SCIENTIFIC PUBLICATIONS

Wild bees on roadsides

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Why we should make road verges more wild bee-friendly, and how we can

Université Gustave Eiffel

How to cite this publication:

FRANÇOIS D., LE FÉON V., Wild bees on roadsides Why we should make road verges more wild bee-friendly, and how we can. Marne-la-Vallée : Université Gustave Eiffel, 2020. Scientific publications, OSI2-A, 118 pages, ISBN 978-2-85782-755-9

Université Gustave Eiffel
5 Boulevard Descartes, 77420 Champs-sur-Marne
www.univ-gustave-eiffel.fr
IFSTTAR Collections Scientific publications
Ref: OSI2-A
ISBN 978-2-85782-755-9 - ISSN 2558-3018
October 2020

About the authors

Denis FRANÇOIS is a senior researcher in the French Environment Ministry's research corps in Université Gustave Eiffel's Planning, Mobility and Environment Department (AME) in Nantes[1]. Building on his initial training in environmental science and technology (Universities of Angers, Montpellier, Paris XII, École Nationale du Génie Rural et des Forêts, École Nationale des Ponts et Chaussées), his work focuses on the management of natural resources and the environment in the context of spatial planning. His research is concerned with identifying and evaluating the effects of linear transport infrastructure (LTI) on biotic and abiotic targets. The aim of his work is to improve how the design and management of LTIs is integrated with the areas they pass through, in order to reduce their environmental impact. As such, he is particularly interested in the ecological functions that are made possible thanks to their vegetated verges.

Violette LE FÉON holds a doctorate in biology, and is a specialist in the ecology of wild bees and pollination. She completed her doctoral thesis at the University of Rennes then worked successively at Buenos Aires University of Agronomy and at the Bee and Environment Unit of the Institut National de Recherche pour l'Agriculture, l'Alimentation et l'Environnement (INRAE, UR 406 in Avignon[2]). Her research focuses on the impacts of human activities on wild bee communities. She began by studying agricultural landscapes, analysing the effects of agricultural practices and the landscape context in France and Argentina (large-scale agriculture in the pampas). She then studied bees in urban areas and in the rights-of-way of linear transportation infrastructure. In these different contexts which are experiencing anthropogenic pressures, her work aims to find a balance between anthropogenic use and the conservation of wild bees with the pollination service which they provide.

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Acknowledgements

This publication is a translation of the book “Abeilles sauvages et dépendances vertes routières” published in December 2017 in France by the French Institute of Science and Technology for Transport, Development and Networks (IFSTTAR). It was intended to raise awareness among national road network managers of the status of wild bees and to help them take concrete steps for their conservation through appropriate maintenance of road verges.

The original document was prepared on the basis of knowledge of the ecology of wild bees, taking into account the operational possibilities and constraints associated with road infrastructure management. It has been reread and commented on by many people, stakeholders in both the construction and maintenance of roads and the study and conservation of wild bees and wild flora.

The objective of the original publication was to provide easily accessible assistance to those responsible maintaining road verges in France. But it has also attracted the interest of people in different countries who are facing the same situation and the same need for action.

As the general method and the proposed techniques for improving habitat conditions for wild bees in road rights-of-way can in fact be used elsewhere than in France, it was decided to provide a version of the document that would be accessible to non-French-speakers. We would like to thank Kevin RILEY for his considerable amount of meticulous work on the translation.

We would also like to thank Anne LARIGAUDERIE, who champions the conservation of biodiversity and the services it provides to humanity at the international level, for encouraging us to share this document outside the French-speaking world.

Photo credits:

Figures:

Denis FRANÇOIS and Violette LE FÉON

Preface

Anne LARIGAUDERIE
Executive secretary of IPBES
Intergovernmental Platform on Biodiversity
and Ecosystem Services

I am delighted to invite people interested in pollination to read this book, which presents in an inviting manner, anchored in science, the potential of roadsides such as shoulders, ditches, or embankments for the conservation of wild bees and the promotion of pollination. This work illustrates in an exemplary manner concrete actions at the national and regional levels, to implement goals agreed at the international level.

Global stakes on pollinators

In Panama in 2012, some 100 countries established a mechanism similar in its operation and objectives to the IPCC (Intergovernmental Panel on Climate Change) in order to regularly assess the state of knowledge on biodiversity and ecosystem services in response to requests from governments and civil society actors. This mechanism is called IPBES, or “Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services”. IPBES currently has 137 Governments as members. Its first assessment report published in 2016 focused on biodiversity and ecosystem services concerning “pollinators, pollination and food production” (Potts et al. 2016). The 23 key messages of the summary for policymakers of this report were negotiated word by word at the IPBES Plenary Members’ Meeting in Kuala Lumpur in February 2016, and the 500 pages of the six chapters underpinning this summary were agreed. The conclusions of this assessment were taken up by the Parties to the Convention on Biological Diversity, including France, at COP13 in its decision XIII/15 on the “Implications of the IPBES assessment on pollinators, pollination and food production for the work of the Convention” (Cancun, Mexico, December 2016). The conclusions of this assessment also contribute to the Sustainable Development Goals of Agenda 2030.

IPBES Report on Pollinators, Pollination and Food Production

The IPBES assessment report highlighted the importance of pollinators for global food production, since globally nearly 90% of wild flowering plants depend, at least in part, on pollen transfer by animals, and more than 75% of the world’s major food crop categories depend to some extent on animal pollination for yield and/or quality. The IPBES report also emphasized the magnitude of the loss of pollinators, and its global nature, as well as its causes: the International Union for the Conservation of Nature (IUCN) Red List assessments indicate that 16.5% of vertebrate pollinators are threatened with extinction globally (this figure reaching 30% for island species), and that in Europe, 9% of bee and butterfly species are threatened and populations are declining for 37% of bees and 31% of butterflies. Threats to pollinators include land use change (e.g. habitat modification or destruction), intensive agriculture and pesticide use, environmental pollution, invasive alien species, pathogens and climate change.

Finally, the IPBES assessment report focused on evaluating the many measures that can be put in place for the benefit of wild and domestic pollinators and pollination. In particular, it highlighted the importance of coordinated collaborative actions and knowledge sharing linking different sectors (e.g. agriculture and nature conservation), different spheres (e.g. private, government, non-profit organizations), and different levels (e.g. local, national, global) to achieve long-term changes beneficial to pollinators.

Local implementation

The work presented here is perfectly in line with these international challenges, and represents one of the ways to implement, at the national and local levels, the decisions of the Convention on Biological Diversity, based on the IPBES assessment, as well as, more broadly, some of the sustainable development objectives of Agenda 2030. It corresponds exactly to the type of initiative that IPBES wishes to generate around the world to promote the protection of wild bees and pollination.

This book is an excellent example of how work at the international level can only be effective if it goes hand in hand with implementation at the local level.

A call to action

The book is of course primarily aimed at managers of roadside green dependencies by providing them with detailed technical advice in a very pedagogical manner, based on a thorough knowledge of bee ecology, with the support of numerous technical illustrations.

It will also, I am convinced, be of interest to a wider public because of the information it provides, in a clear and accessible manner, on the ecology of bees, the plants and habitats that favour their conservation, and the ways to promote them, thus allowing individuals who own a garden or land to participate in these efforts and support pollination.

I therefore invite all the actors to contribute to this beautiful global cause and to take action to bring back wild bees in our gardens and on the sides of our roads and paths!

Contents

Introduction

During the last twenty years, the decline of pollinating insects and its consequences on the reproduction of wild and cultivated plants have raised concerns and questions not only within the scientific community but also the public authorities.

In France, the worrying status of the honey bee (*Apis mellifera*) led to the launch of a national action programme in 2013: the Sustainable development plan for beekeeping[1].

Although it is less familiar to the general public, the status of thousands of wild bee species (there are nearly 1,000 species in mainland France and about 20,000 worldwide) is no less worrying and challenging. In addition to their role in the reproduction of many wild plants, it is now recognised that wild bees (bumblebees, solitary bees such as in the genera *Xylocopa*, *Osmia*, *Halictus* or *Andrena*) play a significant role in pollination and productivity for many crops. With all other wild pollinating insects (such as true flies, butterflies, moths, and beetles), wild bees have been the subject of a national action plan since 2016 which goes by the name of “France, land of pollinators” (France, terre de pollinisateurs)[2].

At the international level, in 2016, referring to the report of the Intergovernmental Science and Policy Platform on Biodiversity and Ecosystem Services (IPBES) on pollinators, pollination and food production (Summary for policymakers[3]), the Convention on Biological Diversity (CBD) for the first time issued a specific decision for pollinator conservation[4].

In common with many insects, wild bees are suffering from various environmental pressures caused by the intensification of agricultural practices and the spread of urbanisation and transport networks. The consequences of these are the destruction and fragmentation of their natural habitats, the depletion of their foraging resources and the lethal and sublethal effects of pesticides. The impact on wild bee populations in Europe is such that today several species are threatened with extinction (European Red List of Bees[5]).

In response to this situation, initiatives have recently been taken in areas with a strong human footprint, such as urban areas (Urbanbees programme in 2014[6]) and sites where construction materials are quarried (sand quarries in 2015[7]), with a view to creating a space for wild bees and permitting their survival.

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1. http://agriculture.gouv.fr/sites/minagri/files/pddapiculture_vf.pdf – In French
2. http://www.insectes.org/opie/pdf/3993_pagesdynadocs570e1d6156925.pdf – In French
3. https://www.ipbes.net/system/tdf/spm_deliverable_3a_pollination_20170222.pdf?file=1&type=node&id=15248
4. https://www.cbd.int/doc/decisions/cop-13/cop-13-dec-15-en.pdf
5. http://ec.europa.eu/environment/nature/conservation/species/redlist/bees/status.htm
6. http://urbanbees.eu/en
7. http://www.unpg.fr/2016/01/20/les-carrieres-de-sable-une-opportunite-pour-les-abeilles-solitaires/ – in French

The general impacts of terrestrial transport networks on natural environments are well known today, and roads add to the pressures affecting wild bee populations. However, in some places, road verges are among the last sites which harbour the natural flora and its associated insects. In particular, they offer habitats similar to hay meadows, which are declining at the European level, in spite of the fact that they support a very large number of wild bee species.

At national scale, road verges cover thousands of hectares and are therefore connected to a wide variety of natural environments that make up the country's green network. In degraded environments, they can remedy some of the problems that affect wild bee populations. The case-by-case analysis and development of their potential for safeguarding local wild bee populations must therefore not be overlooked.

This document aims to show how road managers, and in particular those responsible for roadside vegetation, can take concrete action to safeguard and maintain wild bees in the area under their control. It provides them with operational recommendations for actions that support the foraging and nesting of wild bees. Effective commitment to a sustainable approach to wild bees is based on a clear overall perception of the issues relating to these species, and also on an understanding of the general importance of pollination and the various pollinating insects. This prerequisite is the subject of the first part of the document. The reasons why the use of road verges is now warranted in order to meet the needs of wild bees, and the fundamental principles for such action, are presented in Part II. The third part of the document makes operational recommendations for providing the foraging resources and the various types of nesting sites necessary for wild bees in road verges, as well as for organizing the consistency among the implemented actions within the road rights-of-way, and in connection with the surrounding green network.

Colletes daviesanus (Colletidae family) on a flower of *Achillea millefolium* (Yarrow)

Photo credit: David GENOUD

Part I.

Wild bees today: status and issues

Previous page

Halictus scabiosae (Halictidae family) on a flower of *Ranunculus repens* (Creeping buttercup)

Photo credit: Denis FRANÇOIS

Section 1.
Pollination, pollinators and wild insect pollinators

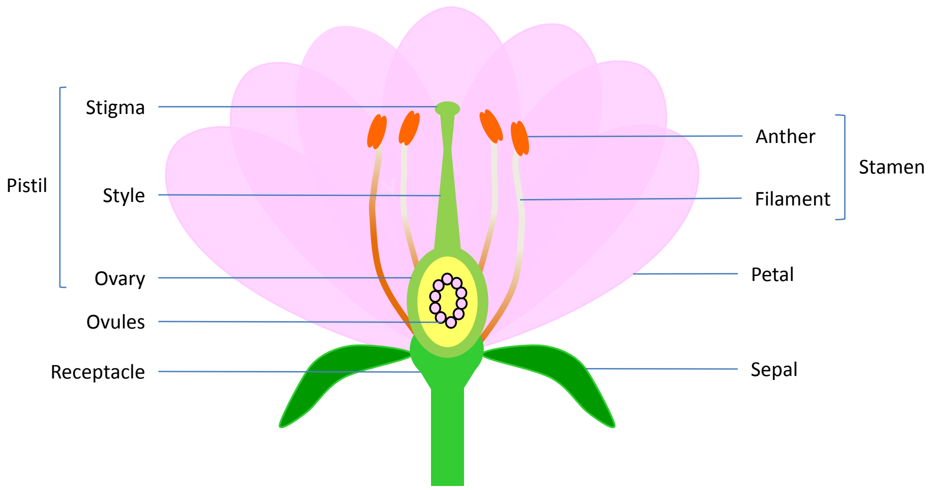
1.1. Pollination

Pollination is the transfer of pollen from the anthers of a flower to the stigma of the same or another flower (Figure 1.1). This transfer is the first step in the process of ensuring that the male reproductive cells (gametes) carried by the pollen grains meet up with the female gametes (the ovules in the ovary) for the reproduction of flowering plants (angiosperms).

Anthers are the terminal parts of the stamens (the male reproductive organ in flowers), which produce and retain pollen. The stigma is the upper tip of the pistil (female reproductive organ in flowers), whose role is to receive the pollen grains. The male gametes then make their way to the ovules.

When the pollen travels from one individual (plant) to another, pollination is referred to as *cross-pollination*. The term *self-pollination* is applied when the pollen fertilises the same flower or another flower belonging to the same individual.

Figure 1.1
Diagram of a flower



Self-pollinating (i.e. autogamous) cultivated plants include wheat, oats, beans, peppers, aubergines and tomatoes, for example. Cross-pollinating (i.e. allogamous) plants include onions, asparagus, radishes, hazel, alfalfa, maize and olive trees. Many plants are able to use both reproductive strategies (e.g. leeks, melons, celery, beetroot, cucumbers, carrots, cabbages, mustard).

In the case of self-pollination, pollen grains are transported by gravity or by direct contact between the stamens and the pistil, for example due to an impact caused by insects.

In the case of cross-pollination a variety of means of transport may be involved in pollen transfer: wind (anemophily or wind pollination), water (hydrophily or water pollination), animals (zoophily or animal pollination). The latter is that which involves the largest number of plant species: almost 90% of flowering plant species are pollinated by animals.

Flowering plants are divided into two main groups according to the number of cotyledons (which are the embryonic leaves contained in the seeds): dicotyledons have two and monocotyledons have only one. Dicotyledons include a large number of families such as Asteraceae, Rosaceae and Fabaceae. Monocotyledons include notably grasses (or Poaceae), Orchidaceae and Asparagaceae.

1.2. The pollinators

A large number of so-called *floricolous* animals, visit flowers to collect food, particularly pollen and nectar. But this floricolous character does not mean they all help pollinate the plants they visit. In fact, most plants are pollinated by a fairly small proportion of their visitors. An animal is referred to as a *pollinator* of a given plant if it is capable, because of its morphological and behavioural characteristics, of contributing to the pollination of that plant.

Animal pollination can be carried out by insects (entomophilic pollination), reptiles (lizards), birds, fruit bats or other types of mammals (marsupials, primates, rodents). During the evolution of species (in this case the co-evolution of plants and pollinators), plants that use zoophily have developed floral organs that are attractive to animals by adapting their shape, colour or perfume. When they visit the flowers to look for nectar and/or pollen, the animals get pollen-covered and then transport it (cross-pollination), and/or cause contact between the stamens and the pistil of the flower (self-pollination). Entomophilic pollination is by far the most frequent. Pollination by birds and mammals has mainly developed in tropical regions.

1.3. Pollinating insects

Different groups of insects are involved in pollination, but four orders contain the main wild pollinators: Hymenoptera, Diptera, Lepidoptera and Coleoptera. Examples of pollinating species from these orders are shown in Figures 1.2 to 1.6.

❀ Member of the order Hymenoptera and more precisely of the superfamily Apoidea, bees (Figure 1.2) are considered to be the main pollinators at the global level because both adults and larvae feed exclusively on nectar and pollen. There are about 20,000 species worldwide. The distribution of bees is less well known than that of some other insect groups (e.g. butterflies, hoverflies). For example, there are currently no national or regional bee atlases, although these are currently widely available for butterflies.

Figure 1.2
Megachile sp. (bee of the Megachilidae family) on a flower of *Ononis spinosa* (Spiny restharrow)

Photo credit: Matthieu AUBERT

The best-known member of the Apoidea is the honey bee (or domestic bee) which makes the honey we eat. The honey bee is just one species (*Apis mellifera*). All the other species are grouped together under the name of *wild bees*. Some of these species (bumblebees, genera *Osmia* and *Megachile*) are bred for their ability to pollinate particular crops. In France, for example, the buff-tailed bumblebee (*Bombus terrestris*) is used to pollinate tomatoes in glass houses.

❀ Pollinating Diptera include notably hoverflies (flies which mimic bees and wasps – Figure 1.3), bee-flies (which resemble small bumblebees) and the Empidinae group. These Diptera feed on pollen and/or nectar thanks to their proboscis.

❀ The Lepidoptera include both butterflies (rhopalocera) which use their long proboscis to imbibe nectar (Figure 1.4) and moths (heterocera), many species of which also visit flowers and participate in pollination. In France, there are some 250 species of rhopalocera and more than 5,000 species of heterocera (Figure 1.5).

❀ Pollinating beetles (Figure 1.6) include the Cetoniidae and longicorns. Beetles often consume the stamens and pollen from flowers.

Figure 1.3
Epistrophe sp. (hoverfly) on an Apiaceae flower

Photo credit: Arnaud LE NEVÉ

Figure 1.4
Lysandra coridon (Chalkhill blue) on a flower of *Knautia arvensis* (Field scabious)

Photo credit: Violette LE FÉON

Figure 1.5
Acontia lucida (Pale shoulder) on a flower of *Thalictrum flavum* (Common meadow-rue)

Photo credit: Arnaud LE NEVÉ

Figure 1.6
Stictoleptura rubra (Red-brown longhorn beetle) on a flower of *Cirsium arvense* (Creeping thistle)

Photo credit: Arnaud LE NEVÉ

1.4. Wild bees

The wild bees found in Europe are classified into six families that can be divided into two groups according to the length of their tongue. Short-tongued bees, which preferentially feed from open corolla flowers (e.g. Rosaceae, Asteraceae – Figure 1.7), includes 4 families: Andrenidae, Colletidae, Halictidae and Melittidae. Long-tongued bees, which can feed from deep corolla flowers (e.g. Lamiaceae, Fabaceae – Figure 1.8), includes the Apidae and Megachilidae families.

Figure 1.7
Andrena flavipes (Andrenidae family) on an open corolla flower: *Bellis perennis* (Common daisy)

Photo credit: Matthieu AUBERT

Figure 1.8
Eucera sp. (Apidae family) on a deep corolla flower: *Trifolium pratense* (Red clover)

Photo credit: Matthieu AUBERT

However, there are certain exceptions: some Andrenidae (e.g. *Andrena curvungula, Andrena paucisquama, Andrena rufizona*) are specialised for feeding on deep corolla flowers such as campanulas, and conversely, some Megachilidae (e.g. *Osmia signata, Osmia spinulosa* and *Megachile* species of the subgenus *Xanthosarus*) and Apidae (e.g. *Tetraloniella fulvescens, Tetraloniella alticincta, Eucera taurica, Eucera nigrifacies*) are specialised for feeding on open corolla flowers. In addition, some very small species (genus *Hylaeus* of the Colletidae family, genus *Ceratina* of the Apidae family, genus *Lasioglossum* of the Halictidae family) are able to completely enter some deep and narrow corolla flowers.

