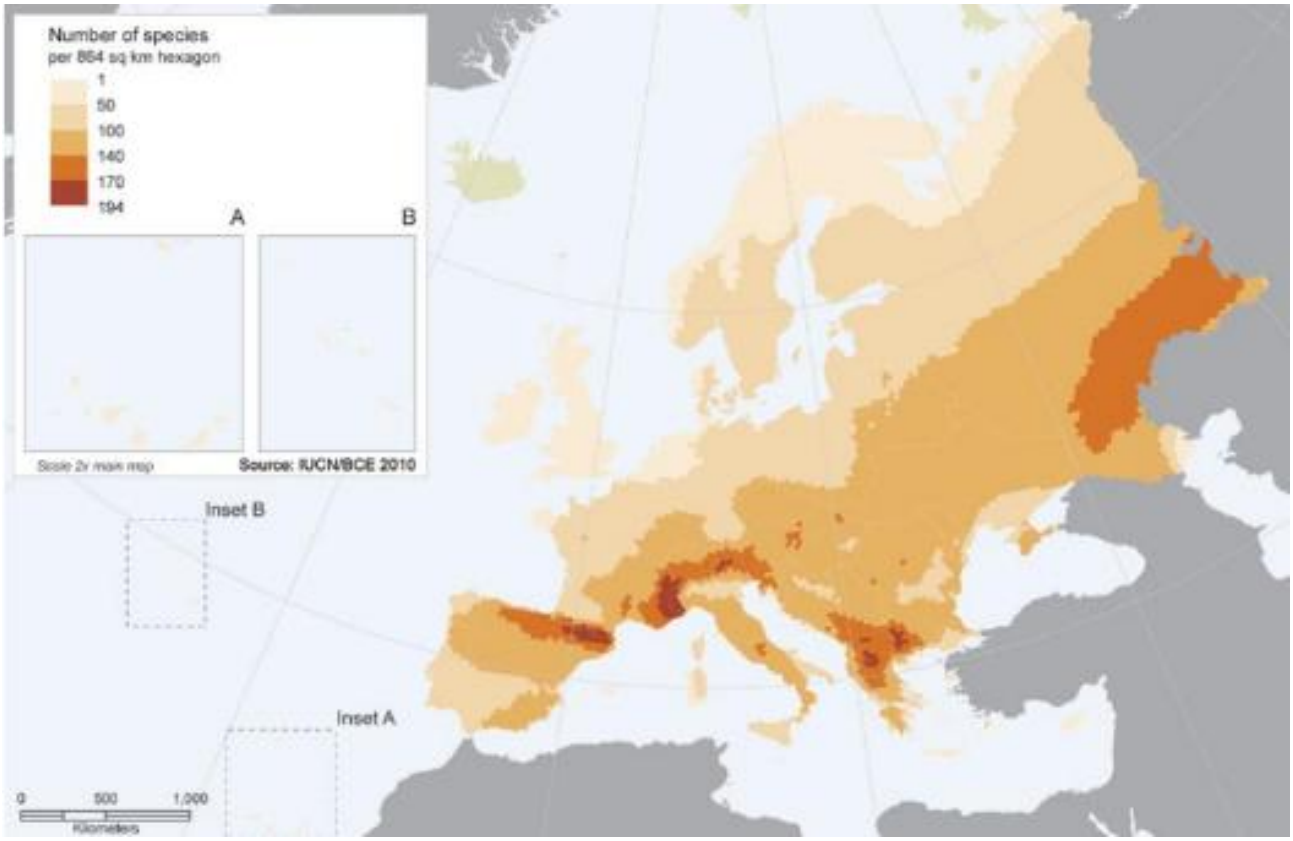
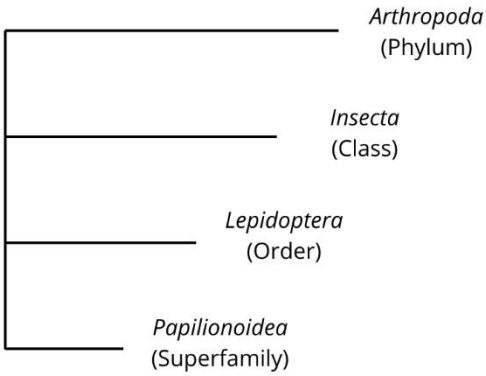


Fig. 10: National records of European species; source: IUCN Red List, 2025

2.3.1 Classification

Butterflies are classified as below:





The updated species list of European butterflies includes 496 species, which belong to 110 genera in 21 subfamilies and six families (Wiemers et al., 2018) (Tab. 4).

Tab. 4: Butterfly classification

Family	Representative species	Approx. number of European species	Distinctive Morphological Feature
Papilionidae	*Papilio machaon*	15	Hindwing often scalloped or bearing a tail (Papilioninae); forewing edge transparent and without scales (Parnassiinae); some caterpillars possess an eversible osmeterium
Pieridae	*Pieris brassicae*	50	Variable body size (small to medium); white, yellow and orange ground colour; often strong sexual dimorphism
Lycaenidae	*Polyommatus icarus*	200	Small size; often iridescent blue or copper colours; frequent sexual dimorphism; common myrmecophily
Nymphalidae	*Vanessa atalanta*	250	Very diverse in size, shape, and color; forelegs reduced and non-functional for walking ("brush-footed")
Hesperiidae	*Ochlodes sylvanus*	50	Large, broad head; thick, massive thorax; relatively small wing area; hooked antennae; rapid, skipping flight
Riodinidae	*Hamearis lucina*	1	Small butterfly with orange-brown wings; metallic patterning

2.3.2 Morphology

In common with all insects, the Butterflies can be divided into three sections: head, thorax and abdomen (Fig.11).

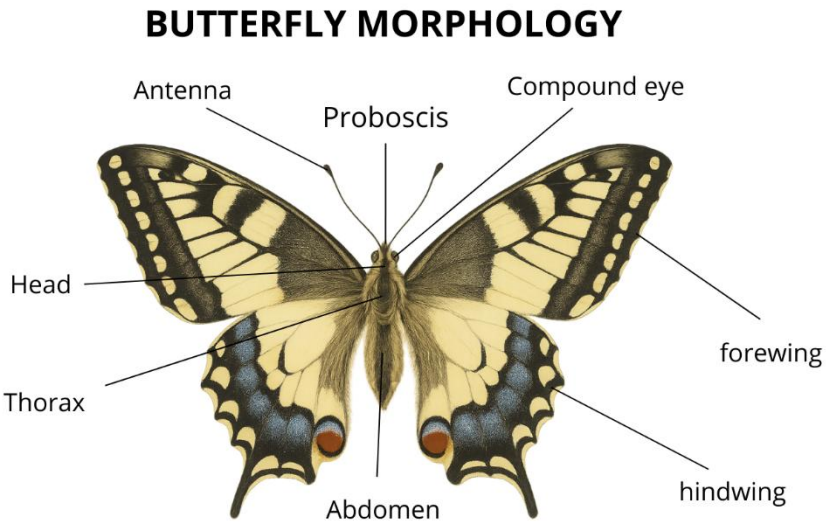


Fig. 11: Butterfly morphology



THE HEAD

- As in Wild bees, Hoverflies and other insects, the head bears a large pair of compound eyes
- The compound eyes play an important role in color perception, detecting reflected UV rays, for that reason many flowers change color when exposed to white light or UV rays
- The antennae in adults are club-shaped antennae and are used as powerful sensory
- The mouthpart, also called **proboscis**, is a long and tubular structure used for sipping liquids like nectar. It's not a true tongue but a tube formed from elongated mouthparts that unroll to feed and coil up tightly beneath the head when not in use, acting like a flexible straw or sponge for a liquid diet



THE THORAX

- It is the center of locomotion and bears the wings and legs
- Butterflies possess 3 pairs of legs and 2 pairs of functional membranous wings adapted for flight
- The wings, that can display a wide range of colors, are covered with scales that cover them like shingles on a roof
- Colors are both physical (optical phenomena) and chemical (pigments)
- The veins are traversed by tracheae and hemolymph and have different shapes
- The wings often look very different at the upper side and under side. It is important to keep this in mind when identifying butterflies.



THE ABDOMEN

- It contains the principal internal organs, including those of the digestive and reproductive systems
- Down the sides of the abdomen are tiny holes called spiracles, which enable the butterfly to breathe

If you want to know more about butterfly morphology check out this link:
https://pollinatoracademy.eu/training/eu-courses/taxonomy-butterfly-courses/butterfly-preliminary

2.3.3 Life cycle

Butterflies are holometabolous insects undergoing complete metamorphosis (holometabolous), a process regulated by a complex endocrine system. Their life cycle comprises four distinct stages: **egg, larva (caterpillar), pupa (chrysalis), and adult (Imago)** (Fig.12)**.**

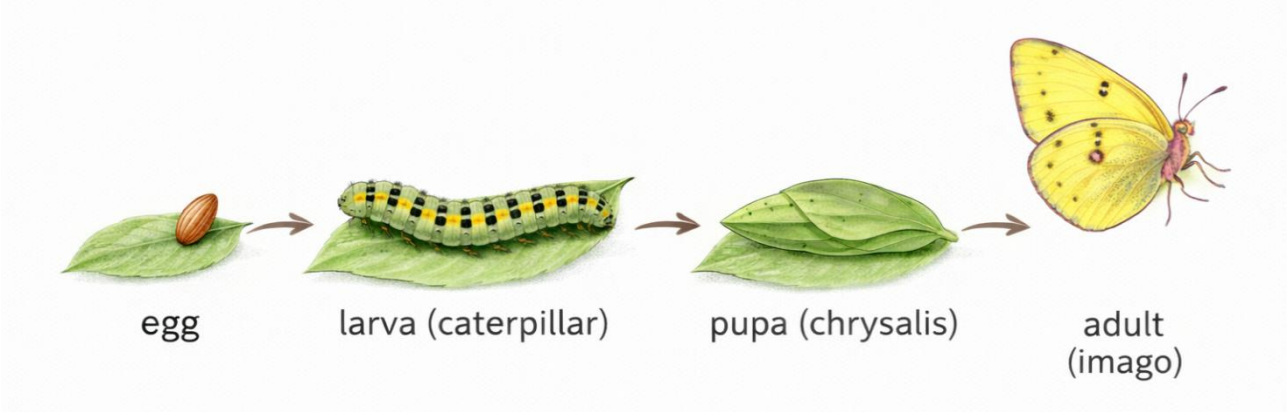


Fig. 12: Butterfly's life cycle

The transition through the immature stages is essential for reaching an adult, winged form capable of reproduction and, in many species, pollination.

Adult females lay their eggs on specific host plants, which subsequently provide food for the emerging larvae. Among the 471 European butterfly species for which larval host plants are known, a total of 1,506 plant species belonging to 72 botanical families are utilized. Based on larval feeding specialization, butterfly species can be classified as monophagous (20%), feeding on a single plant species or genus; oligophagous (50%), feeding on a limited group of related plants; or polyphagous (30%), feeding on a wide range of host plants. Notably, *Celastrina argiolus* is able to exploit host plants from 19 different families. While most plant families support fewer than six butterfly species, *Poaceae* and *Fabaceae* are particularly important, hosting the highest number of species. Similarly, although most plant species are used by only a few butterflies, *Festuca ovina* and *Festuca rubra* are exploited by a remarkably large number of species (Clarke, 2022).

The larval stage is primarily dedicated to feeding and growth. Once fully developed, the caterpillar enters the pupal stage, forming a chrysalis that may be suspended from vegetation, concealed among leaves, or buried in the soil, depending on the species. The duration of this stage varies widely, lasting from a few weeks to several months; in some species, pupae may remain in diapause for up to two years.

Adult butterflies are mainly devoted to reproduction, mating and oviposition. Many species obtain energy by feeding on floral nectar, thereby contributing to pollination, although some species do not feed during the adult stage. Adult lifespan is typically short, often one to two weeks; however, species that overwinter as adults may survive for several months. According to the number of generations produced per year, butterfly species are classified as univoltine, bivoltine, or multivoltine, a trait strongly influenced by climatic conditions and host plant availability (Stefanescu et al., 2003).

2.3.4 Butterfly or Moth

The shape of the antenna is an important characteristic to determine if it is a butterfly or a moth.



BUTTERFLIES

- The antennae end in a club-shaped apical dilation
- Mainly active during the day
- Wings folded vertically above their backs when resting



MOTHS

- The antennae can have various shapes: filiform, sickle-shaped, pectinate, bipectinate, etc
- Mainly active at night
- Wings held in a roof-like position or horizontally when resting

3. Monitoring methodologies

This chapter describes the standardized monitoring methodologies adopted within the Zoo LIFE Pollinators project to collect comparable and high-quality data on insect pollinators and vegetation across all partner sites. The proposed methods are designed to be scientifically robust while remaining feasible for zoo staff with basic training, ensuring consistency, repeatability, and compatibility with national and European monitoring schemes.

The insect pollinator monitoring methodology is focused on the three main groups of pollinating insects targeted by the project (*Apoidea, Lepidoptera (Rhopalocera)* and *Syrphidae*) and combines transect surveys, based on the **Pollard transect methodology** adopted by the European Butterfly Monitoring Scheme (eBMS), with fixed-time counts (optional).

In addition to entomological monitoring, Zoo LIFE Pollinators will carry out phytosociological surveys and count entomogamous floral units at five fixed 1 m² points along each partner's transect to assess the status and effectiveness of ecological restoration measures.

3.1 Standardized methods

All monitoring activities must follow standardized protocols to ensure data comparability among sites and over time. Each site adopts formally approved transects, which must be surveyed following the same procedures throughout the entire monitoring period.

Sampling is carried out:

- From March to October, or restricted to a shorter period in northern Europe
- Wild bees, honey bees and Hoverflies, Monthly session
- Butterfly, 7-15 days session
- Suitable weather conditions for insect activity: sunny or lightly cloudy days (cloud cover < 50%), air temperature suitable for insect flight (approximately ≥14 °C), and absent or weak wind (maximum Beaufort scale 3) (See Fig.13).

Beaufort number	Wind Speed (mph)	Seaman's term		Effects on Land
0	Under 1	Calm		Calm; smoke rises vertically.
1	1-3	Light Air		Smoke drift indicates wind direction; vanes do not move.
2	4-7	Light Breeze		Wind felt on face; leaves rustle; vanes begin to move.
3	8-12	Gentle Breeze		Leaves, small twigs in constant motion; light flags extended.
4	13-18	Moderate Breeze		Dust, leaves and loose paper raised up; small branches move.
5	19-24	Fresh Breeze		Small trees begin to sway.

Fig. 13: Beaufort scale; Source: Butterfly monitoring scheme

To minimize observer-related bias, sampling should preferably be carried out by the same operator over time. However, it is recommended that operators specialize by taxonomic group when possible. Depending on site organization, monitoring can be performed by:

- one single operator surveying all three groups,
- three different operators, each responsible for one group (**MAIN METHODOLOGY SELECTED**)
- or two operators, dividing the groups between them.

Before scheduling a survey, it is essential to verify that no other activities potentially affecting pollinators (e.g. insect sampling, chemical treatments, mowing) are planned near the transects or plots. Such activities must not occur on the same day and should be temporally separated.

Operators are advised to wear appropriate field equipment, including a sun hat and water bottle during hot days, and must always carry an entomological net, field guides for bees, butterflies and hoverflies, transparent observation boxes, plastic vials filled with 70% ethanol, labels, and a pencil or waterproof ink pen.

For documentation and communication purposes, at least one photograph of each transect should be taken and archived, together with additional field photos collected during surveys.

3.1.1 Transect: description of the proposed methodology for the three groups

Each transect within the project has a fixed length, between 500-1000 m long, defined at site level. Although absolute length may vary slightly among sites due to local characteristics, all operators must strictly follow the formally approved transect layout.

Transects must be subdivided into segments according to habitat type. Each segment is identified with a specific code (e.g. S1, S2, S3), which must be reported on the field data sheet for each observation (See Fig 14).