The principal characteristics of the 6 families of wild bees are set out below and for each one, the approximate number of species in metropolitan France is given as an example. Some species belonging to each of these families are presented in Figures 1.9 to 1.14.

The Andrenidae, with about 160 species in France (Figure 1.9) are known as *sand bees* or *mining bees* because they often build their nests by burrowing into sandy soils. The females have a typical brush of curly hairs at the base of their hind legs, called *flocculi*. Some species, referred to as *bivoltine*, have two generations in a year, others, referred to as *monovoltine*, have only one (see Figure 2.1).

Figure 1.9
Andrena thoracica on a flower of *Prunus spinosa* (Blackthorn)

Photo credit: Arnaud LE NEVÉ

Figure 1.10
Colletes cunicularius on a flower of *Salix atrocinerea* (Large grey willow)

Photo credit: Arnaud LE NEVÉ

The Colletidae, with about 70 solitary species in France, are divided into two genera (*Hylaeus* and *Colletes* – Figure 1.10). *Colletes* (so-called *plasterer bees*) build their nests in the ground and cover the walls with a waterproof membrane. *Hylaeus* species are very small, shiny and almost hairless. Their face is characterised by yellow or white spots forming masks, hence their name of *masked bees*. They nest in the stems of plants such as brambles and some Apiaceae (Umbelliferae).

The Halictidae with roughly 160 species in France (Figure 1.11), nest in the ground, especially compacted soils on paths. Commonly called *sweat bees*, they are mostly solitary. However, some species have certain social traits: a dominant female lays her eggs and the other females perform the tasks of foraging, feeding the larvae and defending the nest.

Figure 1.11
Halictus scabiosae on a flower of *Andryala integrifolia* (Common andryala)

Photo credit: David GENOUD

The Melittidae, with about fifteen solitary species in France, are mainly seen in the summer months. They nest in the ground. Most of them are specialised foragers, feeding on a single or a limited number of plant species (Figure 1.12).

Figure 1.12
Macropis europaea on a flower of *Lysimachia vulgaris* (Yellow loosestrife)

Photo credit: David GENOUD

Figure 1.13
Bombus pascuorum (Common carder bee) on a flower of *Rhinanthus minor*

Photo credit: Gilles MAHÉ

The Apidae include about 260 species in France (Figure 1.13). This large family includes many genera with a wide range of morphologies and behaviours. For example, they include bumblebees (genus *Bombus*), which are social bees with dense colourful hair. They live in colonies, made up of between a few dozen and a few hundred individuals, whose workers are responsible for collecting pollen. Colonies are established in underground cavities (e.g. former rodent burrows) or in elevated locations (e.g. tree trunks and abandoned nesting boxes). Bees of the genera *Anthophora* and *Eucera* are also very hairy and look a little like bumblebees, but they are solitary. They nest in the ground. *Eucera* males are characterised by their very long antennae. Bees of the genus *Xylocopa* are among Europe's largest bees. Except for one species (*Xylocopa cantabrita*), they are all black with bluish highlights. They nest in cavities which they hollow out in dead wood, hence their common name of *carpenter bees*.

The Megachilidae, which are represented by about 200 species in France (Figure 1.14), have the particularity of collecting and transporting pollen using hair brushes located under their abdomen (called *ventral brushes*). The Megachilidae are also characterised by their nesting behaviour: most species nest in cavities of various types (e.g. holes in wood, plant stems, empty snail shells, holes in walls or rocks) that can be lined with materials (e.g. cut leaves, vegetable down, resin, mud). Among

Figure 1.14
Trachusa interrupta on a flower of *Knautia arvensis* (Field scabious)

Photo credit: David GENOUD

the main genera in this family are *Osmia* (*mason bees*), *Megachile* (*leafcutter bees*) that frequently line their nests with pieces of leaf rolled like cigars, or *Anthidium* (so-called solitary *carder bees*) that often nest in cells made with plant down. Some *Megachile* and *Anthidium* species are called *resin bees* because they use conifer resin to build their nest cells.

The females of the genus *Hylaeus* (family of Colletidae) and most of those of the genus *Ceratina* (Apidae family) carry the food resources they collect (a mixture of nectar and pollen) in their crop. Other females (of non-parasitic genera) have an external food-carrying apparatus (called a *scopa*) such as pollen baskets on their hind legs (in Andrenidae, some Apidae, the Halictidae, Melittidae and Colletidae of the genus *Colletes*) or ventral brushes (in Megachilidae) or dorsal brushes (genus *Systropha* in Apidae), or even facial hairs (genus *Rophites* in Halictidae).

Some bee species are parasitic. They are known as *cuckoo bees* because, like the cuckoo, they lay their eggs in the nests of other bees and leave these bees to feed their larvae. They therefore do not have a scopa. But they nevertheless contribute to pollination by moving from flower to flower to feed on nectar. For example, in France, there are 201 species of *cuckoo bees* (almost 20% of all wild bee species). They are found in three families: Halictidae (genus *Sphecodes*), Megachilidae (e.g. the genera *Coelioxys* and *Stelis*), Apidae (e.g. the genera *Epeolus, Melecta, Nomada* and the subgenus *Psithyrus* in the genus *Bombus*). The presence of cuckoo bees in an environment is an indicator of the health of other bee populations as it means that the host species are sufficiently abundant to support them.

Female *Nomada lathburiana* (Apidae family), a *cuckoo bee*

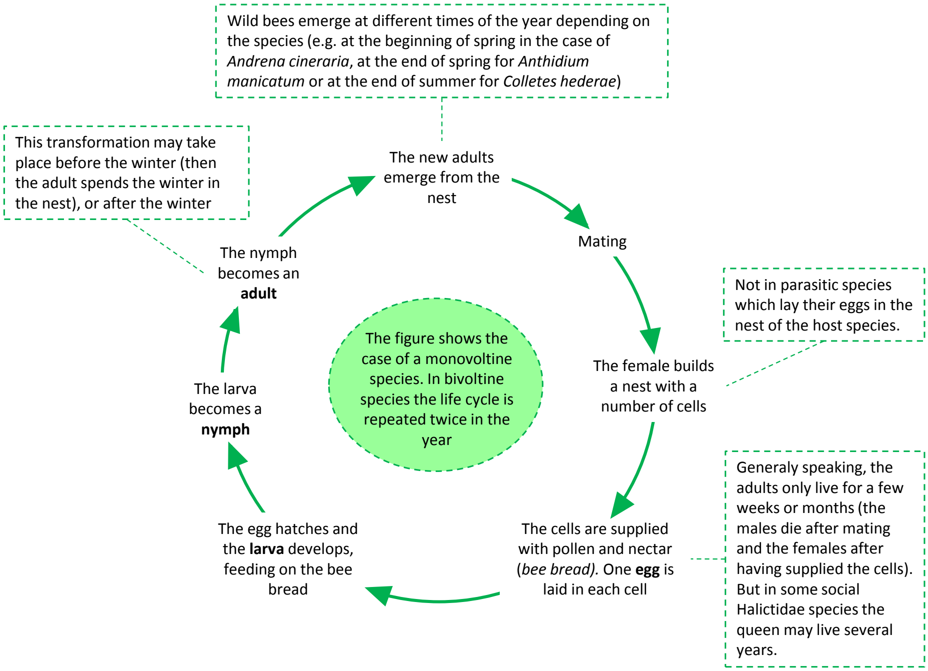
Photo credit: David GENOUD

Section 2.
The ecology of wild bees

2.1. The needs of wild bees

As is the case for the majority of insects (those so-called “with complete metamorphosis”) the bee has a four-stage life cycle: egg, larva, nymph and adult (or imago). There is great variability between bee species with regard to the timing in the year and duration of each stage. Figure 2.1 provides a general outline of the life cycle of bees. The egg hatches a few days after it has been laid and the larvae feed for a few weeks on the food reserve left by their mother. This consists of a mixture of nectar and pollen called *bee bread*. The larva then turns into a nymph and remains in its cells without eating for several months. Depending on the species, the adult bee emerges from the nest between early spring and late summer.

Figure 2.1
The life cycle of bees



Establishing and maintaining a wild bee population depends on the presence of suitable habitats and the ability to move between them. The movement of individuals may be hindered by obstacles or by excessive distances between the different areas of habitat (called habitat patches) compared to the species' ability to travel.

2.1.1. Habitats

For a wild bee population to be able to establish and sustain itself in a given area, the latter must be able to provide the bees with two things: sufficient food resources for both adults and larvae, and nesting sites that suit the needs of the species.

With the exception of species that are adapted to mountain environments (for example, some bumblebee species), bees are mainly thermophilic and heliophilic. They are therefore typically associated with warm, open, flower-rich environments with some sparsely vegetated areas that allow them to nest in the ground.

2.1.1.1. Foraging resources

Pollen and nectar

Adult bees feed exclusively on the resources gathered in flowers: nectar, pollen, and sometimes floral oils. Pollen is a source of protids (amino acids), carbohydrates (starch), fats (sterols), vitamins and minerals.

Nectar is a liquid secreted by glands (nectaries) located in the flowers. It is a source of water and sugars (fructose, glucose, sucrose) with a high energy value. Nectar contains odorous compounds that attract pollinating insects.

Specialist bees and generalist bees

Bees that forage on several plant families are called *polylectic*. Such generalist bees can be found in the Andrenidae, Colletidae, Halictidae, Megachilidae and Apidae families.

Some bee species forage on the flowers of a single plant family (e.g. Asteraceae). These specialist bees are called *oligolectic*. The term also applies to even more restricted associations, to a single plant genus or even a single species, the latter being very rare. Oligolectic bees are found mainly in the Mellitidae, Andrenidae and Colletidae families. Examples of specialist bees are given in Table 2.1.

Table 2.1
Some plants that are visited by specialist bees.

Plants[a] **Family, *Genus*, *species* (common english name)**	**Specialist bees *Genus*, *species***	**Family**
Apiaceae	*Andrena alutacea*	Andrenidae
Asteraceae	*Andrena fulvago* *Andrena humilis* *Andrena nigroolivacea* *Panurgus dentipes*	Andrenidae
	Dasypoda hirtipes	Melittidae
	Heriades truncorum	Megachilidae
Brassicaceae	*Andrena agilissima* *Andrena distinguenda* *Andrena lagopus*	Andrenidae
Bryonia cretica ssp. *dioica* (White bryony)[b]	*Andrena florea*	Andrenidae
Campanulaceae	*Andrena pandellei*	Andrenidae
	Chelostoma campanularum *Chelostoma rapunculi*	Megachilidae
Echium vulgare (Viper's bugloss)[c]	*Hoplitis adunca*	Megachilidae
Eryngium campestre (Field eryngo)[d]	*Colletes hylaeiformis*	Colletidae
Fabaceae	*Andrena labialis* *Andrena ovatula*	Andrenidae
	Eucera nigrescens	Apidae
Hedera (ivy)[e]	*Colletes hederae*	Colletidae
Ranunculaceae	*Andrena ranunculi*	Andrenidae
	Chelostoma florisomne	Megachilidae
Salicaceae (willows)	*Andrena clarkella* *Andrena mitis* *Andrena praecox* *Andrena vaga*	Andrenidae

[a] Plants are shown by the name of their family, genus or species depending on the bees' level of specialisation.
[b] Cucurbitaceae family.
[c] Boraginaceae family.
[d] Apiaceae family.
[e] Araliaceae family.

Figure 2.2
Willows in flower

Photo credit: Denis FRANÇOIS

Figure 2.3
Daucus carota (Wild carrot), a common member of the Apiaceae family

Photo credit: Arnaud LE NEVÉ

Figure 2.4
Centaurea decipiens (Chalk knapweed) a common species of the Asteraceae

Photo credit: Denis FRANÇOIS

Figure 2.5
Raphanus raphanistrum (Wild radish), a common member of the Brassicaceae

Photo credit: Denis FRANÇOIS

Figure 2.6
Andrena florea on a flower of *Bryonia cretica* (White bryony)

Photo credit: Nicolas MORISON

Figure 2.7
Ranunculus bulbosus (Bulbous buttercup), a common species of the Renunculaceae

Photo credit: Denis FRANÇOIS

Figure 2.8
Echium vulgare (Viper's bugloss)

Photo credit: Denis FRANÇOIS

Figure 2.9
Andrena pandellei in a flower of *Campanula rapunculus* (Rampion bellflower), a common member of the Campanulaceae

Photo credit: Denis FRANÇOIS

Figure 2.10
Colletes hederae on a flower of *Hedera helix* (Common ivy)

Photo credit: David GENOUD

Figure 2.11
Trifolium pratense (Red clover), a common species of the Fabaceae

Photo credit: Denis FRANÇOIS

B1 | B2 | B3 | B4 | B5 | B6 | B7 | B8 | B9

Dicotyledons, monocotyledons and grasses

Flowering plants fall into two large groups: dicotyledons (dicots) and monocotyledons (monocots). A very large number of dicotyledons are foraged by bees. In general, increasing the number of species and the abundance of dicots in an environment makes it more bee-friendly. Monocots include in particular grasses, which are wind-pollinated and usually provide little interest in the way of food for bees. One of the objectives of a management plan to support bees will therefore be to limit the proportion of grasses.

In the rest of this document, we will often oppose grasses (recommendations aim to reduce their presence in road verges) to dicotyledons (whose presence should be increased). This is a simplification which we adopt knowingly to make the presentation easier, without forgetting that among monocots there are also many species visited by bees, such as some orchids (e.g. *Anacamptis laxiflora* – Loose-flowered orchid; *Anacamptis morio* – Green-veined orchid; *Ophrys sphegodes* – Early spider orchid) and some Asparagaceae (e.g. *Prospero autumnale* – Autumn squill, *Hyacinthoides non-scripta* – Bluebell).

Anacamptis laxiflora
(Loose-flowered Orchid)

Photo credit: Arnaud LE NEVÉ

Hyacinthoides non-scripta (Bluebell)
visited by *Rhingia campestris*
(a hoverfly)

Photo credit: Denis FRANÇOIS

The importance of floral diversity

Floral resources of a habitat must be sufficiently abundant to cover the dietary needs of adults and larvae. They must be available long enough to meet the needs of the different species that succeed one another in the course of the year (from the end of winter to the middle of autumn) and to the two generations of bivoltine species. For oligolectic bee species, the important thing is for the plant species they feed on to be in flower during the period when they are active. In addition, it has been shown in honey bee that dietary diversity (in terms of sources of pollen and nectar) increases resistance to some pathogens.

2.1.1.2. Nesting sites

Solitary bees and social bees

Most wild bee species are solitary: each female builds her own nest to lay eggs. In this nest, the adult female makes one cell for each egg, in which she leaves bee bread for the future larvae to eat. In some species, cells are weatherproofed with materials sourced outside (plant down, dried mud, pieces of leaves, etc.). In general, adult wild bees do not look after their offspring, except for bumblebees and some Halictidae species which clean the larval cells regularly.

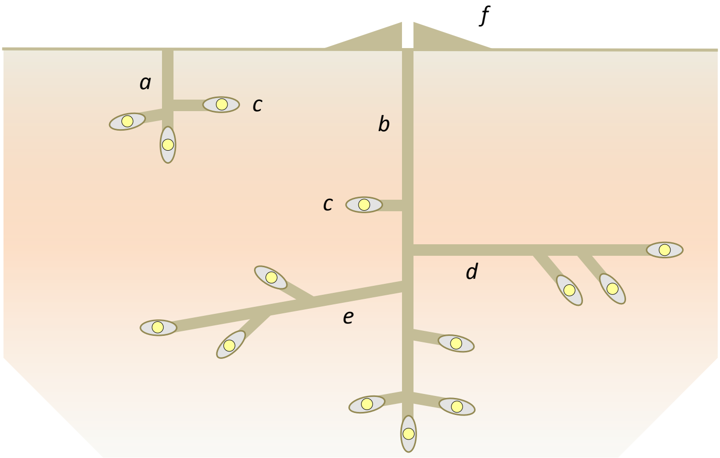
Some wild bees, such as bumblebees and some Halictidae species, are social. Hence, bumblebees establish colonies with an annual lifespan. Each colony is constructed around a queen (the only fertile female), with workers (sterile females) who maintain the nest and the cells, and feed the larvae. Only young, fertilised, females (future queens) survive the winter which they spend in a shelter (a cavity in the soil, a rock or trees). Depending on the species, in the spring the new colony will be established in abandoned underground burrows of small mammals (e.g. voles, field mice), in trees or thickets of vegetation (e.g. piles of leaves, moss). Suitable sites are typically found in hedgerows, the woodland edges, heath- or wasteland and embankments.

Ground nesting

Most wild bees build their nests in the ground. These *ground-nesting bees* (also called *terricolous*) need bare or sparsely vegetated soil surfaces such as those on paths and embankments or on moderately trampled locations. Some ground-nesting species preferentially build their nests from vertical surfaces, for example embankments or cliffs.

The structure of the nest varies from species to species. The nests (Figure 2.12) consist of a main vertical tunnel which may vary from several tens of centimetres in depth to 1 metre. The cells (each of which contains one larva) are connected to this tunnel either directly or by secondary horizontal or subhorizontal tunnels. The nests contain between less than 10 cells (e.g. *Colletes cunicularius*) and several dozen cells (e.g. certain Halictidae species). On the surface, the entrance to some nests is revealed by a small turret made of earth and/or various agglomerated materials (Figure 2.13), or by a tumulus made of excavated earth (Figure 2.14).

Figure 2.12
The main parts of underground nests



a: shallow nest (≈30 cm); ***b***: deep nest; ***c***: cell and egg; ***d***: secondary horizontal tunnel; ***e***: subhorizontal tunnel; ***f***: tumulus

Figure 2.13
A nest entrance turret

Photo credit: Denis FRANÇOIS

Figure 2.14
Tumulus

Photo credit: Violette LE FÉON

Isolated nests and aggregations

The nests are usually isolated and inconspicuous. However, some gregarious species (e.g. some Andrenidae and Colletidae species) build them in groups forming large nesting *aggregations*. Depending on the species, an aggregation can range from a few tens of nests to a few thousand covering several square metres (Figure 2.15).

Above-ground nesting

Non-terricolous bees nest in various types of cavities: holes in walls or rocks, holes in wood, empty snail shells, plant stems. They are called *cavity-nesting bees*. Species that nest in galleries made in the wood are called *xylicolous*. Those that nest in hollow plant stems are calles *lignicolous*. Plants with dry stems for nesting include brambles and some Apiaceae such as fennel, angelica, wild chervil and hogweed.

Figure 2.15
An aggregation

Photo credit: Violette LE FÉON

2.1.2. Travel

2.1.2.1. Daily foraging trips

Females make frequent journeys between their nest and floral resources to collect pollen and nectar for their larvae (Section 2.1.1.1). Species which line their nest with materials collected outside (especially in the Megachilidae family – see Section 1.4), also travel back and forth for that purpose (Figure 2.16).