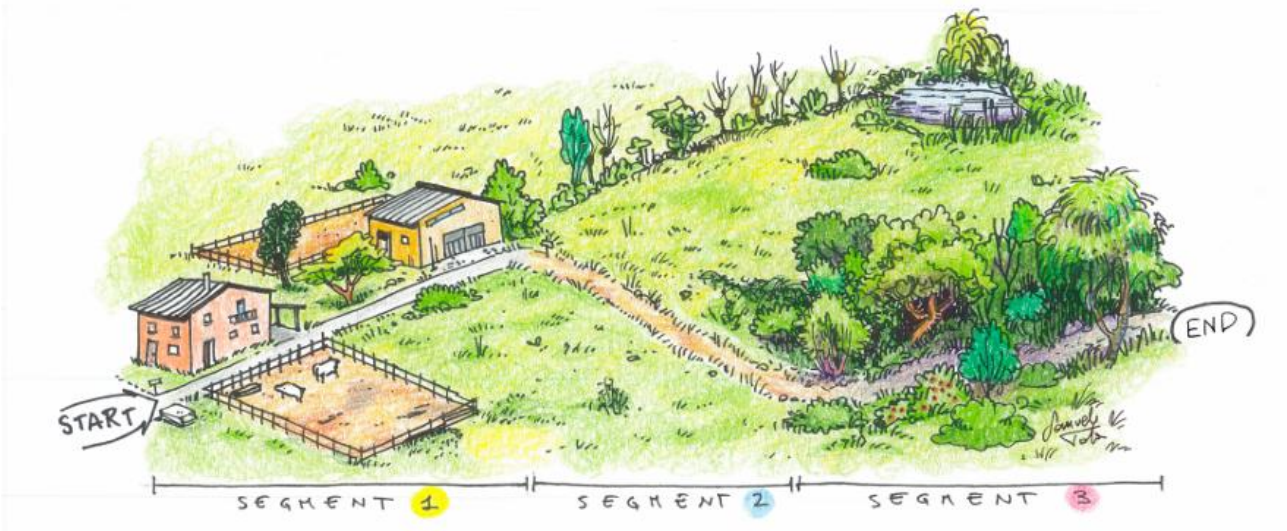


Fig. 14: Example of transect sections

Each transect must always be walked entirely from one end to the other at a slow and constant pace. As a reference, a 500-m transect should be completed in approximately 50 minutes. During a single monitoring session, the transect is walked three times (outward, return, and outward again). At each passage, only one taxonomic group is surveyed.

From the start of each passage, all pollinators belonging to the target group observed within an imaginary sampling volume are recorded (See Fig. 15):

- for butterflies: a cube 5 m wide (2.5 m on each side)
- for wild bees, honey bees and hoverflies: a cube 4 m wide (2 m on each side).

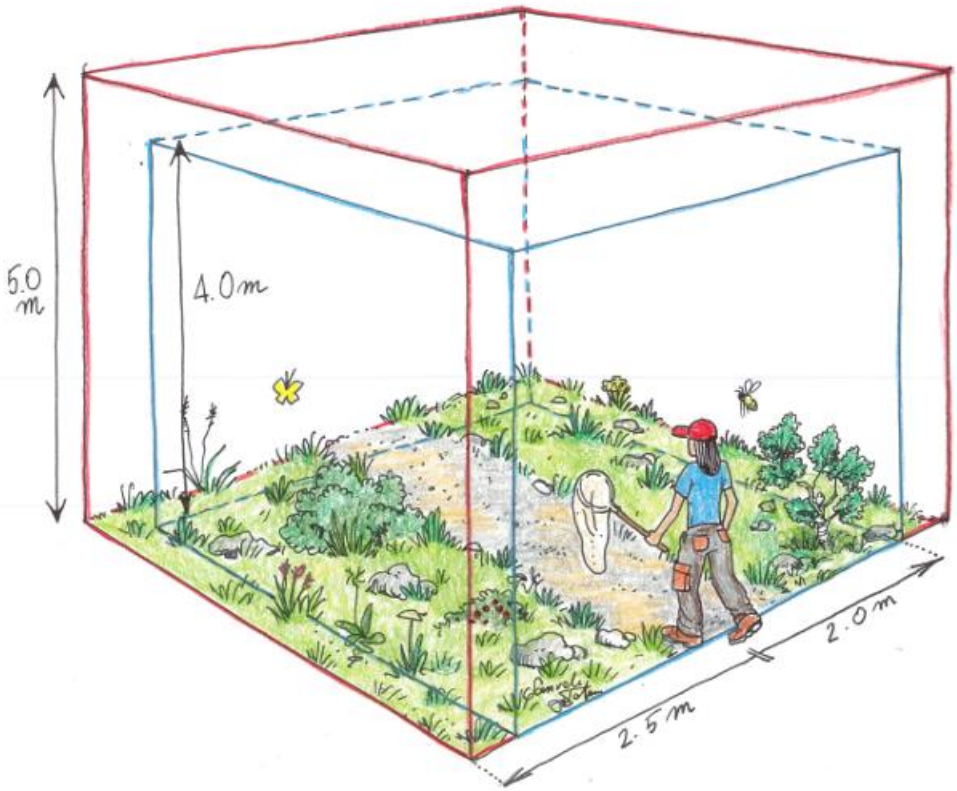


Fig. 15: Example of the transect monitoring survey

Only individuals observed in front of the operator are counted; insects approaching from behind are excluded.

All observations must be recorded on the official field data sheet, reporting for each survey: operator name(s), unique transect code, date, start and end time, cloud cover, wind conditions (Beaufort scale), number of the segment and average grass height per segment, relative abundance (number of individuals observed) and species' name or other taxonomic classification level (genus, morphogroup…). Below you can see an example of field data sheet (See Fig. 16). Specific templates will be provided.

BUTTERFLY MONITORING SCHEME
FIELD SHEET

TRANSECT NAME _____ OBSERVER _____

DATE _____ WEEK _____ START TIME _____ END TIME _____

START/ END TEMP (°C) _____ / _____ START / END WIND SPEED BEAUFORT SCALE _____ / _____

AVERAGE TEMP (°C) _____ AVERAGE WIND SPEED BEAUFORT SCALE _____

BEAUFORT SCALE: 0 - Calm, smoke rises vertically; 1 - Smoke drift indicates wind direction, still wind vanes; 2 - Wind felt on face, leaves rustle, vanes begin to move; 3 - Leaves and small twigs constantly moving, light flags extended; 4 -Dust, leaves, and loose paper lifted, small tree branches move; 5 - Small trees in leaf begin to sway

	SECTIONS										
SPECIES	1	2	3	4	5	6	7	8	9	10	TOTAL
TOTAL											

Average cloud cover

CLOUD COVER											

NOTES:

Fig.16: example of field data sheet

If an insect needs to be captured for identification, the operator should perform a quick horizontal sweep with the entomological net and rapidly rotate the wrist to trap the insect at the bottom of the net. The specimen can then be gently transferred into a transparent box for closer observation, comparison with field guides, or photography.

If identification is successful in the field, the specimen must be released**. Only for hoverflies, honey bees and wild bees, if the insect was observed on a flower, the flower colour (or the species name if known) should be recorded on the data sheet.**

During capture and identification, the effective walking time of the transect is paused and resumed once sampling continues. You may stop (e.g. to take a picture), but do not count when you are stationary, or when looking behind. This will boost the number of insect pollinators seen in a non-standard way.

If weather conditions suddenly become unsuitable (rain, strong wind, or other prohibitive conditions), the transect must be interrupted and resumed as soon as conditions allow.

All individuals are recorded at species level whenever possible, including abundance. If identification to species is not feasible, records may be assigned to tribe, genus, or morphogroup, as described in later chapters of this handbook. Individuals observed within the sampling volume but escaping before identification should be noted in the comments, specifying the uncertainty.

Only butterflies can be recorded directly using the BMS app (eBMS - mobile application | European Butterfly Monitoring). Wild bees, honey bees and hoverflies can be recorded only in the project Excel file, which must be carefully archived.

WHAT IF THE IDENTIFICATION IS NOT SURE?

If identification is uncertain and collection is required, the specimen should be transferred into a plastic vial containing 70% transparent ethanol. This is done by keeping the vial vertical and allowing the insect to enter the liquid without spilling. The insect dies rapidly and can be preserved indefinitely.

Each vial must:

- Be labelled with a card written in pencil or waterproof ink (including transect code and date) placed inside the vial, and an additional external label with the same information (See Fig. 17).
- Corresponding code must be reported on the field sheet
- Collected material must be stored at room temperature until the end of the season and then shipped to Fondazione Zoom, where it will be examined by expert taxonomists.



Fig.17: Example of labelling

Each shipment must be packed in a robust box, with vials protected against movement, and labelled as "**laboratory material for LIFE project**" to avoid transport issues.

For doubtful butterfly identifications, specimens should be photographed inside a transparent box (preferably with magnification) and images sent to the regional BMS contact or to Simona Bonelli (See contact in Annex 5.3 “Useful contacts”)

For doubtful wild bees or hoverflies, specimens must be collected and preserved in ethanol and later sent for expert identification (See contact in the Annex 5.3 “Useful contact”).

As good practice, some specimen per species or morphogroup of wild bees and hoverflies should be collected at each site to build a reference collection for further support in identification process or educational purposes. **The creation of a reference collection is optional and left to the discretion of each individual partner.**

These specimens can be prepared dry by pinning and stored in an entomological box with labels reporting date, location, genus, and species as described in the video below, while doubtful specimens must always be kept in ethanol.

The pinning methodology for hoverflies involves inserting the pin through the thorax. This technique is valid only for syrphids; for wild bees and honey bees, pinning is a very delicate process that can compromise subsequent identification.

The following video demonstrates the correct procedure: Pinning Bees - instruction video | Rise 360

For the first surveys, collected data should be shared with Fondazione Zoom and the group experts for formal and technical validation. Experts remain available for support throughout the monitoring activities. The following diagram summarizes the flow of actions planned for different situations (see fig. 18).

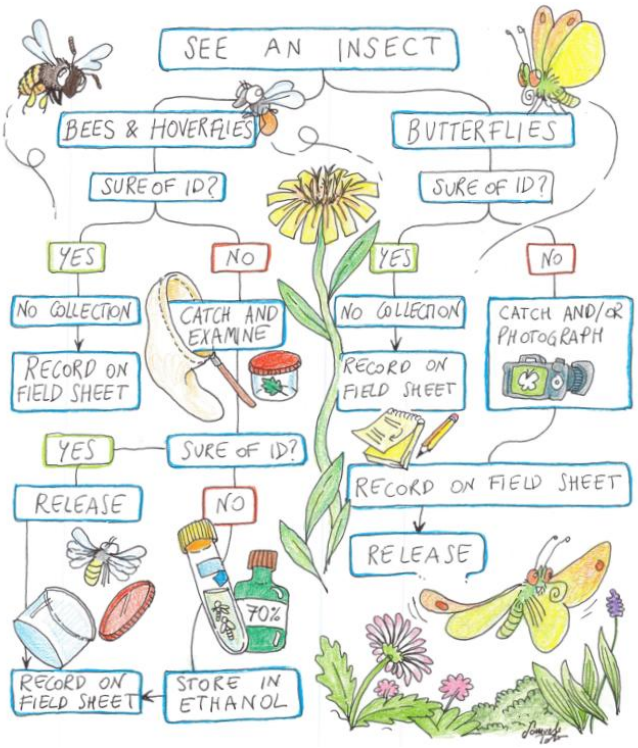


Fig.18: flow of actions planned for different situations

SETTING UP YOUR TRANSECT (MAIN METHODOLOGY)

- When you decide the place to set up the transect, be sure to recognize the sections of the transect by landmarks. This is convenient for you and helps anyone else who might do the transect. Try to use natural landmarks such as poles, prominent trees or other artificial landmarks (e.g. fences or paths) as starting points for each section. If possible, mark the start and end of each section on a detailed map and by GPS (often available on modern smartphones). They can also be marked on the ground with small posts or ribbons.
- Try to take pictures of the sections and enter them in the description of the transect. It will help to recognize the landmarks and the different habitats present.
- Draw the transect on a map**. When the transect is already supervised by an expert or coordinator, you can register your transect on the European Butterfly Monitoring Scheme website (**Butterfly Monitoring Schemes | European Butterfly Monitoring**).** Create your own transect with different sections, the website will measure the exact length of each section and the complete transect.
- Zoo LIFE Pollinators ID CODE transect: **ZLP_Name of the Zoo_Country** (e.g. ZLP_ZOOM_ITALY)

3.1.2 15-minutes count: Description of the proposed methodology for the three groups (optional)

As an alternative to transect surveys, the fixed-time counts can be conducted within those areas object of restoration activities not crossed by a transect and far from it.

For these kinds of sites, the operator can walk through the area for a fixed time (15 minutes) counting all the individuals observed. This process should be performed separately for each pollinator taxon, all on the same day or within the same week. Sampling conditions, capture procedures, identification rules, and data recording follow exactly the same protocols described above for transects.

As always, butterfly counts are recorded using the BMS app in the “15-minute count” section (eBMS - mobile application | European Butterfly Monitoring), while honey bees, wild bees and hoverflies are recorded in the project Excel file.

3.1.3 Vegetation Plots positioning and survey schedule

Vegetation monitoring will be performed in permanent 1x1 m plots (See Fig. 19):

- For each restoration treatment, a defined number of replicates (N° 5 plots) will be established

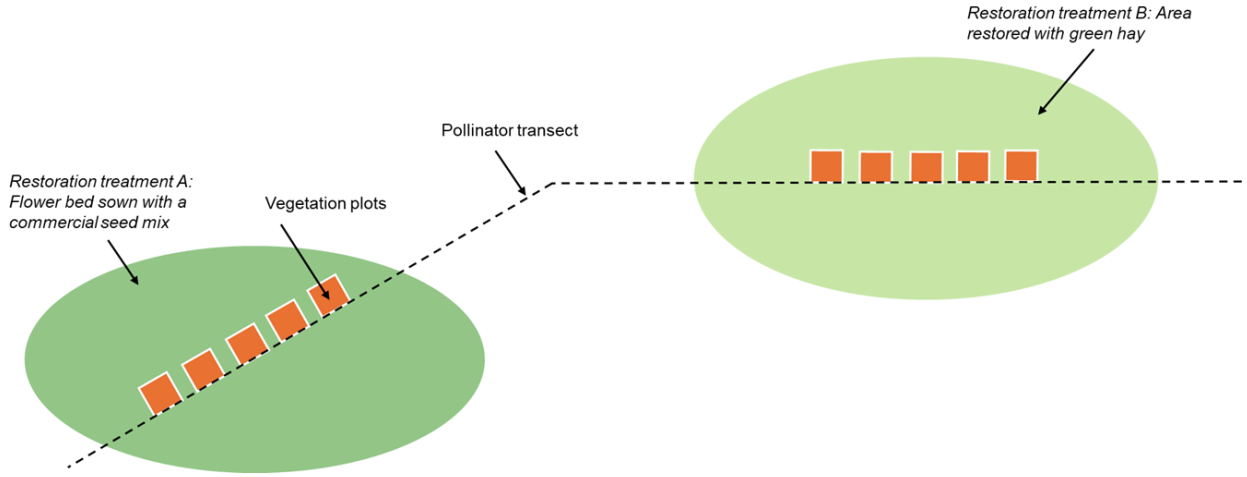


Fig. 19: Example of vegetation and pollinator monitoring survey design

- Plots will be established in homogeneous vegetation patches inside the restoration areas (See Fig. 20)



Fig. 20: 1x1 m frame and examples of plots established in a fixed position on homogeneous vegetation patches and along a marked transect

- Plot corners marked in the field with metal/wooden stakes, or plots established at fixed positions along a marked transect (See Fig. 21)