Figure 2.16
Diagrammatic representation of the resource collection behaviour in bees

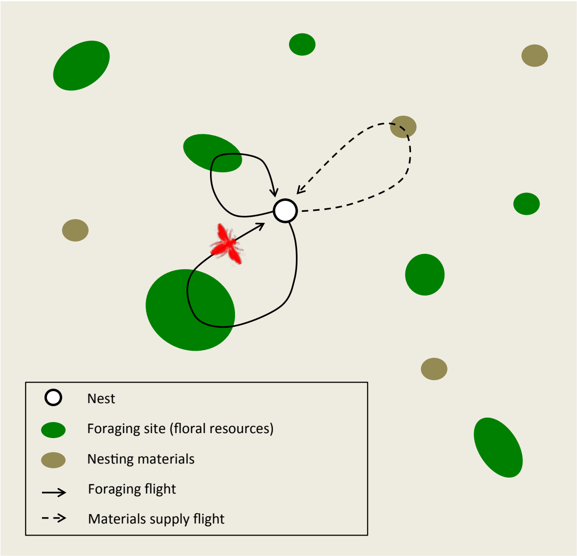
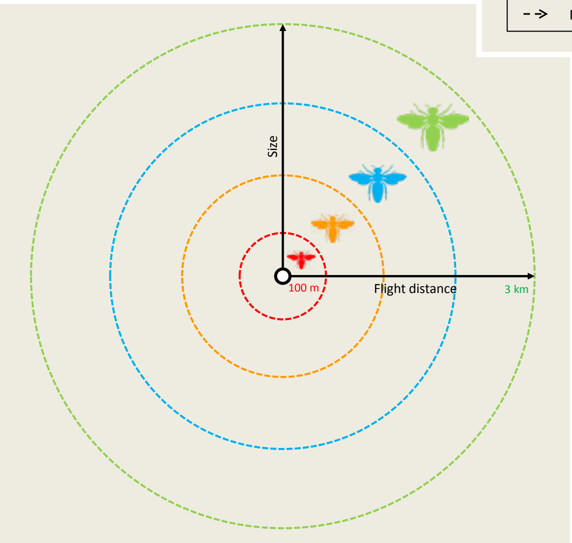


Figure 2.17
Flight distance around the nest (O) according to size of species



The surface area that can be explored around the nest is determined by the species-specific flight distance, which is a function of species' size (Figure 2.17). The radius of the zone in question thus varies from less than 100 m to a few hundred metres for small species (e.g. small species in the genus *Andrena*) to several kilometres for large species, such as bumblebees and carpenter bees (in the genus *Xylocopa*).

For a given species, an increase in the distance between the nest and foraging sites results in increased energy expenditure for foraging, which leads to a decrease in reproductive success (fewer cells in the nest and fewer offspring per female).

2.1.2.2 Colonisation and dispersal movements

For bees, as for all plant and animal species, genetic exchanges between populations are a key factor for long-term survival. Movement of individuals for genetic exchange is dependent on landscape features and the degree of connectivity between habitats. For example, a road, with its associated collision risks, or an urban area that is large and therefore difficult to cross for species with short flight distance, may constitute obstacles to movement and, in some cases, produce dangerously isolated populations. Conversely, a continuous network of open spaces with flowers allows individuals to disperse over long distances.

2.2. The current status of wild bees and its consequences for nature and humans

2.2.1. Population decline

Since the end of the 1990s, the issue of pollinating insect decline and its consequences for the reproduction of wild and cultivated plants has been given increasing importance both in scientific thought and in the media. A 2006 study showed that during the twentieth century, the number of bee species decreased in many locations in the Netherlands and the United Kingdom (based on comparisons between situations before and after 1980), as a result of changes in the landscape and farming practices. During the same period, a number of countries (including France) experienced the same types of agricultural and landscape changes. Despite such complete and precise evaluations of changes in wild bee populations are not available, local studies also reveal a degree of population decline there (e.g. spatial distribution of bumblebees in the department of Loire-Atlantique (6,880 km^2 in the west of France) by Mahé in 2015).

2014 saw the publication of the first Red List of European Wild Bees. This document attempts to characterise the status of the different species, hence to indicate which are the most under threat. Because the distribution of European bees is not well known, no status could be established for over half the listed species. However, among the species which were well enough known to be evaluated, over 9% are deemed to be threatened with extinction. Considering that a large number of species, many of which may be extremely rare, could not be evaluated, the experts who drew up the Red List estimate that the actual proportion of species that are threatened with extinction in Europe is higher.

2.2.2. Causes

Wild bee populations are subject to various environmental pressures (Fig. 2.18). These affect bees both directly and indirectly – through the depletion of floral resources or the reduction in the number of nesting sites. Examples of direct effects include the lethal and sublethal effects of pesticides. The installation of honey bee colonies may introduce diseases into the environment that can affect wild bees. The destruction of favourable habitat, the use of herbicides and excessive fertilization, the increase in the size of agricultural parcels, monoculture, the mowing of meadows too frequently or too early or the introduction of competing exotic plant species can all decrease floral resources. If the density of honey bee populations becomes too high, competition with them can also diminish floral resources. Finally, climate change can also induce a reduction in floral resources, especially if bee flight periods no longer coincide with the flowering of the plants they feed on. The destruction of favourable habitat, excessively deep tilling of soil or the disappearance of beneficial plants because of herbicides or fertiliser use, can affect nesting sites.

Generally speaking, habitat destruction due to urbanisation, transport infrastructure or the increase in the size of agricultural parcels and more intensive agricultural practices, are deemed to be the main causes for the decline in wild bee populations. In addition, different pressures can operate together. For example, it has been shown that bumblebees are more vulnerable to disease when food resources are scarce.

2.2.3. Consequences

The decline in wild bee populations can have impacts on both cultivated and wild plants, and on food-webs (food chains).

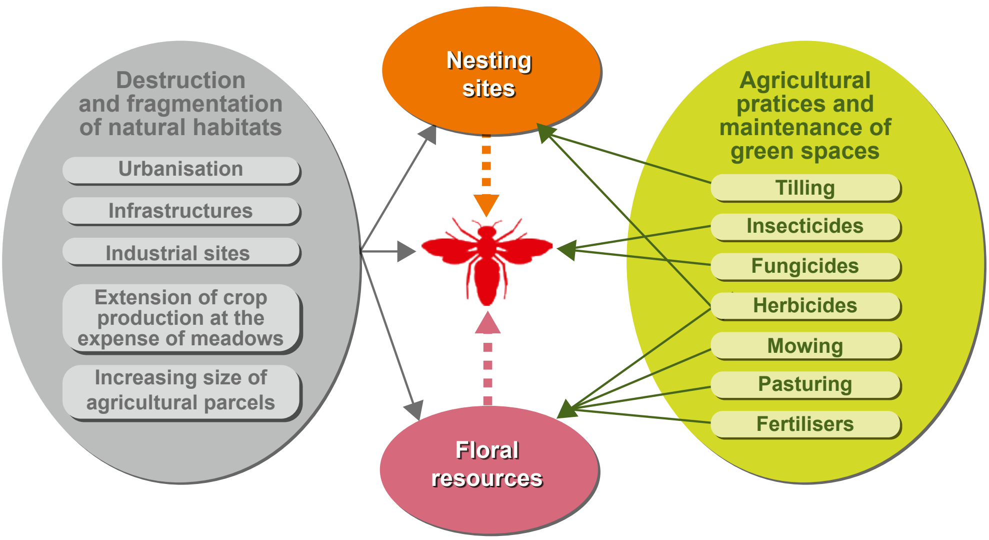
Worldwide, 65% of the species that are cultivated for human consumption (fruit, vegetables, seeds), depend on animal pollination, mainly by insects. In terms of the volume of production, crops which depend on animal pollination account for 34% of world food production. The 43 plants for which animal pollination is essential or very important (i.e. when production is reduced by over 40% in the absence of pollinators), include fruit trees from the tropics (cocoa, mango, some coffee varieties) or temperate regions (apple, pear, plum, cherry, almond), Cucurbitaceae (melon, cucumber, squash), aromatic plants (coriander, cumin, cardamom), berries (blueberries, cranberries, raspberries, blackberries), as well as kiwi, avocado and fennel.

Within the current context of population growth and a global reduction in the surface area allocated to agriculture, the decline in bee populations could lead to a reduction in dietary intakes of essential vitamins and nutrients, and thus negatively impact human health.

An increasing number of scientific studies demonstrate the existence of a complementary and synergetic relationship between honey bees and wild bees, as well as between bees and other pollinating insects. This is because, depending on their own morphology and ecology, the different species have different flower visiting and/or pollen harvesting behaviours which, acting together, improve the overall pollen flow. Thus, even if one regards things from a uniquely agronomic perspective, it is unrealistic to hope that we can compensate for the consequences of the disappearance of wild bees by increasing the number of honey bee colonies (hives) near crops. Moreover, the resulting overabundance of honey bees in an environment can have adverse impacts on the wild bees that remain present there (Section 2.2.2).

Apart from its consequences on human food production, bee population decline may affect the entire functioning of ecosystems. The reproduction of some wild plants, in particular those that are visited by only a few pollinating insects, can be compromised. The increasing scarcity of these plants can in turn speed up wild pollinator decline. The consequences for local biodiversity go beyond this vicious circle: animals, for example other insects, amphibians, reptiles, birds and mammals, which feed on bees, or which feed on plants that are threatened by bee decline, may also be under threat.

Figure 2.18
Main environmental pressures affecting wild bee populations. These pressures can affect bees directly or indirectly by depleting floral resources and nesting sites



Part II.

Fundamentals of action to support wild bees in road verges

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A ground-nesting bee leaving its nest

Photo credit: Violette LE FÉON

Section 3.
Why try to meet the needs of wild bees in road verges

3.1. The potential of road verges for wild bees

In recent years, the management of road verges has become less and less intensive due to measures such as reductions in the use of pesticides and the frequency of mowing. This may allow them to become habitats similar to hay meadows. Thus, in some, increasingly numerous, locations large numbers of flowers from a variety of species are present, sometimes over a long period during the year. Moreover, human presence in road verges is very rare and limited to occasional visits by maintenance teams. Such extensive management also provides an opportunity for shrubs and trees to grow (brambles, broom, gorse, willows, rowans, etc.). Road cuttings often provide bare soil and rocky outcrops.

On a national scale, road verges can cover large expanses of land. For example, for metropolitan France it has been estimated that for the national road network they would cover about 1% of the country's surface area (i.e. roughly 5,000 km^2). In zones where the quality of the environment has been degraded, for example due to intensive agricultural practices or urbanisation, road verges can therefore constitute areas relatively unaffected by the principal sources of wild bee decline and provide these species with forage and nesting sites.

3.2. Issues

3.2.1. Helping to conserve declining species

Land transport infrastructures are not the primary cause of declining wild pollinator populations, but they play a role, in particular through habitat destruction due to their insertion in the landscape and the obstacles they create for movement which contributes to population fragmentation.

Harnessing the potential of road verges for wild bees by the greater application of extensive management practices is a simple measure to reduce the impacts of infrastructure and to repair damage created by other activities in areas where the natural environment has been degraded (islands of conservation). Road verges provide an opportunity to create pesticide-free habitats, in line with the recommendations of IUCN (International Union for Conservation of Nature) for European bees (see Red List of Wild Bees in Europe).

Safeguarding these populations is also essential in order to halt the decline of many native flowering plants, breaking the vicious circle of joint extinctions of pollinators and their natural floral resources. This is a crucial issue for specialised species (see Section 2.1.1.1).

3.2.2. Helping to restore ecological corridors and the functioning of ecosystems

Building roads in a landscape contributes to the fragmentation of ecosystems and the disruption of ecological corridors. However, the restoration of habitats within road verges can be a way to re-instate connectivity between disconnected sections of the landscape network, whether the origin of the disconnection is the infrastructure itself or other causes (agricultural consolidation of the landscapes through which they pass, urbanised zones, etc.). The restoration of connectivity between sections of the green network outside road rights-of-way could, thanks to the flight distances of wild pollinators, be brought about in a discontinuous manner within the verges, by creating patches of habitat similar to *stepping stones*, according to the potentialities of the individual sites.

3.2.3. Helping to maintain pollination services

Insects pollinate both wild and cultivated plants. However in everyday language ecosystem pollination “services” are often taken to refer to the contribution to food crop productivity. In fact, for many cultivated plants, visits by wild pollinators permit or improve production in quantity and quality.

Wild pollinators nesting in road verges could help maintain pollination services and the productivity of insect pollinated crops near roads (within the flight distance of the visiting species).

In addition, unlike honey bees, whose hives must be maintained and relocated by beekeepers in order to make sure they have sufficient food and/or pollinate crops, the contribution of thousands of wild pollinator species to pollination services is completely independent from any human intervention.

3.3. Limits

In this document as well as in various research and experimentation projects, road verges are seen as potential areas for biodiversity conservation. However, encouraging the settlement and development of animal populations near a roadway may raise concerns because of the risk of collision mortality. Where this is high, is it advisable to take measures to support wild bees in road verges? In fact, studies on the impact of motor traffic on insect mortality are few and far between and have focused mainly on butterflies. Results obtained in Poland in 2013 provide some information about the life of these insects in the road environment. The intensity of vehicular traffic is, of course, a factor that increases mortality, but the abundance and diversity of flowers in roadside vegetation are factors that significantly reduce collisions. The collision mortality rate for butterflies is lower near road verges where floral resources are abundant and varied. Thus the road verges that are most supportive of butterflies are also those where the risk of collision is lowest. Smaller species of butterflies are more affected than larger ones which fly more quickly.

In the absence of specific observations for bees, in view of those made on butterflies, and the possibility of implementing measures limiting the need for bees to cross roads (see Section 7), one can reasonably assume that a measure to encourage wild bees in road verges will have a globally beneficial impact.

3.4. Benefits

In order to achieve a successful outcome in the field, the limits described above and local environmental factors must be taken into account. On the one hand, encouraging nesting on a site must go hand in hand with the provision of sufficient food resources there. On the other hand, the location of favourable sites in road verges must take into account the attractiveness of the surrounding green network: allow direct connectivity with the food resources present in the adjoining landscape, and avoid the need for wild bees to cross roads with heavy traffic, which would cause losses by collision. In order to keep the collision mortality rate down, no operations should be envisaged less than a certain distance from the edge of the roadway (3 to 7 metres depending on the type of road – see Section 7.3.1). In addition direct interconnections between the habitats in the road verge and the green network adjoining the right-of-way will be encouraged.

In view of the current status of wild bee populations and its consequences for biodiversity and humans as well as the potential afforded by road verges, the possibility of using them to safeguard wild bees cannot be overlooked. Besides, similar initiatives have already been taken to promote bee-friendly management methods in other areas with a significant human footprint, such as the urban environment and quarries, (e.g. the Urbanbees programme and the initiative of the Nord – Pas-de-Calais public land agency with the French National Union of Aggregate Producers).

For land transport infrastructure (both existing and new), achieving positive effects on wild bee populations would improve its overall environmental impact on the landscapes it passes through: safeguarding declining species, contributing to the restoration of green networks and supporting pollination services. In its evaluation report on pollinators, pollination and food production (2016), the IPBES identified using road verges as one of the immediately available options to improve the current status of pollinators and maintain pollination services.

Bombus pascuorum (Common carder bee) on a flower of *Carduus nutans* (Musk thistle)

Photo credit: Aurélia LACHAUD

Section 4.
How to meet the needs of bees in road verges

4.1. Guiding principle of action to support wild bees in road verges

Taking action to support wild bees within road verges consists not only of trying to meet their needs in terms of foraging and nesting sites, but also ensuring they are able to travel between these sites when they are not immediately adjacent. Recommendations to address these three needs are made in sections 5, 6 and 7 respectively.

The objective of these recommendations is to provide conditions within road verges that meet the needs of wild bees. This is not about direct action to help the populations, but simply allowing the environmental factors that favour the settlement and development of wild bee populations express themselves. This settlement and development will occur spontaneously, depending on the species present in the local environment and their colonisation capacity. The philosophy underlying all the recommendations presented in this document is to give the local ecological heritage the opportunity to express itself and develop spontaneously by creating the most favourable initial conditions possible and by limiting human intervention to what is strictly necessary. As far as existing situations are concerned, this intervention may simply consist of restoring favourable conditions when inappropriate facilities or practices have resulted in their loss.

These recommendations are based on an understanding of the ecology of wild bees, on existing knowledge about measures to support them and on observations made in the road environment. They take into account the specific characteristics and challenges that apply in this particular environment. They relate to the verges not only of existing roads but also those to be built in the future, and are also applicable to road-widening schemes.

4.2. Principle of action to support food resources

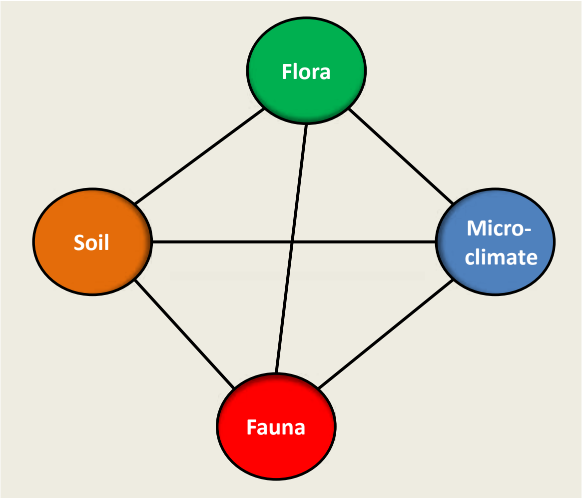
In each place, the local characteristics of the soil and climate determine the ability of plant species to become established spontaneously and continue to exist in the long term. The vegetation naturally present in a given location is therefore the result of the expression of local edaphic and climatic factors. The natural zone of distribution of plants is dictated by these so-called *abiotic factors*.

Like that of plants, the geographical distribution of animals is influenced by abiotic factors. But their feeding requirements have an influence too, through the presence of the plant species on which they depend more or less directly: herbivores exhibit varying degrees of specialisation in terms of the plants they consume, but carnivores too in terms of the herbivores they predate.

Their feeding requirements mean the various wild bee species are directly dependent on a certain diversity of plant species, whose long-term presence is dictated by local abiotic factors (soil and microclimate). There is therefore an inescapable set of links between the abiotic factors, the local plant species and the bee species that may be present in a given location (Figure 4.1).

Allowing wild bees to establish themselves in a given location therefore means targeting only those species – but there may be very many of them – that are adapted to local abiotic factors (species that already exist locally but whose populations have been decimated), by providing them with the food resources with which they are naturally associated. It is therefore not a question of planting ornamental and/or exotic plant species (see Box B2). Action with regard to food resources (pollen and nectar supply) therefore consists simply of encouraging the conservation or return of native forage

Figure 4.1
Tetrahedron of links Micro-climate – Soil – Flora – Fauna



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Flower fallows

Flower fallows have been proposed since the 1990s to provide flowers suitable for floricolous insects in non-cultivated areas. The mixtures proposed by seed suppliers contain diverse large colourful flowers because they also have an aesthetic purpose that adds to their popularity.

The mixtures are mostly made up of ornamental species that are mainly non-indigenous (from Africa or South, Central and North America), such as red flax (*Linum grandiflorum*), sunflowers (*Helianthus annuus*), California poppy (*Eschscholzia californica*), common, blanketflower (*Gaillardia aristata*), zinnia (*Zinnia elegans*) or cosmos (*Cosmos bipinnatus, Cosmos sulphureus*).

The intention of those using these mixtures to feed insects is commendable and reflects an awareness of the current status of pollinators. Some species in the mixtures can indeed provide food resources for some bee species, particularly polylectic ones. But this is generally only true for a short period of the year. However, species such as bumblebees, for example, need to provision their nests from spring to autumn. Moreover, these flower fallows are not suitable for the many oligolectic species that have a strong association with the local flora and cannot survive on ornamental and/or exotic plants.

A flower fallow with a high proportion of *Cosmos bipinnatus*

Photo credit: Denis FRANÇOIS

Initiatives exist in Belgium and Switzerland to develop flowering fallows from seeds of local species solely (several dozen species on offer). In addition to the direct benefit of feeding local populations of wild bees, these local mixtures also reduce the risk highlighted by botanists of spreading non-indigenous species in the environment and the risk of hybridisation with local flora (e.g. natural species selected to become ornamental, such as the cornflower). In the absence of ready-to-use local seed mixtures, it is possible to apply by oneself the so-called *hay seeds* technique (see Section 5.1.2.1) which applies the same principle and can be used in road verges.

species, which are inherently adapted to local abiotic factors. These species are present in the local environment but current maintenance and construction practices do not encourage their development or reproduction. This applies to plants in the herbaceous, shrub and tree vegetation strata. Species in each of these strata can provide forage flowers for wild bees.