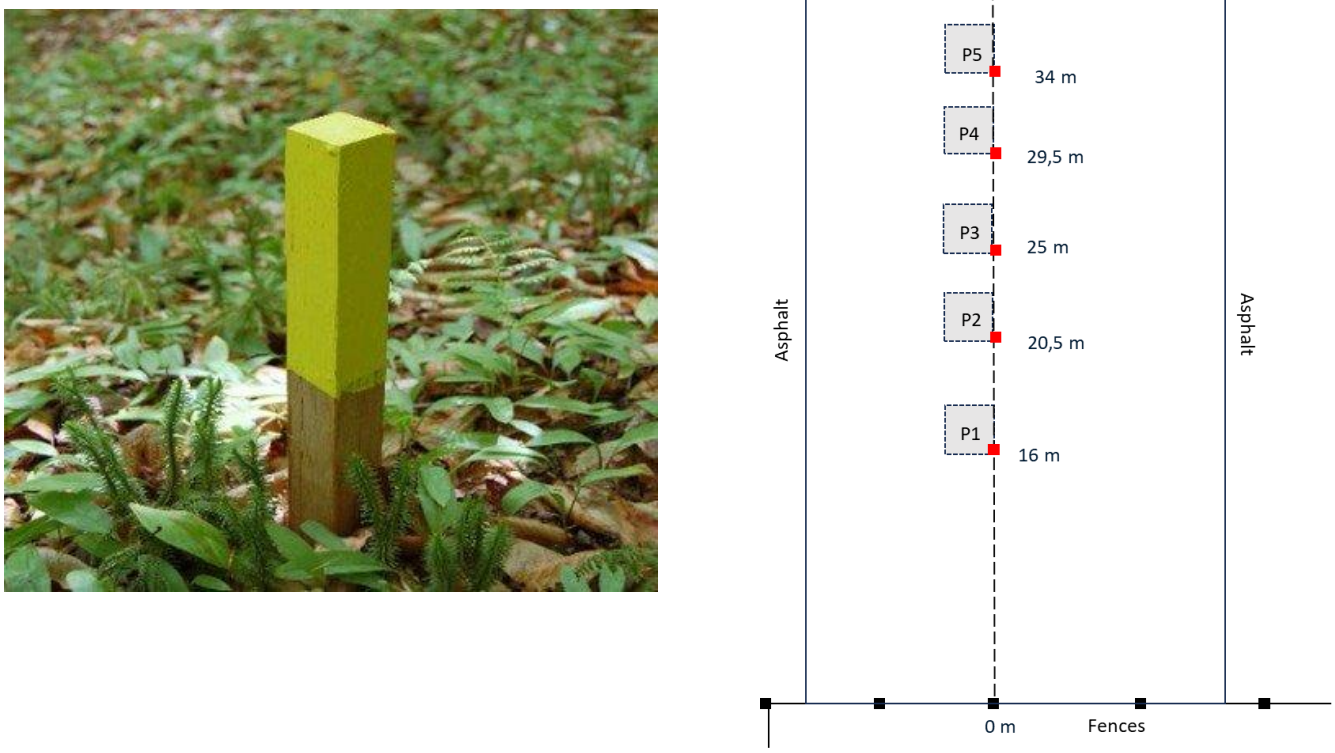


Fig. 21: Examples of a wooden stake and a detailed transect scheme at a fixed position.

- GPS coordinates of each plot

a. Timing and Frequency

The vegetation monitoring will be performed throughout the monitoring season on multiple dates, with a minimum of four survey dates per year. This frequency allows the detection of temporal changes in vegetation communities while maintaining feasibility for the operator.

Survey dates should be synchronized with pollinator monitoring to enable joint analysis of plant–pollinator interactions.

b. Monitoring season

Monitoring activities will be carried out from March to October, corresponding to the main activity period for pollinators across most European regions. Adjustments may be made locally to account for regional climatic differences (e.g. Fuerteventura).

c. Time of day

The vegetation monitoring must be conducted between 08:00 and 17:00, with precise timing adjusted according to latitude, season, and local environmental conditions.

d. Weather Parameters

Sunny weather is preferable but, not specific weather conditions are required. However, good lighting is necessary to obtain reliable photos. Ideally, flowers should be fully open, at least to ensure that photos are clear and informative.

4. Identification

4.1 Butterfly

In the process of field identification of species, it is essential as a first step to understand the family of the observed individual. Below are the main distinguishing characteristics of each family:
The material needed to identify the most common butterfly species, organized by country, can be accessed at the following link: [Field Guides | European Butterfly Monitoring]

Papilionidae

- Large size
- Colourful
- Some with small tails
- Sexual dimorphism not very pronounced
- Larvae with aposematic coloration (except the scarce swallowtail)



Pieridae

- Every common butterflies
- White or yellow in colour with black spots or markings
- Some with sexual dimorphism
- Larvae with cryptic or aposematic colouration
- Some adapted to feed on varieties of domesticated Brassicaceae (cabbages)



Nymphalidae

- Some migratory species
- Larvae often colourful
- Brown, orange, dark red in colour
- Mostly medium to large
- Some overwinter as adults



Lycaenidae

- Small size
- Family with numerous species in Europe
- Blue or brown-orange colouration, metallic colours
- Sexual dimorphism
- Identification through wing patterns on the underside of the wings



Hesperiidae

- Small size
- Stout body
- Brown and orange colors
- Characteristic flight, some very fast and close to the ground
- Larvae pupate and feed in protective shelters made of leaves and silk
- Sexual dimorphism not very pronounced



4.2 Hoverfly

Some hoverfly species can be readily identified at species level even by non-specialist operators, provided that basic attention is paid to key morphological features.

These 23 representative species, listed below, must always be recorded on the field data sheet with the highest taxonomic detail, as they can be reliably identified during field surveys. All remaining hoverfly species that cannot be easily identified at species level in the field are grouped into 14 broad morphogroups, which are described and listed in the following sections.

Blera fallax

Large saproxylic hoverfly typically associated with coniferous forests, characterized by an orange-coloured second half of the abdomen.



BLERA
Blera fallax, m
(photo: M C D Speight)

Caliprobola speciosa

Large saproxylic hoverfly with bright metallic green coloration, frequently visiting flowers of Crataegus.



CALIPROBOLA
Caliprobola speciosa, m
(photo: M C D Speight)

ZOOLIFE pollinators

The future is on their wings.

Chrysotoxum bicinctum

The long Chrysotoxum antennae and the two broad yellow abdominal bands make this species easily identifiable.



CHRYSOTOXUM
Chrysotoxum bicinctum, f
(photo : M C D Speight)

Copestylum melleum

Characterized by a protruding face directed downwards, an orange abdomen, a plumose arista, hairy eyes, and distinctly spotted wings. This is a neotropical species native in Mexico that in the European region has been introduced to the Canary Islands.



COPESTYLUM
Copestylum melleum, f
(photo : M C D Speight)

Criorhina floccosa

Saproxylic hoverfly resembling a bumblebee, with long white hairs on the lateral basal part of the abdomen, frequently visiting Prunus flowers.



CRIORHINA
Criorhina floccosa, m
(photo: M C D Speight)

Dasysyrphus albostriatus

Wings with a dark spot on the pterostigma; abdomen black with oblique yellow spots that may touch in the middle. Thorax with two perpendicular dusted stripes.



DASYSYRPHUS
Dasysyrphus albostriatus, m
(photo : M C D Speight)

Epistrophe eligans
Hoverfly with predatory larvae, early spring phenology. Shiny black abdomen with two orange spots followed by a thin yellow–orange band.



EPISTROPHE
Epistrophe eligans, m
(photo : M C D Speight)

Episyrphus balteatus
Polyvoltine and widespread species, easily recognizable by its distinctive abdominal pattern.



Episyrphus balteatus, m

Eristalinus taeniops
Characterized by very distinctive striped eyes; a typically autumnal species commonly observed visiting *Hedera* and *Mentha* flowers.



Eristalinus taeniops, f

Eumerus ovatus
Very rare species and endangered at the European level, characterized by reddish markings on the abdomen and dense, highly reflective white hairs.



EUMERUS
Eumerus ovatus, m
(photo: M C D Speight)

Hammerschmidtia ferruginea
Very distinctive pattern unique among hoverflies: orange coloration, elongated abdomen. Found in Scandinavia on poplar trees.



HAMMERSCHMIDTIA
Hammerschmidtia ferruginea, m
(photo: M C D Speight)

Lejops vittatus
Very rare species typical of marshy habitats, with characteristic pattern with white abdominal spots.



LEJOPS
Lejops vittatus, f
(photo: M C D Speight)

ZOOLIFE pollinators

The future is on their wings.

Merodon clavipes

Large hoverfly species with phytophagous larvae, showing strongly thickened hind femora and a characteristic pattern of hairs on the thorax and abdomen.



MERODON
Merodon clavipes, m
(photo: M C D Speight)

Milesia crabroniformis

The largest European hoverfly, reaching up to 25 mm. Inhabits mature forests with autumn phenology (August–October).



MILESIA
Milesia crabroniformis, m
(photo, M C D Speight)

Milesia semiluctifera

Similar to the previous species, but characterized by a more contrasting and clearly defined abdominal colour pattern.



MILESIA
Milesia semiluctifera, m
(photo: M C D Speight)

Myathropa florea

Very common species, polyvoltine hoverfly, known as "Batman" for the black bat-shaped mark on the thorax.



MYATHROPA
Myathropa florea, m
(photo: M C D Speight)

ZOOLIFE pollinators

The future is on their wings.

Pyrophaena rosarum

Small hoverfly flying among grass, characterized by a distinctly shaped abdomen, slightly wider at the apex in male and with two characteristic yellow spots at mid-abdomen.



PYROPHAENA
Pyrophaena rosarum, m
(photo: M C D Speight)

Scaeva pyrastri

Migratory hoverfly, capable of flying many dozens of kilometers. Distinctive pattern with oblique whitish comma-shaped spots.



SCAEVA
Scaeva pyrastri, f
(photo: M C D Speight)

Sphaerophoria scripta

Very common hoverfly. Male has abdomen longer than wings; female has pointed abdomen. Flies among grass in meadows.



SPHAEROPHORIA
Sphaerophoria scripta, f
(photo: M C D Speight)



SPHAEROPHORIA
Sphaerophoria scripta, m
(photo: M C D Speight)

Temnostoma bombylans

Saproxylic hoverfly characterized by a distinctive abdominal pattern, short antennae and infuscated wings; the black forelegs are frequently lifted and waved in front of the head, mimicking antennae when the insect is disturbed.