4.3. Principle of action to support nesting sites

Due to the links which inevitably exist (Figure 4.1) between, on the one hand, the plant and animal species that are naturally present in an ecosystem and abiotic factors on the other, sustainable measures to support nesting sites should only be based solely on indigenous substrates, i.e. ones which have links with the site in question. By virtue of the above links, these substrates actually correspond naturally (in the literal sense) to the needs and capabilities of the wild bee species in the local ecosystem. By virtue of these same links, local plant and mineral substrates also correspond to local abiotic factors: host plants are adapted to the soil and climate and mineral substrates are in a state of equilibrium with local climatic factors (e.g. weathering and erosion).

In addition, the use of indigenous rather than artificial substrates (see Box B3) has several practical advantages for the roadside vegetation manager: resources are available on site, so they cost nothing or very little to procure or install, and the substrates are in keeping with the landscape of the entire local environment.

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Bee hotels

Bee hotels are shelters that are specifically made for various species to nest in, depending on the substrates they contain. The structure of these shelters and the boxes in which the various substrates are installed are made of sophisticated materials (planks, rafters, slats, a roof to keep rainwater out). The substrates installed in the boxes are of various types, from the most natural to the most sophisticated: small bundles of hollow stems of various plant species, logs drilled with holes of various diameters, wood and bark debris, pine cones, snail shells, rubble, hollow bricks, clay pots, roof tiles and pipes of various types. The variety of the substrates they bring together offers an immediate nesting opportunity for various species of cavity-nesting bees. However, in general, the number of bee species benefiting from the installation of such structures is relatively small compared to the total number of species present in the area in question.

However, such structures can be of real value in areas where there is only limited space available for natural nesting sites (e.g. areas with bare ground, thickets of brambles or favourable herbaceous plants). This is typically the case in urban areas, where these hotels can be installed in public gardens. These structures also have the advantage of contributing to public awareness about the existence and diversity of wild bees, raising awareness about the increasing scarcity of their habitats, and possibly encouraging individual or collective initiatives to support bees (e.g. conserving or creating favourable substrates in private gardens or corporate green spaces).

A bee hotel in an urban environment

Photo credit: Arnaud LE NEVÉ

Installing bee hotels in the very different setting of road verges – where both space and indigenous substrates are available and where human visits are rare – would be completely inappropriate a wasteful expense (around €2,500 per hotel according to an Urbanbees programme estimate in 2012). In road settings, their installation might only be of value in rest areas, supporting action to raise awareness and inform users about more general measures implemented for wild bees in the road verges on link sections.

Part III.
Operational recommendations for the management of road verges

Previous page

The floral diversity of a road embankment

Photo credit: Violette LE FÉON

Section 5.
Food resources

5.1. Food from herbaceous plants

5.1.1. Herbaceous plants that are useful for food

A non-exhaustive list of herbaceous plants that provide useful forage for wild bees in spring, summer or autumn is provided in Table 5.1. The roadside vegetation manager will be able to refer to the list to observe their presence and encourage their conservation and development. The listed species are more or less widespread throughout the continent of Europe. The information on their flowering period was taken from the Tela Botanica database[1], supplemented in some cases (designated by the symbol ‡) by information on blooming periods taken from the "Flore et Végétation de France" database[2].

Some species provide early forage for bees, for example *Erodium cicutarium*, *Glechoma hederacea*, *Primula veris*, *Veronica arvensis*, *Veronica persica*, *Ficaria verna*… Others are particularly valuable at the end of the season, for example *Daucus carota*, *Convolvulus arvensis*, *Medicago lupulina*, *Trifolium repens*, *Epilobium angustifolium*, *Linaria vulgaris*… (see Table 5.1).

Figure 5.1
Glechoma hederacea (Ground ivy), an early food source

Photo credit: Denis FRANÇOIS

1. http://www.tela-botanica.org/
2. http://philippe.julve.pagesperso-orange.fr/catminat.htm

Table 5.1
Examples of useful herbaceous plants for feeding wild bees

Family:		Month of flowering									
Scientific name	**Common english name**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**
Apiaceae:											
Angelica sylvestris L.	Wild angelica						✻	✻	✻		
Anthriscus sylvestris (L.) Hoffm.	Cow parsley				✻	✻	✻				
Daucus carota L.	Wild carrot					✻	✻	✻	✻	✻	✻
Foeniculum vulgare Mill.	Fennel							✻	✻	✻	✻
Heracleum sphondylium L.	Hogweed					✻	✻	✻	✻		
Pastinaca sativa L. subsp. *sativa* ‡	Parsnip						✻	✻			
Asteraceae:											
Achillea millefolium L.	Yarrow					✻	✻	✻	✻		
Carduus nutans L.	Musk thistle							✻	✻	✻	
Carduus pycnocephalus L.	Plymouth thistle				✻	✻					
Carduus tenuiflorus Curtis	Slender thistle				✻	✻					
Centaurea decipiens subsp. *thuillieri* (Dostál) B. Bock	Chalk knapweeds						✻	✻	✻		
Cichorium intybus L.	Chicory						✻	✻	✻		
Cirsium arvense (L.) Scop.	Creeping thistle						✻	✻	✻		
Cirsium vulgare (Savi) Ten.	Spear thistle						✻	✻	✻	✻	
Crepis biennis L.	Rough hawk's-beard				✻	✻	✻				
Crepis capillaris (L.) Wallr.	Smooth hawk's-beard					✻	✻	✻	✻		
Crepis vesicaria subsp. *taraxacifolia* (Thuill.) Thell.	Beaked hawk's- beard					✻	✻				
Hypochaeris radicata L.	Cat's-ear				✻	✻	✻	✻	✻		
Leontodon saxatilis Lam.	Lesser hawkbit					✻	✻	✻			
Leucanthemum vulgare (Vaill.) Lam.	Oxeye daisy				✻	✻	✻	✻			
Picris hieracoides L.	Hawkweed oxtongue						✻	✻	✻		
Pilosella officinarum Vaill.	Mouse-ear hawkweed				✻	✻	✻	✻	✻		
Pulicaria dysenterica (L.) Bernh.	Common fleabane						✻	✻	✻		
Scorzoneroides autumnalis (L.) Moench	Autumn hawkbit						✻	✻	✻	✻	
Tanacetum vulgare L.	Tansy						✻	✻	✻		
Taraxacum officinale F.H. Wigg.	Dandelion			✻	✻	✻	✻	✻	✻	✻	
Boraginaceae:											
Echium vulgare L.	Viper's-bugloss				✻	✻	✻	✻			
Brassicaceae:											
Brassica nigra (L.) W.D.J.Koch	Black mustard					✻	✻	✻	✻		
Brassica rapa L.	Turnip				✻	✻	✻				
Cardamine pratensis L.	Cuckooflower			✻	✻	✻					
Coincya monensis subsp. *cheiranthos* (Vill.) Aedo, Leadlay & Muñoz Garm.	Wallflower cabbage					✻	✻	✻	✻		
Raphanus raphanistrum L.	Wild radish				✻	✻	✻				
Sinapis arvensis L.	Charlock				✻	✻	✻	✻	✻		

Family:		Month of flowering									
Scientific name	**Common english name**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**
Caprifoliaceae:											
Dipsacus fullonum L.	Wild teasel						❊	❊	❊		
Knautia arvensis (L.) Coult.	Field scabious					❊	❊	❊			
Scabiosa columbaria L.	Small scabious					❊	❊	❊	❊	❊	
Succisa pratensis Moench	Devil's-bit scabious						❊	❊	❊	❊	
Caryophyllaceae:											
Lychnis flos-cuculi L. subsp. *flos-cuculi* ‡	Ragged robin				❊	❊	❊				
Silene dioica (L.) Clairv. var. *dioica* ‡	Red campion				❊	❊	❊				
Silene latifolia subsp. *Alba* (Mill.) Greuter & Burdet	White campion				❊	❊	❊				
Silene vulgaris (Moench) Garcke subsp. *vulgaris* ‡	Bladder campion			❊	❊	❊	❊	❊			
Stellaria holostea L.	Greater Stitchwort			❊	❊	❊					
Convolvulaceae:											
Convolvulus arvensis L.	Field bindweed				❊	❊	❊	❊	❊	❊	
Convolvulus sepium L.	Hedge bindweed.						❊	❊	❊	❊	
Cucurbitaceae:											
Bryonia cretica subsp. *dioica* (Jacq.) Tutin	White bryony				❊	❊	❊	❊			
Fabaceae:											
Lathyrus pratensis L.	Meadow vetchling.				❊	❊	❊	❊			
Lotus corniculatus L.	Bird's-foot trefoil				❊	❊	❊	❊	❊		
Lotus pedunculatus Cav.	Greater bird's-foot trefoil					❊	❊	❊	❊		
Medicago lupulina L.	Black medick			❊	❊	❊	❊	❊	❊	❊	
Medicago sativa L. subsp. *sativa* ‡	Alfalfa					❊	❊	❊	❊		
Onobrychis viciifolia subsp. *viciifolia*	Sainfoin				❊	❊	❊	❊			
Trifolium pratense L.	Red clover				❊	❊	❊	❊	❊		
Trifolium repens L.	White clover				❊	❊	❊	❊	❊	❊	
Trigonella alba (Medik.) Coulot & Rabaute	White melilot					❊	❊	❊	❊		
Trigonella officinalis (L.) Coulot & Rabaute	Yellow sweet clover				❊	❊	❊	❊	❊		
Vicia cracca L.	Tufted vetch					❊	❊	❊			
Vicia sativa L.	Common vetch				❊	❊	❊				
Vicia sepium L.	Bush vetch				❊	❊	❊	❊	❊		
Geraniaceae:											
Erodium cicutarium (L.) L'Hér. ‡	Common stork's-bill		❊	❊	❊	❊	❊	❊	❊	❊	
Geranium molle L.	Dove's-foot crane's-bill			❊	❊	❊	❊	❊	❊		
Geranium rotundifolium L.	Round-leaved crane's-bill			❊	❊	❊	❊	❊	❊		
Hypericaceae:											
Hypericum perforatum L.	Perforate St John's-wort					❊	❊	❊	❊		

Family:		Month of flowering									
Scientific name	**Common english name**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**
Lamiaceae:											
Ajuga reptans L.	Bugle			✻	✻	✻	✻				
Betonica officinalis L. ‡	Betony					✻	✻	✻	✻		
Clinopodium vulgare L.	Wild basil							✻	✻	✻	
Glechoma hederacea L.	Ground ivy		✻	✻	✻						
Lamium purpureum L.	Red dead-nettle”			✻	✻	✻	✻	✻	✻	✻	
Mentha suaveolens Ehrh. ‡	Round-leaved mint						✻	✻	✻		
Origanum vulgare L.	Wild marjoram						✻	✻	✻		
Prunella vulgaris L. ‡	Selfheal					✻	✻	✻	✻		
Salvia pratensis L. subsp. *pratensis* ‡	Meadow clary				✻	✻	✻				
Teucrium scorodonia L.	Wood sage					✻	✻	✻	✻		
Lythraceae:											
Lythrum salicaria L.	Purple loosestrife					✻	✻	✻	✻		
Malvaceae:											
Malva moschata L.	Musk mallow					✻	✻	✻	✻		
Malva sylvestris L.	Common mallow					✻	✻	✻	✻		
Onagraceae:											
Epilobium angustifolium L.	Rosebay willowherb						✻	✻	✻	✻	
Epilobium hirsutum L.	Great willowherb						✻	✻	✻		
Epilobium lanceolatum Sebast. & Mauri	Spear- leaved willowherb					✻	✻	✻	✻		
Epilobium palustre L.	Marsh willowherb						✻	✻	✻		
Epilobium parviflorum Scherb.	Hoary willowherb					✻	✻	✻	✻		
Epilobium tetragonum L.	Square-stalked willowherb					✻	✻	✻	✻		
Orobanchaceae:											
Melampyrum pratense L.	Common cow-wheat					✻	✻	✻			
Odontites vernus (Bellardi) Dumort.	Red bartsia				✻	✻	✻				
Papaveraceae:											
Fumaria muralis subsp. *muralis*	Common ramping-fumitory				✻	✻	✻	✻			
Papaver rhoeas L.	Common poppy				✻	✻	✻				
Plantaginaceae:											
Digitalis purpurea L.	Foxglove				✻	✻	✻	✻	✻		
Kickxia elatine (L.) Dumort.	Sharp-leaved fluellen						✻	✻	✻	✻	✻
Linaria vulgaris Mill.	Common T toadflax					✻	✻	✻	✻		
Veronica arvensis L.	Wall speedwell		✻	✻	✻	✻	✻	✻	✻	✻	
Veronica persica Poir.	Common field-speedwell.		✻	✻	✻	✻	✻	✻	✻	✻	
Primulaceae:											
Lysimachia arvensis (L.) U.Manns & Anderb.	Scarlet pimpernel				✻	✻	✻	✻	✻	✻	✻
Lysimachia vulgaris L.	Yellow loosestrife					✻	✻	✻			
Primula veris L. var. *veris* ‡	Cowslip		✻	✻	✻						

Family:		Month of flowering									
Scientific name	**Common english name**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**
Ranunculaceae:											
Ficaria verna Huds. ‡	Lesser celandine		❊	❊	❊						
Ranunculus acris L.	Meadow buttercup				❊	❊	❊	❊	❊		
Ranunculus bulbosus L.	Bulbous buttercup			❊	❊	❊	❊				
Ranunculus repens L.	Creeping buttercup				❊	❊	❊	❊	❊		
Rosaceae:											
Poterium sanguisorba L. ‡	Salad burnet				❊	❊	❊	❊	❊		
Rubiaceae:											
Galium verum L.	Lady's bedstraw					❊	❊	❊	❊		
Rubia peregrina L.	Wild madder				❊	❊	❊	❊			
Scrophulariaceae:											
Verbascum thaspus L.	Great mullein					❊	❊	❊	❊	❊	❊
Solanaceae:											
Solanum dulcamara L.	Bittersweet					❊	❊	❊	❊		

Figure 5.2
Pilosella officinarum (Mouse-ear hawkweed), a species that leaves bare soil between each individual

Photo credit: Denis FRANÇOIS

Figure 5.3
Lychnis flos-cuculi (Ragged robin), a good source of forage for bumblebees

Photo credit: Denis FRANÇOIS

Figure 5.4
Medicago lupulina (Black medick), a low-growing species with an abundance of small flowers

Photo credit: Denis FRANÇOIS

5.1.2. Obtaining herbaceous plants that are useful for food in road verges

The earthworks required for the construction of a road disturb the soil to a considerable depth. At the beginning of the earthworks, the stripping operation is to remove a layer of *topsoil* up to 40 cm thick. This is stockpiled in order to be spread back on the surface as soon as the earthworks have been completed, to be used for the grassing (the term used is *revegetation*) of embankments, cuttings and landscaping works. Revegetation is carried out by using seed mixtures (see Box B4) designed to quickly stabilise the soil, as a result of root development, and protect it from rainfall through the development of foliage.

Sometimes, particularly in cuttings, the bedrock is exposed by earthworks. In this case, revegetation is not necessary and the rock is left bare. The only vegetation arrives spontaneously, gradually becoming established by taking advantage of irregularities in the slope, cracks or spaces in the rock. The same applies to embankments and cuttings consisting of not covered boulders measuring between 1 and several decimetres in diameter. The empty spaces left between rocks and the absence of a fine fraction prevent the settlement of herbaceous cover. These rocky areas will slowly be colonised by plants capable of establishing themselves in substrates with high macroporosity (shrubs, bushes and trees).

Geotechnical and landscaping seed mixes

Seed mixtures are sown in order to stabilize and protect the earthworks as quickly as possible. The greening allowed by this revegetation is also intended to improve the aesthetics of the road or motorway landscape. Rapid soil coverage is also sought to reduce the possibility of colonisation by invasive plants.

These mixtures are composed of a small number of species (<15). Their composition can be chosen (standard mixtures) according to the slope of the ground, to the moistness or dryness of the soil, and to whether or not the public will be able walk on it (as in rest areas). However, these mixtures are composed mainly (75%) of grasses such as *Lolium perenne* (ryegrass), *Festuca rubra* (red fescue), *Schedonorus arundinaceus* (tall fescue), *Dactylis glomerata* (cock's foot). Almost half of the 25% of dicotyledons are Fabaceae (*Trifolium repens, Trifolium pratense*). The seeding density varies from 150 to 300 kg/ha. Hydroseeding techniques are applied, in which the seeds are mixed with fertilisers and soil improvers.

Roadside vegetation where grasses are highly dominant

Photo credit: Violette LE FÉON

The usual seed mixtures, which contain few dicotyledons, therefore do not provide good forage for pollinating insects. In the medium to long term, mowing can be used to modify composition of the herbaceous plant community in road verges to include a higher proportion of dicotyledons, provided that the mowings (cut residues) are removed in a way that prevents the nitrogen they contain returning to the soil. The progressive depletion of nitrogen in the soil will make it less favourable to nitrophilic grasses, facilitating the spontaneous settlement of dicotyledons from the local environment.

When a road is constructed on sandy soil, the sand removed during earthworks is often laid nearby to form berms with a landscape and acoustic function. The slope of these structures is designed to prevent erosion. They may also have flat tops. As they stand, they offer a poor substrate, ideal for the spontaneous settlement (or the planting) of dry grassland or dry heath vegetation (*Ulex minor*, *Ulex gallii*, *Erica cinerea*, *Erica ciliaris*, *Calluna vulgaris*), which provides a favourable habitat for many bee species (see Section 6.1.2).

Figure 5.5
Erica cinerea (Bell heather)

Photo credit: Aurélia LACHAUD

5.1.2.1. During construction works

During construction of a new road section, in those areas of the right-of-way where the earthworks have left a layer of bare soil, three types of measures to encourage vegetation that is favourable to wild bees are available.

❀ On the area set aside to provide food resources from herbaceous plants (see Section 7), the simplest solution is not to sow a seed mixture so as to permit the expression of the seed bank contained in the re-spread topsoil (in particular dicotyledonous seeds). The topsoil will remain uncovered longer than if it had been sown and will allow seeds from the local environment to settle there too (seed rain). The arrival of any invasive plants should be monitored regularly until the soil is completely covered and undesirable species should be cleared.

❀ A second technique (called the *hay seeds* technique) is to maximise expression of the local seed bank. Plants that are in seed are mowed in the local zone (including at the site before the works) during the different seasons. The hay is kept until the completion of the works and spread over the topsoil. The area set aside to provide food resources thus receives a massive supply of local seeds. The ground is covered by vegetation much more quickly than with the previous technique. This technique, which has been used in Switzerland, has resulted in a plant community that is rich in entomophilic plants.

❀ A third technique, called *transitional seeding*, has been considered more recently in some countries (Belgium, England, Czech Republic, France). It consists of sowing a seed mixture with the same objective of stabilising, protecting and immediately revegetating the earthworks as conventional mixtures, but which has the ability to evolve spontaneously towards a flora rich in local dicotyledons. The technique involves adding to the conventional seed mixture a proportion of seed from plants that are hemiparasitic on grasses. The hemiparasitic species will develop by taking sap from the grasses, causing the disappearance of their host over the years and thus creating space for the spontaneous settlement of local dicotyledons, which are unaffected by the hemiparasites. Since the hemiparasitic plant is entirely dependent on its host, it also disappears from the local environment when there are no longer any suitable hosts. Hemiparasites of grasses exist in the natural environment (species of the Orobanchaceae family: e.g. *Euphrasia stricta* (Drug eyebright), *Rhinanthus minor* (Yellow rattle – Figure 5.6)). Moreover, these species provide foraging resources for bees (Figure 1.13).

Figure 5.6
Development of *Rhinanthus minor* (Yellow rattle) in a meadow

Photo credit: Guillaume LEMOINE

5.1.2.2. For existing roads

In the case of existing infrastructure, the road verges are mainly populated by grasses provided by the initial seed mixture (see Box B4) and the effect of standard “mowing” practices. Such standard “mowing” operations are carried out by means of rotary slashers that shred the plants without collecting them.

These shredded plant fragments are left permanently on the ground. This practice is in fact similar to mulching, which returns to the soil all the organic matter and the nutrients in the plants. Today, many technical and scientific documents dealing with “mowing” of roadside vegetation actually mean mulching. Strictly speaking, mowing is intended to collect the cut grass to make hay, and not to leave it to decompose on site (see Box B6). In this document, the term *mowing* is used in the strict sense: cutting the grass in order to take it away. The practical implications of mowing and the options for addressing them are discussed in Section 7.

B1 B2 B3 B4 **B5** B6 B7 B8 B9

The biological types of herbaceous plants in roadside vegetation

The grasses that grow in road verges are mostly perennial (ryegrass, fescue, bluegrass, orchard grass, etc.). They remain visible all year round and their many leaves cover the ground in winter. This is not the case for most dicotyledons, which are mainly annual or biennial and spend the winter in the soil, in the case of therophytes as seeds (e.g. *Centaurea cyanus* (cornflower), *Daucus carota*, *Cichorium intybus*, *Papaver rhoeas*), and in the case of geophytes, as bulbs (e.g. *Ranunculus bulbosus*), rhizomes (e.g. *Lysimachia vulgaris*, *Lythrum salicaria*) or turbers (e.g. *Raphanus raphanistrum*, *Ficaria verna*). The dicotyledons also include hemicryptophytes, biennial plants that overwinter in the form of rosettes (a set of leaves arranged in a circle at the base of the residual stem, e.g. *Achillea millefolium*, *Prunella vulgaris*, *Silene latifolia*, *Foeniculum vulgare*, *Lotus corniculatus*, *Medicago lupulina*, *Malva moschata*, *Verbascum thaspus*, *Pastinaca sativa*, *Hypochaeris radicata*, *Primula veris*, *Taraxacum officinale*, *Leucanthemum vulgare*, *Silene vulgaris*, *Echium vulgare).*

A roadside verge with varied spontaneous flora

Photo credit: Violette LE FÉON

In this situation, there are three possible ways to develop food resources for wild bees from a pre-existing road verge.

❀ One of them involves turning the soil over (ploughing and tilling) in the area set aside for herbaceous plants to provide the food resource, in order to apply the *hay seeds* technique or that intended to allow the progressive expression of the soil seed bank and the seed rain from the neighbouring landscape.

❀ Another approach is to promote the gradual return of vegetation that has a higher proportion of dicotyledons through more appropriate mowing, in terms of frequency and timing, cutting height, and removal of mowings from the area set aside to provide the food resource (Section 5.1.3).

❀ The third method (which is similar to transitional seeding) is to sow seeds of plants that are hemiparasites on grass among the existing vegetation and then allow dicotyledons from the local environment to develop spontaneously in areas left free by the gradual disappearance of the grasses.

5.1.3. Conserving herbaceous plants that are useful for forage

5.1.3.1. Guiding principles

The only way of sustainably conserving food resources from herbaceous plants in the long term is by means of appropriate mowing.

The fundamental principle that should be followed by the manager with regard to mowing is, first of all, not to deprive wild bees of the floral resources (flowering plants) they need in terms of diversity and abundance by mowing at the wrong time of year or mowing excessive surface areas.

In order to best meet the needs of all bee species likely to succeed one another on the site, it is important not to bring about an interruption in the sequence of flowering periods provided by all the plants present (Table 5.1). In addition, allowing as many species as possible to reach their flowering stage will help maintain the site's floral diversity and, thanks to the dispersal ability of seeds, help them to spontaneously settle in neighbouring sites (see Section 7).

The second guiding principle of mowing should be to encourage the development of dicotyledons over grasses. Indeed, the generalisation of the initial seeding of road verges by conventional seed mixtures and the current "mowing" practice (Section 5.1.2), lead to the predominance of grasses, which do not provide food resources for wild bees.

Therefore, the shredded fragments should be removed after any mowing operation. When left in place, they constitute a nitrogen store that constantly fertilises the soil, making it unfavourable to plants with low nutrient requirements, and favourable to plants with high nutrient requirements, such as nitrophilic grasses (e.g. brome grass, orchard grass, velvetgrass, ryegrass). The regular removal of cut residues from the area that has been set aside to provide forage resources from herbaceous plants gradually depletes the soil's nitrogen store. The growth of grasses is consequently reduced, providing opportunities for colonisation by dicotyledons.

5.1.3.2. The right times for mowing

⚒ Late mowing aims to allow all herbaceous species to reach their flowering stage. They can thus provide a food resource for wild pollinators regardless of their flowering period, and also produce seeds to maintain the floral diversity of the site during the next season. As a result of this dual advantage, this maintenance practice is relatively common today for roadside vegetation. Such autumn mowing is therefore to be carried out after the latest species on the site has flowered. The height of cut should be adjusted to the lowest setting (10 cm) to anticipate as far as possible any fast renewed grass growth the following spring.

⚒ As a result of a mild winter, rapid early growth, or the absence of mowing the previous autumn, fairly large grasses may be present in early spring. The earliest dicotyledons, some of which are small (e.g. *Taraxacum officinale*, *Medicago lupulina*, *Geranium molle*, *Glechoma hederacea*, *Primula veris*, *Ranunculus bulbosus* – Table 5.1) may then be buried under a mass of developing grasses. A possible way of avoiding this problem is to mow in spring, before the beginning of the vegetative development of the earliest dicotyledons. The cutting height should be set low (about 10 cm). If the first dicotyledons have already reached this size, the height of cut should be increased to 20 cm.

⚒ Summer mowing (in early summer) can have a beneficial effect on the species diversity of the herbaceous plant community by improving the effectiveness of the seed rain from the surrounding environment. This facilitates the settlement of new species that can increase the floristic diversity for pollinators. This practice can typically be adopted during a habitat reconstruction phase (see Section 7). In addition, it has been observed that this mowing may stimulate the regrowth of cut dicotyledons which leads to the development of new flowers and therefore extends their flowering periods.

Normally, the same area should only be mowed once a year, at most twice if corrective spring mowing is required (see above). In order not to create a gap in the sequence of flowering periods on a given site (see Section 5.1.3.1), mowing should never be carried out over the entire site. Section 7 provides a practical approach to meeting this requirement. Considering the variability of weather conditions from one year to the next and the effects of previous mowing, the dates of mowing cannot be precisely determined several months in advance in the area set aside to provide food resources. In order to decide when it is appropriate to mow, the manager should regularly monitor the development of dicotyledons in the verge.

B1 B2 B3 B4 B5 B6 B7 B8 B9

The hay meadow model

In road verges, the areas covered by tall herbaceous vegetation have strong similarities with hay meadows. This type of agropastoral habitat is in decline today in Europe for various reasons. This may be due to its transformation into pasture (with fertiliser inputs, trampling and shift towards low-height vegetation). It may also be due to its being put into cultivation for various crops – including temporary grassland (<5 years) which is fertilised and sown with a small number of forage species resulting in low species diversity. Finally, it may be due to its outright abandonment, gradually leading to the restoration of a forest environment.

The purpose of a hay meadow is to produce hay for livestock feed. Transporting hay from the field to the barn or sheepfold (rather than grazing) leads to reducing the nutrient content of the soil and keeps it low, promoting the spontaneous appearance of dicotyledons in the meadow plant community. Fertilising the soil, whether directly (through the use of fertilisers) or indirectly (through overgrazing), can reverse the process: dicotyledons disappear in favour of grasses (see Box B1). Hay meadows have a great many flowers and provide a habitat for many pollinating insects and their predators. The later the mowing date, the greater the probability that all plant species will reach the fruiting stage and produce seeds, making it possible to conserve this floral diversity the following year.

Floral diversity of a hay meadow

Photo credit: Arnaud LE NEVÉ

In road verges, allowing the mowings to rot on site does not favour nutrient depletion in the soil and therefore hinders the development of dicotyledons. As in the agricultural management of hay meadows (the time required for the hay to dry on site before it is made into bales), the mowings can be removed a few days after cutting. This period of time allows part of the entomofauna to escape from the mowed grass and not be taken away with it.

5.2. Food from shrubs and bushes

5.2.1. Shrubs and bushes that are useful for food

A non-exhaustive list of shrub and bush species that are of value for feeding wild bees in spring, summer and autumn is provided in Table 5.2. The road vegetation manager will be able to refer to the list to monitor their presence and encourage their conservation and development. These species are variously distributed throughout Europe. The information on their flowering period has been taken from the Tela Botanica database.

Hazel and European gorse offer the year's earliest food resources. Ivy and western gorse, on the other hand, offer a resource at the end of the season when others are scarce.

5.2.2. Obtaining shrubs and bushes that are useful for food in road verges

When a new section of road is under construction, there may already be some shrubs and bushes belonging to species that provide forage for wild bees (Table 5.2) within the construction site. Depending on their initial abundance, the conservation of some or all of them is the first action to be recommended to ensure that this form of food resource is conserved in the surrounding area (see Section 7).

Shrubs and bushes are the main plants that are concerned when vegetation is cleared during the construction phase. In order to quickly re-establish this type of vegetation in the habitat areas to be restored, young plants that are already present in the right-of-way can be preserved in order to be transplanted to the road verge. Such planting may be carried out directly in unstripped areas (Section 5.1.2) which are sometimes present at the edge of the right-of-way. On sites where the entire width of the right-of-way has been stripped, if the resource is too scarce in the local environment to consider taking plants from the landscape network, those present in the right-of-way may be moved to nurseries pending the completion of the earthworks (similar to what is done with temporary topsoil stockpiles – Section 5.1.2). In the case of the largest construction sites, for which the work is carried out in sections that are a few kilometres in length and staggered over time to suit the availability of construction equipment, the plants can be transplanted directly from one section in the clearing phase to another section where the earthworks have been finished. In the event that plants from outside the right-of-way are necessary, only species from the local ecosystem and locally-sourced specimens should be chosen.

Table 5.2
Examples of useful shrubs and bushes for feeding wild bees

Family:		**Month of flowering**									
Scientific name	**Common english name**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**
Adoxaceae:											
Viburnum lantana L.	Wayfaring tree			✻	✻						
Viburnum opulus L.	Guelder rose				✻	✻					
Sambucus nigra L.	Elder					✻					
Araliaceae:											
Hedera helix L.	Common ivy								✻	✻	
Hedera hibernica (Kirchn.) Bean	Irish ivy									✻	✻
Betulaceae:											
Corylus avellana L.	Hazel	✻	✻								
Caprifoliaceae:											
Lonicera periclymenum L.	Honeysuckle					✻	✻	✻	✻		
Celastraceae:											
Euonymus europaeus L.	Spindle			✻	✻						
Cornaceae:											
Cornus sanguinea L.	Dogwood					✻	✻				
Ericaceae:											
Calluna vulgaris (L.) Hull	Common heather						✻	✻	✻	✻	
Erica ciliaris Loefl. ex L.	Dorset heath					✻	✻	✻	✻	✻	
Erica cinerea L.	Bell heather					✻	✻	✻	✻	✻	
Fabaceae:											
Cytisus scoparius (L.) Link	Broom				✻	✻	✻	✻			
Ulex europaeus L.	Gorse	✻	✻	✻	✻	✻					
Ulex gallii Planch.	Western gorse							✻	✻	✻	✻
Ulex minor Roth	Dwarf gorse						✻	✻	✻	✻	
Oleaceae:											
Ligustrum vulgare L.	Wild privet				✻	✻					
Rhamnaceae:											
Frangula alnus Mill.	Alder blackthorn			✻	✻	✻	✻				
Rhamnus cathartica L.	Buckthorn				✻	✻					
Rosaceae:											
Crataegus monogyna Jacq.	Hawthorn				✻	✻					
Prunus spinosa L.	Blackthorn			✻							
Rosa canina L.	Dog-rose				✻	✻	✻				
Rubus fruticosus L.	Bramble						✻				
Rubus ulmifolius Schott	Elm-leaved bramble					✻	✻	✻			
Salicaceae:											
Salix atrocinerea Brot.	Large grey willow		✻	✻							
Salix caprea L.	Dewberry		✻	✻							
Salix cinerea L.	Grey Willow		✻	✻							

Figure 5.7
Cytisus scoparius (Broom)

Photo credit: Denis FRANÇOIS

Figure 5.8
Andrena nigroaenea on a willow flower (*Salix* sp.)

Photo credit: Arnaud LE NEVÉ

The plant species in question (Table 5.2) are characterised by a good capacity for spontaneous settlement (especially on soil with a low organic and nutrient content). Starting from bare soil, it is possible to obtain flowering individuals within 4 to 5 years. These species are not considered for infrastructure landscaping operations, or not widely so. However, due to their high capacity for spontaneous establishment, they are a significant source of flowers in road verges.

It is therefore recommended to take advantage of the capacity of these species to become established spontaneously, not only to maintain the functioning of habitat zones that are favourable to wild bees, but also to create longitudinal connectivity between these zones within the road verges. The settlement of these species will primarily take place within link sections, but it is also a possibility in rest or service areas.

5.2.3. Conserving shrubs and bushes that are useful for food

Some of these species (gorse, broom, bramble) develop into thickets whose maintenance generally consists in radical clearance (cutting back to ground level). The main disadvantage of which for food resources is that it prevents flowering for several years. In the context of more wild bee-friendly management, in a given location only the oldest part of the thickets should be cleared each year, in order to ensure they are regularly renewed and that floral resources remain constant from one year to the next.

The proportion to be cleared will be determined according to the life cycle of the species. For a species that takes n years to reach the adult stage (i.e. to produce flowers), the proportion to be cleared each year should be 1/n+1 (a safety margin of one year to take into account individual variability and guarantee a sufficient resource). This management procedure will mean that it is necessary to keep the annual scrub clearance calendar up to date. For gorse and blackthorn, the maximum proportion of the vegetation cleared in a year should be equal to 1/6th (n = 5) and should be 1/4 for brambles and brooms. This treatment will not be applied to plants that take many years to flower and produce few shoots (e.g. hawthorn).

Figure 5.9
Flower of *Crataegus monogyna* (Hawthorn)

Photo credit: Denis FRANÇOIS

Figure 5.10
Thicket of brambles (*Rubus* sp.) in bloom

Photo credit: Violette LE FÉON

It is not recommended to clear woody plants during the growing season. Moreover, from the point of view of value for floricolous insects, in order to make the most of the available food resource, as a matter of principle, no operation should be carried out before the end of flowering. As most of the plants in question flower in spring (Table 5.2), this will also prevent the destruction of many broods of sparrows breeding in the thickets in question.

Stems from the clearing of vegetation (especially brambles) may be used to make dry wood piles that are useful for nesting (see Section 6.3.2.2.2).

5.3. Food from trees

5.3.1. Trees that are useful for food

A few tree species that are of value to wild bees in spring, summer or autumn are listed in Table 5.3. These species are variously distributed throughout Europe. The road verge manager will be able to refer to them to monitor their presence and foster their conservation and development. The information on their flowering period has been taken from the Tela Botanica database. Where necessary this has been supplemented by data from the “Flore et Végétation de France” database (shown by the symbol ‡).

Table 5.3
Examples of useful trees for feeding wild bees

Family:		**Mois de floraison**									
Scientific name	**Common english name**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**
Fagaceae:											
Castanea sativa Mill.	Sweet chestnut					❊	❊				
Rosaceae:											
Prunus avium (L.) L. var. *avium* ‡	Wild cherry			❊	❊						
Pyrus communis L.	Common pear				❊	❊					
Sorbus aucuparia L.	Rowan				❊	❊	❊				
Sorbus domestica L.	Service tree			❊	❊	❊					
Sorbus torminalis (L.) Crantz	Wild service tree				❊						
Salicaceae:											
Salix alba L.	White willow			❊	❊						

Figure 5.11
Flower of *Sorbus aucuparia* (Rowan)

Photo credit: Guillaume LEMOINE

Figure 5.12
Flower of *Castanea sativa*
(Sweet chestnut)

Photo credit: Denis FRANÇOIS

5.3.2. Obtaining trees that are useful for food in road verges

When a new section of road is under construction, there may be some trees belonging to species that provide forage for wild bees (Table 5.3) within the area covered by the planned road verges. Conserving these trees is the first recommended action to ensure that this food resource continues to be available in the surrounding area. This is easily possible in areas where no soil stripping is performed, such as on the edges of some rights-of-way.

If there are no such trees in the area of the future road verges, they can be planted there if the planner so wishes. In this case, species that are naturally present in the local ecosystem should be selected, and specimens should preferably be sourced locally. Such planting may regard solely habitat zones created for wild bees (see Section 7), or, if the construction plans allow it, be carried out in association with general landscaping operations for the road. In this case, the link sections or rest and service areas could help to provide longitudinal connectivity between areas of wild bee-friendly habitat within road verges.

These recommendations cover both existing and new roads. Indeed, when creating areas of wild bee-friendly habitat in an existing road verge, the presence of trees that provide food for bees in the surrounding environment (in or outside the road verges) will be a factor to consider (see Section 7). If there are no trees, the planner may resort to planting as described above.

In order to support wild bees, it would be counterproductive to establish dense woodland cover consisting of useful tree species. Bees would only visit the edges of such closed environments. In a space that is kept open, isolated trees, small groups of trees, or trees that are part of peripheral diversified hedges, will be of much more practical value.

5.3.3. Conserving trees that are useful for food

In the long term, management of the road verge could allow the natural regeneration of trees, whether from trees already present in the right-of-way or from seeds originating from the surrounding landscape. The young trees that are selected for this purpose should be identified and reported to protect them from inadvertent mowing.

Mellita tricincta (Melittidae family) on a flower of *Odontites vernus* (Red bartsia)

Photo credit: Gilles MAHÉ

Section 6.
Nesting sites

6.1. Nesting in the soil

6.1.1. Suitable substrates

The majority of wild bee species make their nests in the soil. Except for some wild bees that use the abandoned burrows of other animals to build their nests (e.g. bumblebees), other ground-nesting species look for sandy, silty or clayey soils. These may be large bare or sparsely vegetated areas (soils with a low organic and nutrient content), smaller areas subject to compaction and regular erosion that prevent the settlement of plants (paths, ruts), or even small unoccupied spaces between plants. These soils exhibit a certain degree of compactness, as can be the case with path sides. To be able to provide a substrate for nesting, they must therefore be protected from any disturbance. They are located in dry places. Good exposure to sunshine is a factor that favours the use of these substrates by the most thermophilic wild bees (the vast majority of species). Burrows can be dug from horizontal (Figure 6.1), sloping, or vertical surfaces (e.g. escarpments, hedge banks – Figure 6.2).

Figure 6.1
Site with an agglomeration of *Tetralonia malvae* (Apidae family) and isolated nests of *Nomiapis diversipes* (Halictidae family)

Photo credit: David GENOUD

Figure 6.2
Site with agglomerations of *Halictus quadricinctus* and *Halictus sexcinctus* (Halictidae) and isolated nests of *Megachile leachella* (Megachilidae)

Photo credit: David GENOUD

6.1.2. Obtaining and conserving soil surfaces that are suitable for nesting

6.1.2.1. During the construction phase

When a new section of road is built, during earthworks large areas of soil are exposed. The surface layer of the levelled soils (the upper layer, which is the most fertile (topsoil)) is kept until the end of the earthworks and then re-spread over the surface and used as a substrate for the seed mixtures that will be sown to improve the surface stability of the disturbed soils to provide protection against erosion and soil slips (see Section 5.1.2). These areas of disturbed soil are typically embankments, but they can also be flattened to accommodate specific facilities (e.g. rest or service areas). When the road under construction passes through a cut, the bedrock is generally exposed. Such rock outcrops are important nesting sites for some bee species so they must not be covered with topsoil. These rocky substrates will allow the settlement of natural vegetation that is suited to skeletal soils and the needs of the bees that nest there. If sandy materials have been removed during the earthworks and stored nearby, their deposits will provide nesting sites for many ground-nesting species. On these areas of soft ground, vegetation remains sparse (dry grassland or dry heathland – see Section 5.1.2) and leaves many bare sandy surfaces.