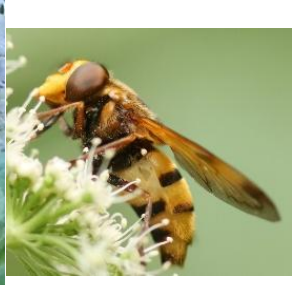


TEMNOSTOMA
Temnostoma bombylans, m
(photo: M C D Speight)

Volucella inanis

Large and robust hoverfly with a plumose arista, frequently visiting flowers in summer, abdomen with sternite 2 white.







VOLUCELLA
Volucella zonaria, f
(photo: M C D Speight)

Volucella zonaria

Large and robust hoverfly with a plumose arista, frequently visiting flowers in summer, abdomen with sternite 2 black.





Xanthogramma laetum

Species typical of swampy woods, recognizable by yellow lateral abdominal stripes combined with yellow abdominal bands, abdomen oval.



XANTHOGRAMMA
Xanthogramma laetum, f
(photo: M C D Speight)

Below is a classification of morphogroups encompassing hoverfly species not included in the species list above. These morphogroups may represent artificial, polyphyletic assemblages, established for practical field identification purposes rather than to reflect phylogenetic relationships.

1.a Bumblebee-like hoverflies

Hoverflies with long abdominal hairs resembling bumblebees, showing a large variety of colour patterns and facial structures, short antennae.



Mallota fuciformis



Sericomyia superbiens



Cheilosia chrysocoma

2.b Hoverflies with enterely orange abdomen

Small to medium-sized hoverflies, short antennae



Brachyopa spp.



Rhingia spp.



Brachyopa spp.

3.c Hoverflies with long antennae and yellow-and-black abdomen



Chrysotoxum spp.



Sphiximorpha spp.



Ceriana spp.

4.d Hoverflies with long antennae, showing different body shapes and morphologies

All the species belonging to this group are rare or very rare and almost all are threatened with extinction.



Callicera spp.



Psarus abdominalis



Ischyroptera bipilosa

5.e Yellow-and-black hoverflies with black face and scutellum (Melanostomatinae)

Many small species with face and scutellum black, few medium species.



Melanostoma spp.



Platycheirus spp.



Xanthandrus comtus

6.f Black or brown hoverflies with a prominent facial knob (Cheilosinae)

Hoverflies ranging from small to large in size, black or brown in colour, often with yellowish legs and characterized by a prominent facial knob. Many difficult species hard to recognise.





Cheilosia spp.



Cheilosia spp.

7.g Black hoverflies, or black hoverflies with two yellow spots on abdomen, with a flat face (Pipizinae)

Small to medium fly, flat abdomen, flat face.



Pipizella spp.



Pipiza spp.

8.h Small hoverflies with a distinctive abdomen (Paragus)

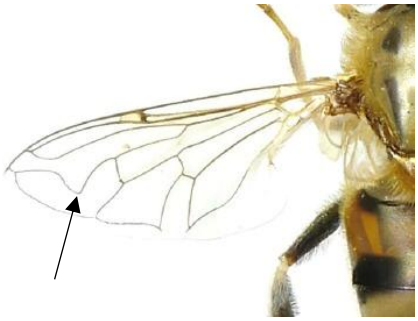
Size 6–8 mm; eyes often with two distinct bands of hairs; first abdominal tergite with a curved shape.



Paragus spp.

9.i Eristalis-like hoverflies

Wing with a characteristic loop and general morphology clearly different from the other categories.



Eristalis wing's loop





Eristalis tenax *Eristalis rupium* *Eristalis arbustorum*

10.j Hoverflies with yellow-and-black bands or spots on the abdomen, with the face or scutellum at least partly yellow





Syrphus ribesii *Epistrophe grossulariae* *Eupeodes luniger*





Meliscaeva auricollis *Eupeodes corollae* *Melangyna umbellatarum*

11.k Hoverflies with distinct longitudinal stripes on the thorax





Ferdinandea spp. *Helophilus* spp. *Eristalinus* spp.

12.l Hoverflies with two lateral yellow bands on the thorax


Melangyna guttata


Doros profuges


Spherophoria spp.

13.m Small to medium-sized hoverflies with a piezolate abdomen


Baccha elongata


Sphegina spp.


Neoascia spp.

13.n Others


Myolepta dubia


Syritta pipiens


Melanogaster spp.


Xylota segnis


Brachypalpoides lentus

4.3 Wild bee

In Europe, more than 2,000 bee species are present, and most can only be identified to species level by experts using microscopic examination. Apart from Apis mellifera, the remaining species cannot be easily identified at species or genus level in the field, especially by non-experts, and are therefore counted by assigning to morphogroups, groups of species with similar characteristics.

Before going into the field, it is essential to acquire a basic understanding of bee morphology. To develop these skills, you can consult the presentation available at the following link: Pollinator Academy — Bee anatomy search tool

Once in the field, you can use the guide at the following link to identify the observed individuals: Pollinator Academy — Quick guide to bees

Be sure to use the reference code from the guide on the official field data sheet to identify the specimens you observed:

- B1. Honey bees
- B2. Bumblebees
- B3. Large bees
- B4. Wasp bees and blood bees
- B5. Other small bees

Bumblebees can be further divided into subgroups, as described in the guide at the following link: Bee morphogroups | Rise 360

In the Zoo LIFE Pollinators project, this subdivision provides an additional level of identification. As before, record the subgroup code from the guide on the official field data sheet:

- B2.1 Thorax ginger
- B2.2 Black-red
- B2.3 All dark
- B2.4 Yellow-black-white
- B2.5 Yellow-black-red

4.4 Vegetation identification

Vegetation monitoring will be performed using five survey methods. The first three methods are mandatory (4.4.1, 4.4.2, 4.4.3), while the remaining two are optional (4.4.4). All surveys will be carried out on the same plots and simultaneously.

4.4.1 Field method - Photos of the plots for color image analysis

The objective of the photos of the plots is to estimate flower coverage and color proportions with machine learning approaches.

- Install the 'Open Camera' App to allow standardization among different smartphone brands and models
- Minimum camera resolution: 8MP; PNG format; aspect ratio preferentially 1:1 or 4:3
- Framing: carefully top-down above the center of the plot, ensuring that photo edges are aligned with the plot boundaries and avoiding any (See Fig. 22)



Fig. 22: Correct and incorrect photos of the plots for color image analysis

- Place the color palette you received in the "survey pack" in one corner of the plot for color calibration in subsequent analysis (See Fig. 23)



Fig. 23: Color palette positioning for color calibration

- Use a device like a large sun umbrella to avoid shadows over the plot
- Take the picture with your smartphone
- Rename each photo using the following coding (all capital letters): "YOUR ZOO NAME_TREATMENT NUMBER PLOT NUMBER_YEAR MONTH DAY", ex. "ZOOM_T1P1_20260625". Remember to use 4 characters for the year, 2 for the month and 2 for the day.
- Upload each photo in the dedicated cloud directory.

4.4.2 Field Method - Photos of single flowering species for species identification

The objective of this activity is to identify flowering species in the plot with the aid of automatic identification apps and botanical expertise

- Take a picture of the flowering plants inside the plot with a smartphone
- Three photos per plant is the minimum (but more are welcome!): 1) close-up of the flower/inflorescence, 2) close-up of the leaves, 3) entire plant (See Fig. 24).



Fig. 24: example of photos of the flowering plants

- For the flower and entire plant, take photos directly of the living plants within the plot; no need to uproot the plant.
- For leaves, detach one or more samples and place them against black or white cardboard to allow better visualization of their shape (See Fig. 25).



Fig. 25: example of photos of the flowering plants

- Each zookeeper will be invited to participate in the specific project for his/her zoo on iNaturalist.
- Go on iNaturalist app with your smartphone, open a new observation editing page, then select "Take Photo" or "Choose Image" (See Fig. 26).