In areas where the topsoil is to be spread, in order to provide sites that are available in the short term for ground-nesting species, it is simply necessary to set aside some areas on which the usual sowing of a seed mix is not performed and/or on which topsoil will not be spread. Alternatively, such areas should be covered with a poorer substrate from deeper soil layers (creating flat surfaces), which will greatly slow down the growth of herbaceous cover.

Visible or hidden bare soil

Keeping bare soil surfaces in areas with fertile soil can be achieved in the long term in two ways.

⚒ The surface in question may be kept without herbaceous cover by the deliberate use of a poor local substrate (for example by placement of a layer of unfertile material – Figure 6.3). The functional maintenance of this surface will simply involve eliminating plant species that may cover it over a period of time.

⚒ The second way is to encourage the development of herbaceous vegetation leaving spaces of bare soil between plants. This bare soil is invisible to an uninitiated observer, but it allows full access for bees (e.g. *Pilosella officinarum* – Figure 6.4). The grasses present in the seed mixtures that are sowed after the completion of earthworks, and the grassland maintenance practices that result from them today, do not allow this type of vegetation to become established easily.

Figure 6.3
Visible bare soil

Photo credit: Violette LE FÉON

Figure 6.4
Hidden bare soil

Photo credit: Violette LE FÉON

Figure 6.5
An outcrop

Photo credit: Denis FRANÇOIS

The removal of mowings (see Section 5.1.3), which favours the colonisation of the soil by dicotyledons rather than grasses, is a way of gradually creating hidden bare soil surfaces. Sowing seeds of plants that are hemiparasites of grasses would be another way of replacing grasses with dicotyledons (see Section 5.1.2) thereby favouring the creation of hidden bare soil.

6.1.2.2. For existing roads

In the case of an existing road verge with abundant grass cover already installed, the technique for obtaining a bare soil surface will involve, as described above, either placing a layer of poor substrate on top of the soil or, after turning over the existing grassland, allowing vegetation from the local seed bank to become established spontaneously.

6.2. Nesting in hollow stems

6.2.1. Suitable plant species

Several species of shrubs and bushes provide a particularly important and abundant resource of hollow stems that are suitable for *lignicolous bees* (examples in Table 6.1). This is the case of honeysuckle, gorse and a wide variety of Rosaceae, including in particular various bramble species (*Rubus* sp.). Because of the abundance of hollow stems that they provide, brambles are genuine natural “bee hotels”. The use of brambles by many bee species has been documented (e.g. *Ceratina cyanea, Hylaeus brevicornis, Hylaeus communis, Hylaeus dilatatus, Hylaeus incongruus, Hylaeus pictipes, Hylaeus signatus*). In order to line its nest, *Megachile centuncularis* also uses honeysuckle leaves.

B1 B2 B3 B4 B5 B6 B7 B8 B9

Creating mounds of bare soil

Road verges provide few vertical surfaces of bare soil. Indeed, in the case of cuttings and embankments with disturbed soil, in order to ensure soil stability, the slopes are not very steep. Vertical surfaces are only created in the case of passages through rock.

In order to provide nesting sites with vertical bare soil in road verges, poor substrate can be taken from deep soil layers during earthworks and piled into mounds between 50 cm and 1 m high. These mounds should preferably be placed in dry, sunny, locations.

Example of bare soil mounds

Photo credit: Violette LE FÉON

The non-vertical parts of the mounds (e.g. at the foot and/or top of the slope) may be used by bee species with different preferences in terms of slope gradient, and this may include the almost flat areas where fallen material builds up at the foot of the mound. Thus, a mound of bare soil constitutes a kind of “bee hotel” for ground-nesting species which is easy to make in large numbers along roads.

Among herbaceous plants, several species in the Apiaceae family also provide hollow stems for wild bees (Table 6.1). Thus, for example, *Hylaeus cornutus* nests in *Pastinaca sativa*. This bee also nests in the stems of several species of *Rumex* (Polygonaceae family). The genus *Rumex* includes species such as *Rumex acetosa* (Sorrel), *Rumex acetosella* (Sheep’s sorrel), *Rumex sanguineus* (Wood dock) for example. The dry stems of *Rumex* are also used by *Hylaeus dilatatus*, as are those of *Artemisia vulgaris* (Mugwort). The Asteraceae include several thistles in the genera *Cirsium* and *Carduus* which provide hollow stems for the nesting of bees in the genera *Ceratina* and *Osmia* as well as *Xylocopa iris*.

Table 6.1
Examples of useful plants for the nesting of wild bees

Family:		
Scientific name	**Common english name**	**Type**
Apiaceae:		
Angelica sylvestis L.	Wild angelica	Herbaceous
Anthriscus sylvestris (L.) Hoffm.	Cow parsley	Herbaceous
Foeniculum vulgare Mill.	Fennel	Herbaceous
Heracleum sphondylium L.	Hogweed	Herbaceous
Pastinaca sativa L.	Parsnip	Herbaceous
Asteraceae:		
Achillea millefolium L.	Yarrow	Herbaceous
Carduus nutans L.	Musk thistle	Herbaceous
Carduus pycnocephalus L.	Plymouth thistle	Herbaceous
Carduus tenuiflorus Curtis	Slender thistle	Herbaceous
Caprifoliaceae:		
Lonicera periclymenum L.	Honeysuckle	Shrub
Fabaceae:		
Lotus corniculatus L.	Bird's foot trefoil	Herbaceous
Ulex europaeus L.	Gorse	Shrub
Rosaceae:		
Rosa canina L.	Dog-rose	Shrub
Rubus sp.	Bramble	Shrub
Scrophulariaceae:		
Verbascum thaspus L.	Great mullein	Herbaceous

Figure 6.6
Rosa canina (Dog-rose)

Photo credit: Denis FRANÇOIS

Some herbaceous plants also provide materials that bees use to build or line their nests. Thus, for example, *Anthidium manicatum* (Megachilidae family) uses, in particular, the down from the leaves of *Achillea millefolium* (Asteraceae) and *Verbascum thaspus* (Scrophulariaceae), to construct the partitions between cells and the plug with which it closes its nest. Generally speaking, bees of the genus *Anthidium* use the down collected from hairy plants such as thistles (genus *Cirsium* and *Carduus*) to make their nests. To line its nest, *Megachile leachella* (see Fig. 6.2) uses in particular the petals of *Lotus corniculatus* (Fabaceae), as well as those of several wild roses (e.g. *Rosa canina*). For the same purpose, *Megachile willughbiella* uses, amongst other things, the leaves of Tutsan (*Hypericum androsaemum*, Hypericaceae) and *Megachile maritima* uses the leaves of Hound's-tongue (*Cynoglossum officinale*, Boraginaceae).

Figure 6.7
Carduus tenuiflorus (Slender thistle)

Photo credit: Denis FRANÇOIS

6.2.2. Obtaining hollow-stemmed plants in road verges

When a new section of road is under construction there may already be some plants with hollow stems within the area covered by the planned road verges. The conservation of these plants is the first recommendation to ensure that this resource is conserved for nesting in the surrounding area.

As in many cases the species in question are those targeted by clearing operations (e.g. brambles, gorse, dog-rose etc.) during the phase prior to earthworks, in order to quickly reintroduce this type of vegetation in the habitat areas to be restored, young specimens of these shrubs and bushes may be conserved within the right-of-way and then transplanted in the road verges. If plants are used from outside the right-of-way, only those species that are naturally present in the local ecosystem should be chosen.

Hollow stemmed herbaceous plants should be obtained as described above (see Section 5). Some, such as those of the Apiaceae family, also provide food resources. These species are relatively common in the road environment (e.g. *Heracleum sphondylium, Daucus carota*… which like the nutrient-rich environments provided by ditches). Their spontaneous settlement in the area of restored favourable habitat, as well as that of other herbaceous plants with hollow stems (e.g. the genus *Rumex*), should not be prevented.

Figure 6.8
Heracleum sphondylium (Hogweed)

Photo credit: Guillaume LEMOINE

6.2.3. Conserving hollow-stemmed plants in road verges

One should take advantage of the capacity of these species, whether herbaceous (Apiaceae family, the genus *Rumex*…) or shrubby (brambles, gorse, wild roses…), to usually become established spontaneously, to ensure the availability of a continuous resource of hollow stems. In the case of shrubs and bushes, this constant availability can be obtained by clearing only the oldest part of the thickets each year (see Section 5).

6.3. Nesting in wood

6.3.1. Suitable types of substrate

Xylicolous bee species are to be found in the genera *Xylocopa* and *Ceratina* (both in the Apidae family), *Lithurgus*, *Megachile, Osmia* and *Hoplitis* (all four in the Megachilidae family), and *Hylaeus* (Colletidae family). Living standing trees (called *living wood*) and *dead wood* provide these bees with this resource.

In living wood, bees use pre-existing cavities, in particular those made by other animals. *Chelostoma campanularum* and *Heriades truncorum*, for example, use old beetle tunnels. Living trees can also serve a purpose for nesting thanks to their leaves. For example, *Megachile maritima* uses the leaves of different species of willow to line its nest.

Dead wood generally contains more cavities and is softer than living wood, allowing bees to deepen and widen the cavities to suit their needs. *Dead wood* includes old standing trees (which may have been pruned and which includes stumps) and wood on the ground (sawn logs and fallen or pruned branches).

Both these types of resources are necessary. The first (living wood) provides nesting opportunities, but also leads to the second (dead wood) both during and at the end of its life, from fallen branches and old trees respectively.

Figure 6.9
A living tree whose branches provide a variety of cavities

Photo credit: Denis FRANÇOIS

Figure 6.10
Standing dead trees

Photo credit: Denis FRANÇOIS

Figure 6.11
Ground-nesting bees using the soil left between the roots of a fallen tree

Photo credit: Denis FRANÇOIS

Figure 6.12
Dead wood with burrows made by various insects

Photo credit: Denis FRANÇOIS

6.3.2. Obtaining and conserving these substrates in road verges

6.3.2.1. Living wood

During the construction of a new road section, there may already be some trees within the future road right-of-way. These trees immediately provide a nesting support for wild bees that are already present or those that may come to settle in the road verges. Conserving existing trees is therefore the first recommended measure to provide nesting substrates in road verges.

If there are no trees in the area of habitat to be restored in the road verge, the planner may plant some (see Box B8). This may be done either specifically as part of the creation of an area of favourable habitat, or if the construction plans are compatible with it, in combination with road landscaping operations (link sections or rest and service areas). For the measure to be effective, the trees that are planted should belong to species that provide forage for wild bees (Table 5.3). For all planting, care should be taken to ensure that the selected species are naturally present in the local ecosystem. If plants are purchased from a nursery, the planner should ensure that only trees provided with a biogeographical guarantee are used.

In the long term, management of the road verge will allow the natural regeneration of trees, whether from specimens already present in the right-of-way or from seeds originating from the surrounding landscape network. Plants that are selected for this purpose should be identified and reported to protect them from inadvertent mowing.

B1 B2 B3 B4 B5 B6 B7 **B8** B9

Avoiding plastic sheeting when planting

Planting trees and shrubs occurs as part of the general landscaping of road verges. It can also be intended to create habitat areas favourable to wild bees. Many wild bees need access to the ground for nesting (ground-nesting bees). In the context of coherent action to support wild bees it is therefore harmful to cover the ground with plastic sheeting when planting as it prevents bees and other insects from accessing the ground. We recommend to group together the fallen and pruned branches near the base of trees and shrubs (see Section 6.3.2.2). In contact with the soil, they will evolve in a way more in line with the natural cycle (drying, decomposition, return of nutrients to the ground).

Plastic sheeting on an embankment
that has been planted with young trees

Photo credit: Héloïse BLANCHARD

6.3.2.2. Dead wood

Standing dead trees

As far as general road maintenance allows, dead trees should not be felled, but left standing. In cases where there is a risk of a tree falling onto the roadway, trees that are too tall should be topped. This recommendation applies both to new roads (dead trees within the future right-of-way) and to existing infrastructure.

Felled or fallen trees

The stumps of trees felled during construction (located on the roadway alignment) should not be systematically destroyed or removed from the right-of-way, but may be moved to another location within the planned road verge. The stumps of any trees that are cut down because they are too close to the roadway should be left in place. The same may apply to trunks and/or primary branches.

Figure 6.13
A mat of branches with good exposure to the sun

Photo credit: Violette LE FÉON

Figure 6.14
A heap of dry wood suitable for the nesting of bees, particularly the genus *Hylaeus*

Photo credit: Violette LE FÉON

Logs and branches on the ground

Branches that fall naturally from living trees and dead standing trees should not be systematically removed, but left on the ground. To make it easier to maintain the restored favourable habitat area, rather than being left scattered around, these branches may be grouped together, preferably in sunny locations (for example, at the foot of isolated trees, or south-facing hedges and woodland edges). These recommendations apply both to new infrastructure as well as infrastructure that is in service. Indeed, during the construction phase, branches from clearing operations can be used to create piles of dead wood in some areas (Figure 6.13).

Pieces of wood that are thicker than branches (logs from pruning, felling and cutting trees) may also be left in situ (Figure 6.14). This wood can be arranged more or less tidily depending on the maintenance requirements of the road verges and the exposure conditions indicated above, and possibly on the desired aesthetic appearance in terms of landscaping.

Xylocopa violacea (Violet carpenter bee)

Photo credit: David GENOUD

Section 7.
Implementation of actions

7.1. Goal

The first part of this document has presented some basic information on the ecological needs of wild bees (see Section 2). Readers wishing to explore this topic in greater depth can do so by referring to the literature (see References). The potential resources that can be used by wild bees in the usual types of road verge and possibly in their immediate surroundings have been presented in the two preceding sections (see Sections 5 and 6). This last section aims to provide road managers with guidelines for implementing concrete actions to support wild bees within road verges and to provide the necessary connectivity with the surrounding ecosystem.

7.2. Principle for coordinating actions

Road verges and their immediate environment present an immense variety of situations in terms of their initial states and their potential for wild bee populations. Seeking to apply a standard planning model for wild bees to all road verges in all possible contexts would come up against many operational difficulties related to local peculiarities, and could even lead to ecological contradictions.

In order to avoid this pitfall, the principle proposed in this document is rather to consider the initial state and the potential of each site in order to identify the nature of the most appropriate measures, their spatial organisation and their timing. This approach thus requires a clear knowledge of the site prior to any action, which is the specific responsibility of the managers of the road verges. Bringing together – and to some extent formalising – this knowledge provides the basis for coherent long-term action (planning sequences of actions and improvements).

A general method is proposed below to help identify the most appropriate measures to be implemented in all local situations, however varied they may be. It is also intended to help organise the spatial distribution and timing of actions.

7.3. A general method for implementing actions

This method is presented with reference to the context of an existing road. This allows showing how it is possible to consider all the potential components of the habitat. The same approach applies to a new road (or section of road). In the latter case, characterising the initial state of the area of the future road verge (Section 7.2.2) is simply lightened. This characterisation can be supplemented, if the planner so decides, by the spatial planning of actions to support wild bees during the construction of the infrastructure (e.g. creation of areas with a large number of entomophilic plants, conservation of brambles and old trees – see Sections 5 and 6).

7.3.1. Delineation of the zone of action

For the road verge manager, the first step is to specify the length and breadth of the zone in which actions to support wild bees can be located. In terms of length, will the manager be able to include the entire length of the road verges under his/her responsibility, or only some of it? Will obstacles or crossing difficulties cause unavoidable breaks (e.g. tunnels or overpasses, major road interchanges)? Will the zone of action extend sideways to the edge of the right-of-way?

Not all roads and road sections are necessarily covered by the actions proposed in this document. Thus, for reasons of safety and road maintenance, as well as their ecological value, action near traffic lanes is not advisable. Similarly, and for the same reasons, no action should be considered in road verges (or parts of them) that are not wide enough. The narrowest verges are especially associated with the narrowest roads, carrying the lightest and slowest traffic. In functional terms, these roads therefore fragment ecosystems less than major roads such as motorway sections, expressways and some national roads. It is therefore the road verges of these large roads that are targeted by the present approach for supporting wild bees.

Consequently, with reference to the usual transversal division of road verges into three zones, actions to support wild bees will only be possible in Zone C (also known as the *distant zone* – see Box B9). The outer boundary of this zone is the edge of the right-of-way. Its internal boundary is 4 to 7 m from the edge of the carriageway for the major road network, and 3 to 5 m for the secondary network. Zone A (also known as the *area near the carriageway* or *recovery zone*) and Zone B (also known as the *intermediate zone* or *limited severity zone*), which together constitute the *safety zone*, are excluded from the zone of action. One of the functions of Zone A is to allow vehicles to stop and manoeuvre. Zone B has, in particular, the function of providing a safe area for persons who have been involved in accidents or whose vehicle has broken down.

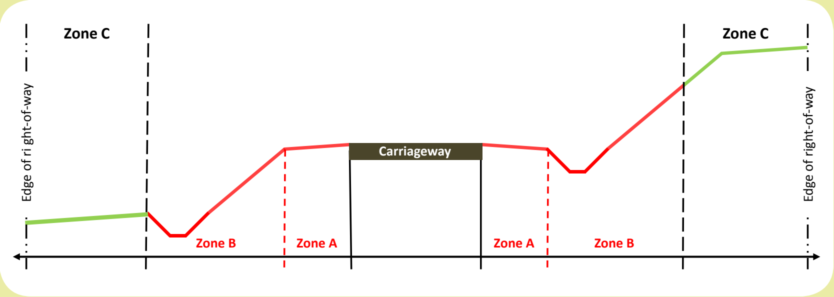
Because bees would inevitably need to cross the traffic lanes, leading to a high risk of collision mortality, the central reservations of roads are excluded from the zone of action. In addition, their narrow width means they are classified as Zone A or B.

B1 B2 B3 B4 B5 B6 B7 B8 **B9**

Zone C

Unlike Zones A and B, Zone C is not intended for vehicles to stop in, road users to take refuge in or pedestrians to cross. It is therefore not subjected to human visits. Nor is it intended to ensure the road layout is legible, road equipment is visible, or to contain traffic and information signs. The rules and obligations for the maintenance of vegetation are therefore more flexible than in Zones A and B, where it may be cut several times a year. Trees, shrubs and bushes are quite acceptable in Zone C. It is moreover the area that can be used as a visual and noise screen, for landscaping the infrastructure and for staging the areas the road passes through. It can be very wide in some places (e.g. where there are large cuttings or embankments). It is the area that allows the installation of facilities requiring large spaces such as road water treatment systems.

Diagrammatic cross-section of a major road right-of-way



7.3.2. Characterising the initial state of the zone of action

The manager of the roadside vegetation should characterise the initial state of the habitat within the specified zone of action on the basis of the factors that are important for the ecology of wild bees (see Sections 5 and 6),

7.3.2.1. Inventory of existing resources

The characterisation of the initial state will involve firstly locating:

– potential food resources such as:
- herbaceous plant communities that could provide such resources (see Section 5.1);
- shrubs and bushes that could provide such resources (see Section 5.2): isolated individuals or thickets and hedges;
- trees that could provide such resources (*see* Section 5.3): whether isolated or in hedges or thickets;

– potential nesting sites such as:
• areas of bare soil, whether visible or hidden (*see* Section 6.1);
• hollow-stemmed plants, whether herbaceous or shrubs and bushes (*see* Section 6.2);
• dead wood, in the form of old standing trees or stumps, logs and branches on the ground (see Section 6.3).

To be considered as a significant food resource in the framework of this assessment, a zone covered by an entomophilic herbaceous plant community (Table 5.1) must have an area of at least 10 m^2. The minimum area of shrubland that can be considered a food resource is 2 m^2 (Table 5.2).

It is accepted that the larger the area covered by a food resource, the more attractive it will be to bees. Likewise, the closer the complementary resources (food and nesting) are to each other, the more functional exchanges there will be between them. Food and nesting resources can moreover occupy the same space (e.g. brambles, bare soil hidden by a herbaceous food resource such as *Pilosella officinarum* – see Figure 5.2), making it possible to limit the bees' need to move and thus boost their reproductive success.

The presence of trees (living wood) of species other than food species (Table 5.3) does not affect the ecology of wild bees. In the context of the inventory of existing resources, there is therefore no need to identify them to characterise habitat quality. However, a large thicket of trees can impede the movement of bees. If such a thicket exists in the road verge and hinders its connectivity (both internal and/or with the surrounding green network), it should be identified as such (obstacle – Section 7.3.1) and corrective actions should be sought (e.g. opening up part of the woodland at the edge of the zone of action, and perhaps using wood to create nesting sites – see Section 6.3.2.2).

7.3.2.2. Distance between existing resources

Actions should be organised spatially and temporally according to the flight distance and the speed at which wild bees colonise the space within the road verges. These two characteristics vary according to the bee species (see Section 2). The action within the verges should not target particular bee species but it must benefit to all the species present in the surrounding environment, including the least mobile. Action which has been designed to meet the needs of the latter will suit the needs of the more mobile species even better.

In this operational perspective, the maximum distance (denoted by *Dm* in the rest of the document) for two sites to be considered connected for all wild bee species has been set at 100 m. Sites that are less than 50 m apart will be deemed to be well connected. Characterisation of the initial state will therefore also involve assessing the distance between the resources in the zone of action.

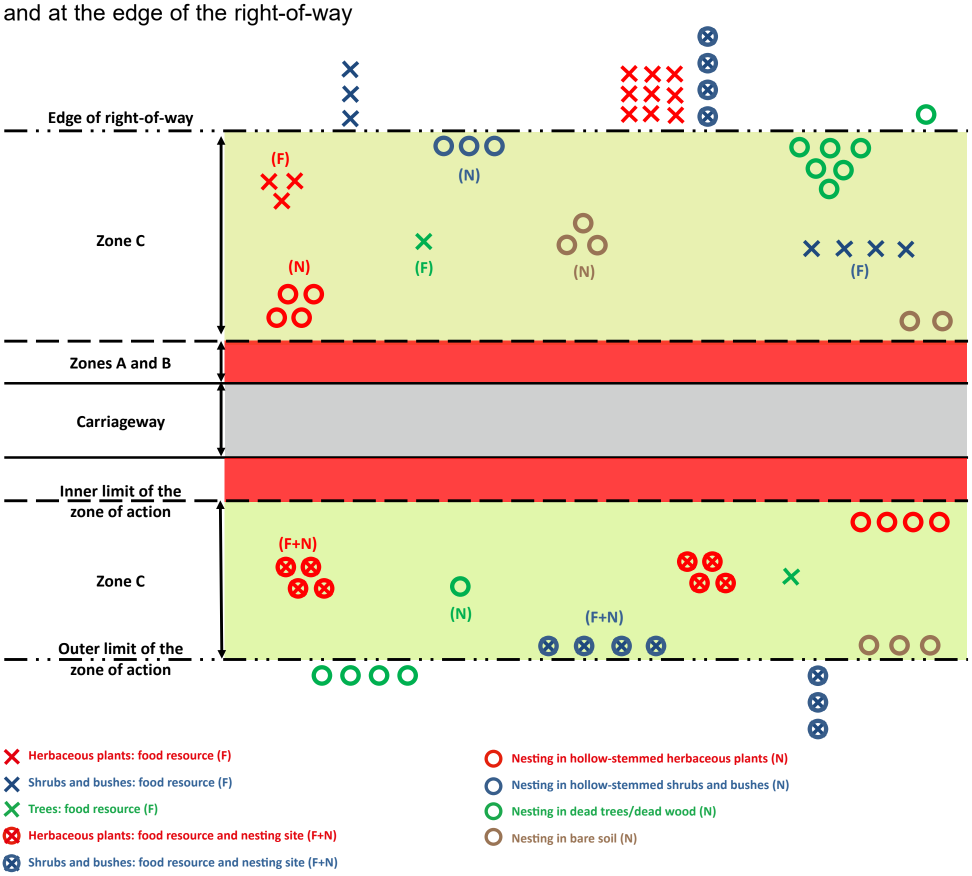
7.3.2.3. Exploiting potential links with the surrounding landscape network

Characterisation of the initial state should also include an assessment of the possible links between the various resources that have been identified in the road verges (Section 7.3.2.1) and similar resources that are present in the landscape mosaic surrounding the road right-of-way. These are long-lasting resources that are of value to wild bees (e.g. hay meadows, hedges containing forage species, trees that provide food resources, woodland edges). Since it is impossible to operate outside the road right-of-way, only resources within 50 m of the right-of-way boundary will be considered.

The presence and abundance of these resources will be a factor that stimulates exchanges between individuals (plant species and wild bees) on both sides of the right-of-way boundary, encouraging individuals nesting or foraging in the road verge to become part of the local biodiversity. Figure 7.1 provides a diagrammatic representation of the identification of existing resources in a road verge and its immediate vicinity.

Figure 7.1

Census of food and nesting resources in the zone of action and at the edge of the right-of-way



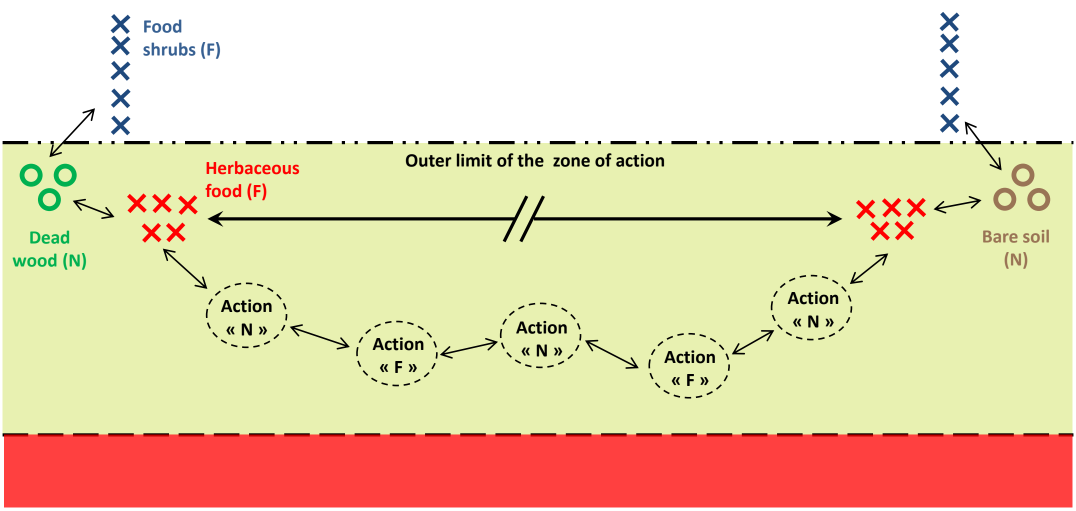
7.1.3. Spatial distribution of actions

7.1.3.1. Organisation of actions along the longitudinal axis of road verges

In a general context of fragmented natural habitats, spatial discontinuity is not an issue as long as the distance between the favourable patches can be covered by as many bee species as possible, i.e. also by the species with the shortest flight distance. Thus, the first actions must be carried out at a distance of less than *Dm* from an existing favourable patch, in the road verge or outside the right-of-way. If colonisation by bees along the length of the road verge is encouraged, actions will be carried out with a maximum distance between them that does not exceed *Dm*.

Connectivity along the longitudinal axis of road verges will be enhanced by alternating *Food Resource* (type F) habitat patches with *Nesting* (type N) habitat patches to form chains with an F-N-F sequence (Figure 7.2). The F-N-F alternation will allow species with short flight distance to find resources that are essential for them easily in a space that is compatible with their capacities. Having distances between patches that do not exceed *Dm* will allow them to be colonised even by species with a short flight distance. Species with greater flight distance will potentially benefit from this "*stepping stone*" habitat more quickly. These chains of resources will form traffic corridors within the road verge and will be able to assist connectivity with the surrounding green network through junctions with it (Section 7.3.2.3).

Figure 7.2
Links with the neighbouring green network and the F-N-F chain in Zone C



To gradually improve or consolidate the hospitality of the habitat for wild bees in the road verge, the basic chain (in which the distance between habitat patches will be roughly *Dm*), can gradually be strengthened or brought closer together through complementary actions over the years. These actions may consist of interspersing other F or N patches in the gaps, and/or increasing the size of the patches (thereby increasing their attractiveness and reducing the gaps).

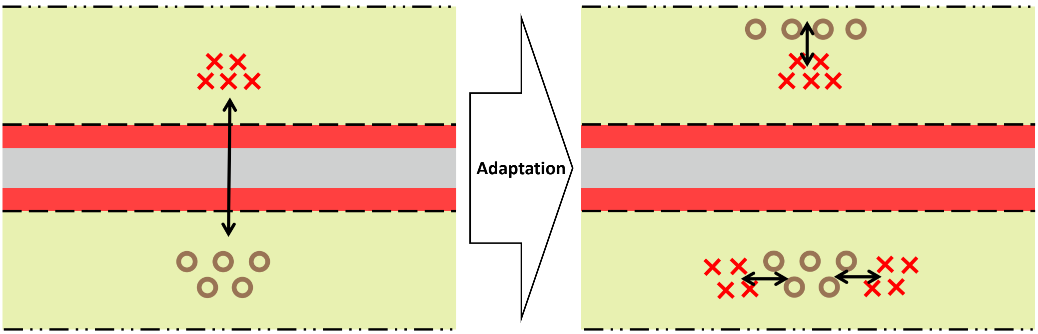
7.1.3.2. Consistency between actions on either side of the road

To avoid increasing the collision mortality of bees living in the road verges, in the case of high traffic roads, care should be taken not to create situations that increase the need for them to cross the traffic lanes. Ensuring that Zones A and B remain unattractive by carrying out closer and more frequent mowing than in Zone C, with a lawnmower or rotary slasher if necessary, and without removing the cut fragments (mulching) in order to limit the appearance of flowers, will help to reduce the attractiveness of the areas close to the traffic lanes. Bees from the adjoining verges will be less tempted to approach, as well as those from the opposite side of the road.

From a similar perspective, care should be taken to ensure that the proximity or attractiveness that exists between the F and N patches on a given side of the road is greater than with patches located on the opposite side of the road. Thus, a large feeding area should not be developed opposite a large nesting area. Should this arise (pre-existing state), on one side of the road a nesting area should be developed near the food resource, and on the other side of the road a food resource should be developed near the nesting site (Figure 7.3). For high-traffic roads such as a 2- to 3-lane motorway, the distance between the opposite Zones C is of the order of 45 to 60 metres. Therefore, providing complementary resources on both sides of the road at a distance less than *Dm*, or even less than the interval between Zones C, is an achievable goal to avoid the need for bees to cross the road.

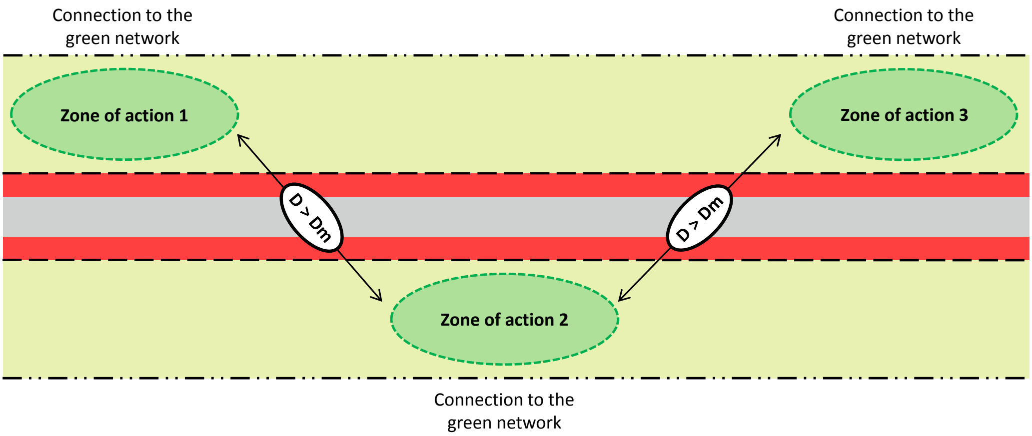
Figure 7.3

Adaptation of actions on opposite sides of the road



If the risks associated with crossing traffic lanes are significant on a long road section (e.g. on a high traffic road), the zones of action (F-N-F chains) may be distributed alternately on either side of the road, with an interval (*D*) of more than *Dm* between them, in order not to encourage bees to cross the road (Figure 7.4).

Figure 7.4
Alternating zones of action along a high-traffic road



7.4. Operational aspects

Implementing actions to support wild bees in road verges includes some specific operational aspects.

7.4.1. The maintenance of meadow type spaces

The removal of the mown grass is essential in order to obtain and maintain meadow type environments with abundant flowering plants (see Section 5). This is an important new factor in the management of road verges which raises the practical issue of how this could be done. If such removal were to be extended to all road verges, it would be necessary to find an outlet for the mown grass. This could include, as sometimes already happens in some locations, providing hay for livestock, or raw materials for anaerobic digestion or composting plants. A manager may need time to find or set up such channels. In the context of the development of favourable areas with *stepping stones*, the smaller volumes generated can mean that it is possible to envisage managing mowings internally and therefore implement the actions more rapidly. The mowings may be dealt with in a small composting unit run by the manager. They can also be used to mulch landscape plantations such as on resting and service areas. As the use of sheep is tending to increase in order to keep certain road verges in the state of short grassland, this hay can also be given to them as fodder.

7.4.2. Maintenance tools for the plants in road verges

In the general context of road maintenance operations, trees in road verges may need to be trimmed or pruned. In this case, the tools used must cut the wood cleanly in order to damage the wood less and reduce the susceptibility of the trees to diseases and pests. Trees that are in good health are of optimal value in terms of services to wild bees, providing long-lasting food resources and nesting sites. They also facilitate management, by making the tree renewal programme easier to apply. Depending on the cross-section of the wood, tools such as chainsaws, hydraulic pruning shears or bar hedge trimmers should be chosen and the use of verge cutters should be prohibited. For the same reasons, hedge trimmers and not verge cutters, should be used to prune shrubs and bushes. Verge cutters should only be used when the oldest part of a thicket has to be cleared (see Section 5.2.3).

In order to be able to maintain the herbaceous areas in a state that resembles hay meadows, the grass should be cut using a mower with a cutter bar. This tool will make it easier to dry and collect the mowings, and will open up the possibility of using them as hay, unlike the rotary slasher, which, shreds vegetation and promotes the return of plant fragments to the ground. Similarly, compared to verge cutters, which are also commonly used for the maintenance of grassed areas, cutter bars are more likely to preserve the lower part of the plants, or even the soil and root system of biennials.

Rotary shredders, which are widely used by technical services departments, may continue to be used for the maintenance of areas that are not intended to be attractive to wild bees and other insects, such as Zones A and B of the road verges (Section 7.3.1).

7.5. Observations on some real situations

Observations in road verges provide us with some examples of situations which are in line with certain actions or combinations of actions proposed in the general method described above. Several of these situations, which have been observed in western France, are presented and commented below in order to assist road vegetation managers in their initiatives. They also show the simplicity of most of the necessary actions.

A suitable space between two hedges that run parallel to the road

Although relatively narrow, the area between the two hedges that run parallel to the road (first photo) is favourable to wild bees.

Photo credit: Violette LE FÉON

It creates an area that is sheltered from the wind (which hinders the flight of bees) and the bare ground (second photo) allows terricolous species to nest.

Hedges with a few specimens of *Prunus spinosa* provide a food resource at the site.

This site could be improved by increasing the diversity of useful shrubs in the small hedge at the edge of the field, in order to provide food resources for a longer period during the year.

The proximity of a field of rapeseed (*Brassica napus*) provides an opportunity for an abundant, but merely temporary, food resource.

Photo credit: Violette LE FÉON

A nesting site provided by a hedge on an embankment

This section of hedge on an embankment exhibits an area of bare soil on a slope, which is well exposed to sunlight and suitable for ground-nesting species (e.g. in the genera *Anthophora*, *Colletes* and *Andrena*). Bees of the genera *Andrena* and *Nomada* have been observed here.

Some buttercups are in bloom. The rapeseed field on the other side of the hedge offers an abundant food resource. Later in the season, brambles will provide another food resource as well as hollow stems for the nesting of lignicolous species (e.g. in the genera *Hylaeus* and *Ceratina*).

Photo credit: Violette LE FÉON

Opportunities for food and nesting provided by brambles in a resource-poor road verge

In a low diversity environment such as this, brambles provide an important food resource for bees and nesting opportunities for lignicolous species.

Photo credit: Violette LE FÉON

Trimming back bramble thickets in surface to restrict their size is the ideal way of providing a large number of hollow stems each year. The ends with good exposure to sunlight are the best for nesting.

The presence of an entomophilic crop nearby (here a rapeseed field) provides an abundant temporary food resource. Wild bees that visit entomophilic crops help their pollination and increase productivity (see Section 2).

A set of resources that are favourable to nesting

This open and fairly well exposed area provides two features that are conducive to nesting. The earth mound (foreground), with several small bare ground surfaces that are exposed to the sun for some of the day, is attractive to ground-nesting species looking for sloping ground (e.g. in the genus *Colletes*).


Photo credit: Violette LE FÉON

The dry branches on the other side of the meadow (in the distance on the right) with good exposure to the sun are attractive for diverse cavity-nesting species (e.g. in the genera *Xylocopa, Ceratina, Lithurgus, Megachile, Osmia, Hoplitis, Hylaeus*).

The environment of this meadow provides food resources in the form of gorse and ivy (on the opposite side of the road). One way of improving the quality of this site for bees nesting on this side of the road would be to develop the floral resource in the meadow.

Varied resources around an engineering structure

Besides its role in improving the integration of water treatment works within the landscape, the varied vegetation (willows, gorse, brooms) around the edges of a stormwater basin such as this supports wild bees.

The sides of the basin, with slopes of varying steepness, provide some south-facing areas of bare soil (top left of the photograph) that are suitable nesting sites for various species of ground-nesting bees.


Photo credit: Denis FRANÇOIS

Food resources and nesting sites with valuable geotechnical properties

This embankment, constructed from non-cohesive materials, including some large stones, was neither covered with topsoil nor seeded.

Photo credit: Denis FRANÇOIS

Willows, brambles, gorse and broom, which provide food resources for bees, show that they are able to settle spontaneously on these poor substrates with steep and unstable slopes, and to protect them against erosion (for example in the gully where gorse is becoming established).

The slow rate of colonisation and the looseness of the sandy soil lead to permanent areas of bare soil whose south-facing slope can be exploited by ground-nesting bees. The dry wood of withered specimens (bottom right) provides opportunities for cavity-nesting bees.

Connection between the road verge and the surrounding ecological network

The road verge can be connected to the local ecological network by a hedge that is part of the bocage network.

Photo credit: Denis FRANÇOIS

Here, there is even physical continuity between the brambles growing on the edge of the right-of-way and the hedge that is part of the surrounding bocage.

This hedge is attractive to bees nesting in the rightof-way as well as those comming in from the surrounding environment, due to its abundant and diversified floral resources (blackthor, broom, hawthorn).

Habitat patches forming small stepping stones in a cutting

This south-facing embankment shows the spontaneous settlement of various resource plants that are distributed between small patches a few metres apart: brambles, brooms, hawthorns, with a few patches composed of Brassicaceae and Asteraceae.

Areas of bare soil that are suitable for the nesting of groundnesting species remain in the areas with the poorest substrate.

Photo credit: Denis FRANÇOIS

Use of the green network when the road verge provides few possibilities

The embankment of the road verge (left) is dominated by grasses and therefore of little interest to wild bees because of its limited floral resources.

On the other hand, thanks to the longitudinal distribution of plants, the surrounding green network offers an abundant and varied floral resource (broom, willows, hawthorn), which it is important to conserve.