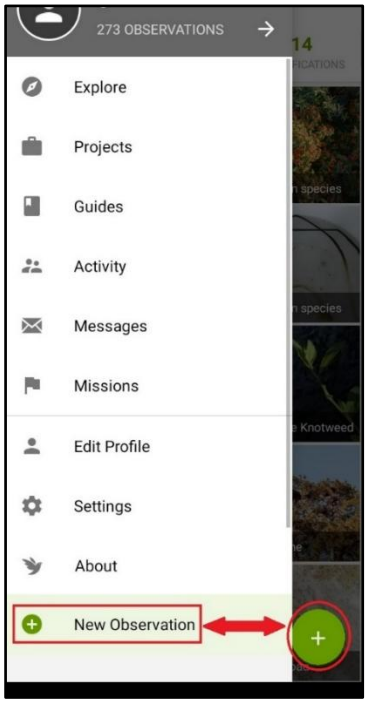


Fig. 26: screenshot from the iNaturalist app

- After having uploaded at least the three images, tap on "What did you see?" and choose the species that best relates with the plant you observed (See Fig. 27).

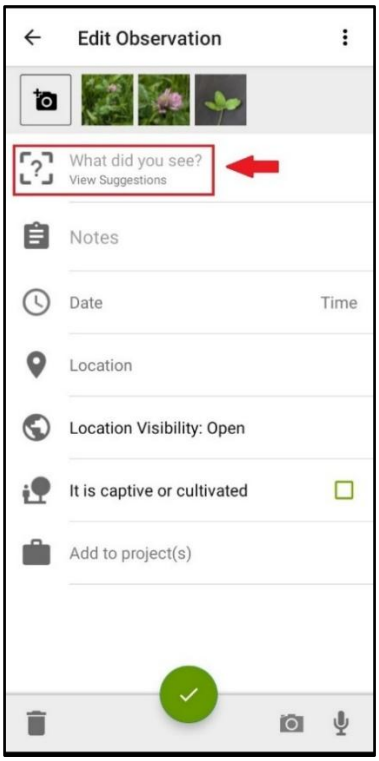


Fig. 27: screenshot from the iNaturalist app

- Make sure that the fields "Date" and "Location" are filled out (See Fig. 28).

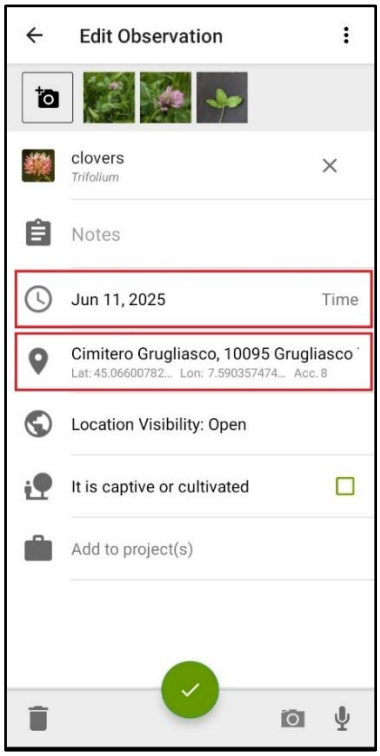


Fig. 28: screenshot from the iNaturalist app

- As last, tap on “Add to project(s)”, select the project “LIFEPollinators_YOURZOONAME_VEG” and write the observation ID in the empty field using the following coding (all capital letters): “YOUR ZOONAME_TREATMENT NUMBER PLOT NUMBER_YEAR MONTH DAY”, ex. “ZOOM_T1P1_20260625”. Remember to use 4 characters for the year, 2 for the month and 2 for the day (See Fig. 29).

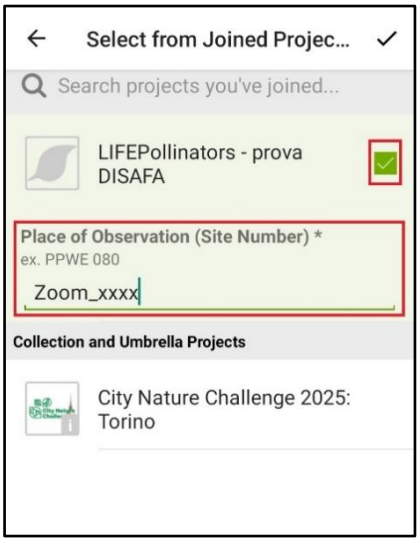


Fig. 29: screenshot from the iNaturalist app

- Confirm the observation

4.4.3 Field Method - Simplified vegetation survey

The Objective of the simplified vegetation survey is to collect basic information on the plant community structure and composition.

For each 1x1 m plot, provide a percentage cover (based on a visual estimation, 0-100%, estimated as a vertical projection onto the ground) of:

- **Total vegetation cover (%)**, i.e. considering all living plants, excluding rocks, bare soil and litter;
- **Graminoids cover (%)**, i.e. including grasses (Poaceae), sedges (Cyperaceae), and rushes (Juncaceae) (See Fig. 30).



Fig. 30: example of vegetation cover

- **Other plant species cover (%),** i.e., all non-graminoid species, such as Legumes and other Forbs (the sum of 'Graminoids cover' and 'Other plant species cover' forbs must be equal to the 'Total vegetation cover') (See Fig. 31).



Fig. 31: example of other plant species cover

- Arrange all collected data in a Common Separated Value file (CSV) using the following structure:

Observation ID	Vegetation cover	Graminoids cover	Other plant species cover
ZOOM_T1P1_20260625	*70*	45	25
ZOOM_T1P2_20260625	*55*	15	35
ZOOM_T2P1_20260625	*95*	50	45

- Once all season observation will be carried out, rename the CSV file using this coding (all capital letters): “YOUR ZOO NAME_SIMPVEG_YEAR.csv”, ex. ZOOM_SIMPVEG_2026.csv
- Upload the CSV file in the dedicated cloud directory.

4.4.4 Field Method - Flower counts and Complete phytosociological survey (Optional vegetation survey)

- Count the number of flowers / flower units per species in the entire 1x1 m plot. It is necessary to compile a list of flowering species and, for each species, count the number of flowers (or floral units, in cases where the insect can move without flying between flowers within the same inflorescence, e.g., capitula of Compositae, inflorescences of Lamiaceae, etc.). If the number of flowers (or floral units) of a species is small (e.g. fewer than 50), a complete count of flowers should be carried out; if the number of flowers (or floral units) of a species is very high, it is possible to estimate the number of flowers (e.g. by counting within an area of 100 × 50 cm and then multiplying by 2, or 50 × 50 cm and then multiplying by 4, etc.).
- Perform a vegetation survey, i.e., compiling the complete list of all species present inside the plot (flowering and non-flowering) and assigning to each species a percentage cover (0–100%, estimated as a vertical projection onto the ground). The sum of the percentage cover of all species must be equal to the ‘Total vegetation cover’.

5. Appendix

5.1 Glossary

- Entomophilous floral units: Specialized structures designed to attract insects for pollination through bright colors, nectar rewards, and scents
- Qualitative abundance: Indicate the presence/absence of the species in a given location, regardless of the sample size
- Quantitative abundance: Indicate the number of individuals of the species in a given location, regardless of the sample size
- Angiosperms: Commonly referred to as flowering plants; they are also known as Anthophytes, from the Greek *anthos*, meaning “flower”.
- Mutualistic: Often described as a "win-win" interaction, the mutualistic relation is a type of symbiotic relationship where two or more species interact, and all parties involved benefit.
- Co-evolution: Reciprocal adaptations between evolutionary lineages (e.g. pollinating insects and their host plants).
- Zoophilous pollen grains: Grains of pollen specialized for animal mediated transfer, characterized by being heavy, sticky to adhere to pollinators.
- Endemic species: Plants or animals native to a specific, restricted geographical area
- Holometabolous: Insects that undergo complete metamorphosis, a four-stage life cycle consisting of egg, larva, pupa, and adult
- Communal: The first step up from a purely solitary existence where multiple females share a common nest, but each builds her own brood cells and cares for her own offspring, an intermediate step toward eusociality.
- Eusocial: Is the highest level of social organization, characterized by reproductive division of labor, overlapping generations, and cooperative brood care
- Fitness: Measures an organism's reproductive success and its genetic contribution to the next generation.
- Harmonized monitoring system: It is a shared, standardized method that allows data collected from different monitoring programs to be compared without inconsistencies, through the use of common protocols for Bees, Hoverflies and Butterflies.