Moderate vehicular traffic on the path maintains small areas of bare compacted soil in the ruts. This is a typical characteristic of tracks, used as an opportunity by certain species of ground-nesting bees, from the Halictidae family, in particular.

Photo credit: Denis FRANÇOIS

A site that looks very ordinary but which is good for nesting

Despite its ordinary appearance, this area brings together several nesting resources for a variety of wild bee species.

It is well exposed to the sun (light spreads inside), and it provides ground-nesting species with both vertical and horizontal surfaces of bare soil (located at the bottom and left of the photo respectively). It also contains abundant dry branches (the heap at the foot of the tree) and hollow stems (dry brambles) for cavity-nesting species.

A few Apiaciae are a bloom. Brambles and ivy climbing up the tree trucks in the background and Asteraceae on the embankment will provide a food resource later in the season.

Photo credit: Denis FRANÇOIS

Vertical bare soil as a substrate for food resources and nesting

This south-facing embankment provides a variety of habitat resources for wild bees.

Photo credit: Denis FRANÇOIS

Vertical bare soil surfaces are available for the nesting of ground-nesting species. At the top of the embankment, brambles provide hollow stems for lignicolous species. Food resources, based on the herbaceous and shrubby strata, are varied, offering possibilities at various times of the season: willows (in the distance) which have finished flowering, *Stellaria holostea*, buttercups and some Asteraceae in flower, Apiaceae (in the ditch) and brambles which will flower later on.

Possible actions to improve the quality of this site include protecting the bare soil from colonisation by grasses, for example by scraping the surface, and by removing the mown grass to increase floral diversity.

W

This sparse woodland edge provides food resources on different strata: willows and gorse in bloom, chestnut trees and brambles that will bloom later.

Photo credit: Denis FRANÇOIS

It also offers a variety of nesting resources: dead standing trees, branches on the ground and bare ground that is exposed to sunlight.

A dead tree that is left standing provides many nesting opportunities for xylicolous species thanks to all parts of its branches.

These possibilities last longer than when the tree is felled: the breaks and fragmentation that occurs in fallen wood, combined with contact with the ground, speed up the wood decomposition.

The dead standing tree is also a natural support for ivy to climb up allowing it to develop optimally both upwards and along the branches. Keeping this type of substrate therefore increases the abundance of the late food resource (September-October) that ivy provides.

Photo credit: Denis FRANÇOIS

Potential offered by an area in Zone C

This part of Zone C overlooking a section of road in a cutting has some features that are valuable for wild bee friendly management.

Photo credit: Denis FRANÇOIS

The area is located at some distance from the traffic lanes. At the top of the embankment (on the left), a line of vegetation, including in particular brooms, *Leucanthemum vulgare* and the genus *Rumex* provides useful foraging and nesting resources for some species. The ditch on the right-hand side has been colonised by Apiaceae (*Anthriscus sylvestris*), close to brambles and shrubs of the genus *Prunus*, which are connected to the bocage network. The south-facing edge of the ditch has vertical surfaces of bare ground. A small amount of dry wood is present.

The central area is dominated by grasses, but thanks to limited mowing, some buttercups and various Asteraceae have managed to settle. Removing the mown grass from this area would help to promote this process.

Postface

The purpose of this document is to drive initiatives and increase know-how among the managers of road verges in order to support wild bees. It fits into the more general framework of biodiversity management in road rights-of-way, within which specific issues have now been identified. Although initiatives do exist, some constraints that are specific to the management of roads apply. The various points set out below provide an overview of the proposed approach in relation to the general context of biodiversity management in road rights-of-way, and highlight some new ways of seeing the relationship between roads and the areas through which they pass.

Biogeographical areas

The recommendations for action outlined in this document were initially illustrated by using knowledge of the plant species that are of value to wild bees in the Atlantic coastal regions of metropolitan France. However, the general approach is not restricted to a given biogeographical area. The plants listed in Tables 5.1, 5.2 and 5.3 are also to varying extents present in different parts of Europe. The recommendations can be applied by managers and planners in regions with continental, Mediterranean or even mountain climates, by choosing resource plant species for food and nesting, from the flora specific to these regions.

Minimum interventionism

The philosophy behind action to support wild bees in road verges is to keep human intervention to a strict minimum in order to allow the local ecological potential to be expressed as naturally as possible. This is reflected in the gradual adaptation of the level of intervention according to the observed needs on a case-by-case basis. The minimum level of intervention involves simply seeking to make the most of what already exists when it is suited to the local environment, achieving an immediate improvement. The intermediate level involves, if necessary, introducing into the road verges only plant species that belong to the surrounding natural environment, achieving a short-to-medium-term effect. The highest level of intervention is to create hosting conditions conducive to the spontaneous return of species that are adapted to the local environment, achieving a medium/long term effect.

The particular value of common plants

Many plant species can play a role in the feeding or nesting of wild bees (see Sections 5 and 6), and most of them are common in the road environment. This so-called “ordinary” biodiversity is an easily accessible resource and particularly important for wild bee conservation. For example, plants in the Apiaceae family (e.g. *Anthriscus sylvestris, Heracleum sphondylium, Angelica sylvestris, Foeniculum vulgare*) or the Asteraceae family (e.g. *Achillea millefolium*, thistles) can provide a supply of food for more than six months of the year, and nesting resources due to their hollow stems and/or plant down. Similarly, if we look at shrubs and bushes, the Rosaceae (brambles, dog-rose), *Ulex europaeus* and *Lonicera periclymenum* for example, provide both food and nesting resources for cavity-nesting bees.

Gorse, a resource for food and nesting

Photo credit: Aurélia LACHAUD

Beneficial effects for other threatened insects

By increasing floral diversity and the variety of nesting substrates (soils, plants), actions to support wild bees will have a positive effect on multiple other local insect species. These will include the other orders of pollinating insects (Lepidoptera, Coleoptera, Diptera) but also predators (e.g. Coleoptera) and decomposing insects, in particular due to the presence of dead wood for xylicolous bees (e.g. saproxylophagous beetles, Glomeridae).

On the other hand, beehives should not be set up in road verges where actions to support wild bees are under way. While it is true that the honey bee is also facing many threats today and is in need of conservation measures, bee colonies can compete with wild bees for food resources. Their presence on the same sites would risk undermining the effects of actions to support wild bees.

The differentiated management of road verges

The actions proposed in this document are in line with the principles for the management of road verges that have been developed in recent years, particularly in France. This so-called *differentiated management* means that all road verges are not treated in the same way. It takes into account the fact that as the distance from the edge of the road increases, the need for actions related to road maintenance and safety decreases. At some distance from the edge of the roadway, vegetation can be left to develop more freely. Differentiated management thus allows the maintenance of road verges to take account of the ecological and landscape dimensions: harbouring the surrounding flora and fauna, reducing the use of phytosanitary products, linking roadsides to the surrounding green and blue (aquatic) network, enhancing the presence of the local natural heritage when integrating roads within the landscape. This management requires less energy and fewer phytosanitary products than former practices. It therefore also leads to direct savings.

Reduction in maintenance costs for road verges

As part of the recommendations made in this document, the progressive lowering of the nitrogen content of the soil in road verges thanks to the removal of mowings should lead to a reduction in biomass production from the areas concerned, due to the reduction in the proportion of grasses. This reduction in primary productivity also provides an opportunity for management savings through a reduction in annual volumes of grass to be mowed. The reduction in the frequency of mowing and the increase in cutting heights are also proven factors in reducing direct and indirect maintenance costs (less wear and tear on equipment).

Simplicity of implementation

Some of the actions recommended in this document, such as the removal of mowings, lead to changes in practices. But for the most part, the actions needed to conserve wild bees in road verges are not radically different – and certainly not incompatible – with current maintenance practices. Above all, they consist of paying more attention to the ecological consequences of these actions and how they are carried out. The objectives for improving the situation on the ground are not considered in a standardised way but according to the existing state of the road verges, the surrounding environment, and the resources available locally.

The intention of this document is for the information it provides to become part of the know-how of managers who will adapt it to their own context of operation and incorporate it into their road verge maintenance plans.

Actions that are distributed between patches (*stepping stones*) according to the existing opportunities and challenges, are not an obstacle to connectivity as long as the gap is crossable, even by bees with a short flight distance. Such actions which spread out around patches also offer flexibility in the general organisation of maintenance operations for road verges.

Melitaea cinxia (Glanville fritillary) on *Pilosella officinarum* (Mouse-ear hawkweed): the benefits of the action for other insects

Photo credit: Denis FRANÇOIS

Andrena cineraria foraging in a field of rapeseed (*Brassica napus*) bordering a road verge

Photo credit: Héloïse BLANCHARD

The involvement of road infrastructures

At the crossroads between global environmental problems such as climate change, species extinction and the provision of food resources for a growing population, the protection of bees has become a key issue. The causes of the decline of wild bee populations are numerous and in its way, through the consumption of space and the destruction of natural habitats, the land transport sector is involved: striving to rebalance the losses and gains for wild bee populations and the pollination of the surrounding flora by exploiting the ecological potential of road verges is only right and fitting.

Lexicon

Abiotic factors: Ecological factors of a physical and chemical nature. For terrestrial environments, the two main categories of abiotic ecological factors are climatic and edaphic factors.

Abundance: A quantitative criterion that describes a population in an environment: the (absolute of relative) number of individuals in a given species.

Angiosperm: A plant whose reproductive organs form a flower and whose seeds are enclosed in a fruit. Angiosperms are a subphylum which is divided into two classes: monocotyledons and dicotyledons.

Biotic factors: Ecological factors caused by the action of living organisms on other living organisms (e.g. competition, predation, parasitism, etc.) and on the abiotic environment (e.g. action of vegetation on the climate and burrowing animals on the soil, etc.).

Bush: A woody plant that is less than 7 metres tall whose stem (trunk) is rigid.

Classification of living organisms: Kingdom > Phylum > Class > Order > Family > *Genus* > *Species*. Example: Animal > Arthropoda > Insecta > Hymenoptera > Apidae > *Bombus* > *terrestris*.

Community: All the populations of different species living in the same biotope and with similar ecology.

Dicotyledons: Plants whose seed contains two cotyledons (embryonic leaves that appear on germination). Dicotyledons can generally be identified by the fact that their leaves contain branching veins and their flowers are made up of similarly-shaped parts arranged in groups of four or five (or multiples of 4 or 5). The major families of dicotyledons include the Asteraceae, Fabaceae and Rosaceae.

Distribution area: An area of variable size, which may be either continuous or discontinuous, which circumscribes all the places where individuals of a species are naturally present.

Diversity: A qualitative criterion applicable to a community, expressed in particular through the number of species present. Species diversity, for example, is an indicator that takes into account the number of species in a community and their relative abundance.

Ecology: Study (and description) of the relationships between living organisms (in this document wild bees) with their biotic and abiotic environment (see Abiotic Factors and Biotic Factors).

Edaphic: Which concerns the soil in its relationship with living beings.

Geophyte: A plant whose perennial organs are buried in the ground (bulbs, rhizomes, tubers).

Grassland: A plant formation made up of small herbaceous plants which becomes established mainly in dry areas (dry calcicolous grassland and dry silicolous grassland).

Green network: Terrestrial ecological network made up of reservoirs of biodiversity linked by wildlife corridors which should enable terrestrial species to complete their lifecycle in spite of the fragmentation of natural environments.

Habitat: The place where a species lives, and its immediate abiotic and biotic environment.

Habitat patch: A continuous area in which a local population finds the resources necessary for its survival, separated from other patches by a less favourable or unfavourable area.

Heathland: A plant formation mainly consisting of evergreen subshrubs generally on poor acidic soil. Dry heathland develops on dry or very dry sandy soil and is characterised by the presence of bell heather and common heather.

Hemicryptophyte: Perennial plant whose aerial part is reduced to a few buds located at ground level during the winter (e.g. dandelion).

Hemiparasite: An organism that draws part of its food from the host organism. In the case of plants, these are plants whose chlorophyll activity is insufficient to meet their needs. They are connected to the host plant by suckers, on their branches (case of mistletoe – *Viscum album*), or on their roots (many plants of the Orobanchaceae family in the genera *Euphrasia, Melempyrum, Rhinanthus* and *Odontitis*).

Imago: the final stage of an insect's development.

Link section: Road section corresponding to the standard cross profile (absence of features such as access/exit roads, unusual engineering structures, tunnels, etc.).

Manager: Person responsible for the management and maintenance of roadside vegetation (in this document).

Monocotyledons: Plants whose seed contains only one cotyledon (embryonic leaf that emerges on germination). Monocotyledons can generally be recognised by their parallel-veined (unbranched) leaves and the similar parts of their flowers arranged in sets of three (or multiples of three). Grasses (Poaceae) are a major family of monocotyledons.

Mowing: Strictly speaking, mowing consists of cutting the grass in meadows in order to make hay with the cut grass (thus to remove it from the site and not to leave it to decompose on the spot, as is the case with mulching). The term for the cut grass produced by mowing is mowings.

Mulching: A technique consisting of finely shredding mown grass and putting the fragments directly back on the ground as fertiliser.

Pesticides: A generic term that includes insecticides, rat poisons, fungicides and herbicides. Chemical compounds that are used to control insects, rodents, fungi and plants.

Phanerogams: Plants that reproduce by means of seeds (synonymous with spermatophytes) unlike cryptogams (without flowers or seeds, for example ferns). Phanerogams are divided into two subphyla: gymnosperms with naked seeds (conifers) and angiosperms with seeds that are enclosed in a fruit. Angiosperms contain many more species than gymnosperms (<1,000 vs. ≈300,000).

Population: All the individuals in a given species.

Road right-of-way: The entire surface area occupied by, and constituting, the infrastructure (roadway, service and rest areas, road verge).

Road verge: All the vegetated areas within the road right-of-way. These areas are located on roadsides, on embankments, or in interchanges, rest areas and service areas.

Seed bank: All the seeds from different plant species naturally present in the soil.

Seed rain: All the seeds from different species that reach the soil by natural means.

Shoot: New growth produced by a plant, particularly after cutting.

Shrub: A woody plant with branches starting from the base, meaning it has no trunk. It includes small plants (subshrubs such as heather) and plants a few metres high (e.g. hazel).

Spontaneous: Which appears (or occurs) without direct human intervention. Otherwise than by direct voluntary human introduction.

Stepping stones: A system of separate patches that is created with spaces between them that are compatible with the travel capacity of the targeted species.

Subshrub: Perennial woody plant less than 50 cm in height (e.g. many species of heather).

Therophyte: A plant that survives the winter as a seed in the soil. Annual plant (for example the Asteraceae and Fabaceae families).

Tree: Woody plant more than 7 metres in height whose stem (trunk) is rigid, unlike that of lianas such as clematis.

Zone of action: A space that is created within the road verge to provide both nesting and feeding functions for wild bees. The dimensions of this space are variable depending on the geometric characteristics of the road verge and the location of food resources and nesting sites.

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Fiche bibliographique

Collection	Sous-collection	
Ouvrages scientifiques		

ISSN	ISBN	Réf.
2558-3018	PDF 978-2-85782-755-9	OSI2-A

Titre
Abeilles sauvages et dépendances vertes routières

Sous-titre
Pourquoi et comment développer la capacité d'accueil des dépendances vertes routières en faveur des abeilles sauvages

Coordinateur
Denis FRANÇOIS

Date de publication	Langue
October 2020	Français

Résumé
Depuis une vingtaine d'années, le déclin des insectes pollinisateurs suscite des inquiétudes et des questions au sein de la communauté scientifique et des pouvoirs publics. Parmi ces insectes, les abeilles sauvages contribuent de façon significative à la pollinisation de nombreuses cultures et plantes sauvages. Comme de nombreux insectes, elles sont victimes de différentes pressions liées à l'intensification des pratiques agricoles et au développement des réseaux de transport. Les conséquences sur les populations d'abeilles sauvages d'Europe sont telles qu'aujourd'hui plusieurs espèces sont menacées d'extinction.
Les infrastructures routières ont leur part dans les pressions qui touchent les populations d'abeilles sauvages. Mais dans des contextes environnementaux dégradés, les dépendances vertes routières (DVR) peuvent apporter des remèdes à certains maux qui affectent ces insectes. Les DVR constituent par endroits les derniers sites d'accueil de la flore naturelle et des insectes associés. Elles couvrent des milliers d'hectares à l'échelle nationale et sont de ce fait en relation avec une grande variété de milieux naturels constitutifs de la trame verte.
Ce document vise à montrer comment les gestionnaires des DVR peuvent agir concrètement pour la sauvegarde des abeilles sauvages. L'importance générale de la pollinisation entomophile et des divers insectes pollinisateurs est présentée, de même que l'intérêt particulier et les principes fondamentaux d'une action en faveur des abeilles sauvages au sein des DVR. Des recommandations opérationnelles sont formulées afin de fournir les ressources alimentaires et les sites de nidification nécessaires aux diverses espèces d'abeilles sauvages, ainsi que pour organiser la cohérence des actions dans l'espace et dans le temps.

Mots-clés
abeilles sauvages, flore locale, nidification, dépendances routières, gestion, sauvegarde

Nbre de pages	Prix
118	gratuit

Publication data form

Collection Scientific publications		Sub-collection
ISSN 2558-3018	**ISBN** PDF 978-2-85782-755-9	**Ref.** OSI2-A
Title Wild bees on roadsides		
Sub-title Why we should make road verges more wild bee-friendly, and how we can		
Coordinator Denis FRANÇOIS		
Date of publication October 2020		**Language** English

Abstract

During the last twenty years, the decline of pollinating insects has raised concerns and questions among the scientific community but also within public authorities. Among these insects, wild bees contribute significantly to the pollination of many crops and wild plants. Like many insects, they are victims of various pressures related to more intensive agricultural practices and the development of transport networks. The consequences on wild bee populations in Europe are such that today a number of species are threatened with extinction.

Roads are partly responsible for the pressures that affect wild bee populations, but in areas that have experienced environmental damage, road verges can help to overcome some of the problems. Indeed, in some places, road verges are the last sites that harbour the natural flora and its associated insects. They cover thousands of hectares on the national scale and are therefore linked to a wide variety of natural environments that make up the green network.

This document aims to show how roadside vegetation managers can take concrete action to conserve wild bees. The general importance of entomophilic pollination and the various pollinating insects are presented, as well as the particular interest and fundamental principles of action to support wild bees in road verges. Operational recommendations are made for providing food resources and nesting sites for the various wild bee species, as well as for ensuring actions are coherent in space and time.

Key-words

Wild bees, local flora, nesting, road verges, management, conservation

Number of pages	Price
118	Free

Document publié par l’Ifsttar
Dépôt légal : October 2020
ISBN : 978-2-85782-755-9
ISSN : 2558-3018
Conception graphique et mise en page : STDI

Siège de l’Université Gustave Eiffel
5 Boulevard Descartes, 77420 Champs-sur-Marne

www.univ-gustave-eiffel.fr

During the last twenty years, the decline of pollinating insects and its consequences on the reproduction of wild and cultivated plants have raised concerns and questions not only among the scientific community but also within public authorities.

Wild bees play a significant role in the pollination of many crops and wild plants. Like many insects, they are victims of various pressures related to more intensive agricultural practices and the development of transport networks. The consequences on wild bee populations in Europe are such that today a number of species are threatened with extinction.

Roads are partly responsible for the pressures that affect wild bee populations, but in areas that have experienced environmental damage, road verges can help to overcome some of the problems. Indeed in some places road verges are the last sites that harbour the natural flora and its associated insects. They cover thousands of hectares on the national scale and are therefore linked to a wide variety of natural environments that make up the green network.

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Cover photos: Denis FRANÇOIS and Violette LE FÉON

Université Gustave Eiffel
IFSTTAR COLLECTIONS

ISBN : 978-2-85782-755-9
ISSN : 2558-3018
Réf : OSI2-A
October 2020
Prix : Free