5.2 Useful resources

- Bot, S., & Van de Meutter, F. (2023). *Hoverflies of Britain and North-West Europe: A Photographic Guide*. Bloomsbury Wildlife. ISBN: 9781399402453.
- Michez, D., Rasmont, P., Terzo, M., & Vereecken, N. J. (2019). *Bees of Europe*. Paris, France: N.A.P. Editions. ISBN**:** 978-2-913688-33-1
- Tolman, T., & Lewington, R. (2008). *Collins Butterfly Guide: The Most Complete Field Guide to the Butterflies of Britain and Europe* (3rd ed.). HarperCollins UK.
- https://www.farfalleitalia.it/
- https://www.leps.it/

- https://www.pbase.com/raypurser/butterflies&page=all
- https://www.wildlifeinsight.com/european-butterflies/
- http://www.eurobutterflies.com/index.php
- https://www.beewatching.it/scopri-le-api/
- https://orbitproject.wordpress.com/
- https://pollinatoracademy.eu/pollinators?lang=EN

5.3 Image credits

1.1 What is pollination?

- Biotic pollination (pag. 7): Umberto Maritano
- Abiotic Pollination (pag. 7): Alex Jones (CC0)

1.3 Main cause of general decline

- Wild bees (pag.9): Myriams-Fotos, Pixabay
- European butterflies (pag. 9): esiuL - Pixabay
- Hoverflies (pag. 9): onixino, Pixabay

2.1.1 Classification

- Wild bee (pag. 13): Valentina Isaja

2.1.2 Morphology

- Bee morphology; the head; the torax; the abdomen (pag. 14): AI generated

2.1.3 Life cycle

- Bee's life cycle (pag. 15): AI generated

2.1.4 Bees or Wasp

- Different characteristics between Bees and Wasp (pag. 16): Samuele Torta

2.2 Hoverflies (*Syrphidae*)

- Spirious vein (pag. 17): Stubbs A.E., Falk S., 2002

2.2.1 Classification

- Spirious vein (pag. 17): Stubbs A.E., Falk S., 2002

2.2.2 Morphology

- Hoverfly morphology; the head; the torax; the abdomen (pag. 19): AI generated

2.2.3 Life cycle

- Hoverfly's life cycle (pag. 20): AI generated
- *Syrphinae* (pag. 20): Speight, M. C. D. and de Courcy Williams, M. (2020)

- *Eristalinae; Microdontinae; Pipizinae* (pag. 21): Speight, M. C. D. and de Courcy Williams, M. (2020)

2.2.4 Hoverfly or bee

- Different characteristics between hoverfly and bee (pag. 21): Samuele Torta

2.3.1 Classification

- Butterfly (pag. 23): Yari Roggia

2.3.2 Morphology

- Butterfly morphology; the head; the thorax; the abdomen (pag. 24): AI generated

2.3.3 Life cycle

- Butterfly's life cycle (pag. 25): AI generated

2.3.4 Butterfly or Moth

- Butterfly (pag. 26): Thomas Elliott - Pexels
- Moths (pag. 26): Ian Lindsay - Pixabay

3.1.1 Transect: description of the proposed methodology for the three groups

- Example of transect section (pag. 28): Samuele Torta
- Example of transect monitoring survey (pag. 29): Samuele Torta
- Example of labelling (pag. 31): Umberto Maritano
- Flow of actions planned for different situations (pag. 32): Samuele Torta

3.1.3 Vegetation Plots positioning and survey schedule

- Frame and example of plot (pag. 34): DISAFA team
- Example of a wooden stake (pag. 35): DISAFA team

4.1 Butterfly

- Images on page 36 are all taken from the "Field Guide Padana Plain region" by the European Butterfly Monitoring Scheme (eBMS), a joint initiative by Butterfly Conservation Europe.

  Authors: Cristina G. Sevilleja (eBMS), Stefano Scalercio (Centro di ricerca Foreste e Legno, CRE _ FL); Simona Bonelli, Marta Depretis & Stefano Masier (Università di Torino); Leonardo Dapporto (Università di Firenze).

  Photographs: Paolo Mazzei, Marco Bonifacino, Raniero Panfili e Daniel Morel (www.leps.it); Jose Rodrigo Dapena, Javier Olivares, B Fransen, Henk Dikkema, Irma Wynhoff, Arthur van Dijik, Izabella Dziekanska, Martin Sielezniew, S. Teixeira, Dan Danahar, G. Zoutter, Bert van Rijsewijk, Martin Wiemers, Kars Veling e Chris van Swaay.

4.2 Hoverflies

- *Episyrphus balteatus* (pag. 40): Ian Ballam iNaturalist (CC BY)

- *Eristalinus taeniops* (pag. 40): Lorenzo Quintana iNaturalist (CC BY NC)
- *Volucella inanis* (pag. 44): John Ashburner, Elio Giacone iNaturalist (CC BY / CC BY NC)
- *Volucella zonaria* (pag. 44): Elio Giacone, Roberto Costantino iNaturalist (CC BY NC)
- *Mallota fuciformis* (pag. 45): Umberto Maritano
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- *Brachyopa* spp. (pag. 45): Frank Vassen Wikipedia (CC BY)
- *Chrysotoxum* spp. (pag. 45): Carnifex iNaturalist (CC BY)
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- *Pipizas* spp. (pag. 47): Janet Graham https://species.wikimedia.org/ (CC BY); Janet Graham Wikipedia (CC BY); Leszek Plackowski https://insektarium.net/
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- *Eristalis wing's loop* (pag. 47): Speight, M. C. D. and de Courcy Williams, M. (2020)
- *Eristalis tenax* (pag. 48): s_scottish_manu iNaturalist (CC BY NC)
- *Eristalis rupium* (pag. 48): insektarium.net
- *Eristalis arbustorum* (pag. 48): insektarium.net
- *Syrphus ribesii* (pag. 47): Alvesgaspar (CC BY SA)
- *Epistrophe grossulariae* (pag. 48): Maks Syratt (CCBY NC)
- *Eupeodes luniger* (pag. 48): Jerry Lanfear iNaturalist (CC BY)
- *Meliscaeva auricollis* (pag. 48): Barry Walter iNaturalist (CC BY)
- *Eupeodes corollae* (pag. 48): Christian Sørensen iNaturalist (CC BY NC)
- *Melangyna umbellatarum* (pag. 48): Hectonichus Wikipedia (CC BY SA)
- *Ferdinandea* spp. (pag. 48): Jessee J. Smith (CC BY NC)
- *Helophilus* spp. (pag. 48): Laurence Livermore (CC BY NC)
- *Eristalinuss* spp. (pag. 48): J E Nash iNaturalist (CC BY NC)
- *Melangyna guttata* (pag. 49): Connie MIsket (CC BY)
- *Doros profuges* (pag. 49): Ryszard Orzechowski (CC BY NC)
- *Spherophoria* spp. (pag. 49): Francisco Welter-Schultes iNaturalist (CC BY NC)

- *Baccha elongata* (pag. 49): Maks Syratt iNaturalist (CC BY NC)
- *Sphegina* spp. (pag. 49): Denis Doucet (CC BY NC)
- *Neoascia* spp. (pag. 49): André Nagelhout iNaturalist (CC BY NC)
- *Myolepta dubia* (pag. 49): Fikret (CC BY NC)
- *Syritta pipiens* (pag. 49): michelcournoyer (CC BY NC)
- *Melanogaster* spp. (pag. 49): Sandy Rae iNaturalist (CC BY)
- *Xylota segnis* (pag. 49): Michael Knapp (CC BY)
- *Brachypalpoides lentus* (pag. 49): Raoul Gerendi Naturalist (CC BY NC)

4.4.1 Field method – Photos of the plots for color image analysis

- Correct and incorrect photos for color image analysis (pag. 51): DISAFA team
- Color palette (pag. 51): DISAFA Team

4.4.2 Field method – Photos of single flowering species for species identification

- Example of photos flowering plants (pag. 52 - 53): DISAFA team

4.4.3 Field method – Simplified vegetation survey

- Example of vegetation cover (pag. 55): Joelle Magnin - Gonze (CC BY NC ND); Beat Baumler – Mauvoisin (CC BY NC ND); Joelle Magnin – Gonze (CC BY NC ND)
- Example of plant species cover (pag. 56): Joelle Magnin – Gonze (CC BY NC ND); Beat Baumler – Simplon (CC BY NC ND); Patrick Veya (CC BY NC SA)

5.4 Useful contacts

- Zoom Turin: Italy - BMS coordinator Simona Bonelli
- Nordens Ark: Sweden BMS coordinator Lars Petterson
- Slottsskogen zoo: Sweden BMS coordinator Lars Petterson
- Copenhagen Zoo: Denmark BMS coordinator Anne Eskildsen
- Zagreb Zoo: Croatia BMS coordinator Martina Sasic
- Zoo Debrecen: Ungheria coordinator Andreas Szabadfalvi
- Brasov zoo: Romania coordinator László Rákosy
- Oasis wildlife Fuerteventura: Spain Coordinator Jose Miguel Barea

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