Belgian Red List of Bees

Maxime Drossart, Pierre Rasmont, Pieter Vanormelingen, Marc Dufrêne, Morgane Folschweiller, Alain Pauly, Nicolas J. Vereecken, Sarah Vray, Ella Zambra, Jens D'Haeseleer and Denis Michez

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Foreword

Notwithstanding that Belgium is a small country only covering some 30,688 km² of land, its biodiversity is relatively high as a consequence of its diverse geology, topography and climate, and its legacy of diverse agricultural practices resulting in a wide range of natural and seminatural habitats. Over the past decades, however, human-induced activities are increasingly impacting on biodiversity, which may ultimately lead to irreversible changes in ecosystem functioning with profound impacts on our society.

One of the critical benefits nature provides us is pollination, as decisively illustrated by the recent assessment report of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) on Pollinators, Pollination and Food Production, and recognized by governments globally through the Convention on Biological Diversity (CBD). In Northwest Europe and Belgium, it is in particular bees who perform the lion's share of the essential ecosystem service of pollination, and there is strong evidence that a decline in insect populations, driven by factors such as agriculture intensification including use of pesticides and fertilizers, urban development, and climate change, amongst others is a particular concern for the region.

Measures to address this threat to biodiversity require that these are based on reliable knowledge in order to be effective. One of the recognized methodologies delivering a scientifically sound basis to underpin actions is the IUCN Red List approach. However, as it requires sufficient data to enable an assessment of the conservation status of an organism, it is at times difficult to obtain comprehensive results for a specific group. For European bees, this turned out to be an issue as data deficiency precluded an evaluation for a majority of species in an Europe-wide study published in 2014. Fortunately, and as a consequence of the availability of an impressive number of observations collected through the sustained efforts by both professional and citizen experts, such is much less the case at the scale of Belgium, as this BELBEES study demonstrates.

The Belgian Red List of Bees contains an urgent cautionary message to policy makers and stakeholders alike, to create an enabling environment and to take action. With almost 33% of bees considered threatened in Belgium, and an additional 6.8% Near Threatened and 11.8% Regionally Extinct, the conservation and continued monitoring of the populations of bees must be a priority, if we wish to maintain the essential ecosystem service of pollination, for the benefit of food production and our living environment.

Hendrik Segers, Ph.D.
National Focal Point to the Convention on Biological Diversity
President of the Steering Group Biodiversity Convention
Royal Belgian Institute of Natural Sciences

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Contributions

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- Etienne Bruneau (CARI): provided expertise concerning *Apis mellifera* and its associated Box.
- Maxime Drossart (UMONS): coordinator of this work, assessor for all bee species and provided pictures of *Anthidium manicatum* and *Osmia cornuta*.
- Marc Dufrêne (ULiège – Gembloux Agro-Bio Tech): provided the applied methodology and the management of statistical analyses.
- Morgane Folschweiller (UMONS): management of the recommendation section and provided maps of the number of observations in Belgium.
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- Leon Marshall (ULB): provided maps of species richness and distribution of threatened species in Belgium.
- Denis Michez (UMONS): assessor of Andrenidae, *Bombus*, other Apidae, Colletidae, Halictidae, Megachilidae and Melittidae species.
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Experts assessed the species recorded in Belgium based on a data set of 268,954 entries (797,539 individuals). This data set resulted from the collection of data by many collaborators, volunteers and students. We would like to thank the following people that contributed 1% or more of the records, including some historical contributors:

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Executive summary

Aim

The Belgian Red List of bees is an assessment of the conservation status of Belgian bee species according to the IUCN guidelines for application of the international IUCN Red List criteria at regional and national levels (IUCN 2012a, b). It identifies the extinction threat to species at this geographical scale. These results can be used to implement conservation actions to improve the threat status of species. This Red List publication summarizes the results of this exercise for all recorded Belgian bees.

Scope

All bee species recorded in Belgium until the first half of 2017 have been included in this Red List. The geographical scope is nation-wide.

Status assessment

The status of all species was assessed using the IUCN Red List Criteria (IUCN 2012a), which is the world's most widely accepted system for extinction risk evaluation. All assessments followed the Guidelines for Application of IUCN Red List Criteria at Regional Levels (IUCN 2012b). These assessments were compiled based on the data and knowledge from a network of national bee experts. A preliminary Red List category was assigned based on the analysis of a total of 268.954 bee records belonging to 403 species. Current distribution of the species was determined with a 5 x 5 km UTM grid. Historical changes in species distributions were analysed by comparing the time periods 1900-1969 and 1970-2017. The preliminary Red List category was then discussed and reviewed during five workshops held in Mons (Belgium) as well as through email correspondence with relevant experts. Individual assessments are available in Appendix 1 and on the dedicated Atlas Hymenoptera web page (www.atlashymenoptera.net).

Results

Overall, 32.8% of bees (i.e. 113 species) are considered threatened in Belgium. Considering the Near Threatened (i.e. 26 species; 6.8%) and Regionally Extinct (i.e. 45 species; 11.8%) bees, the present study suggests that more than half (i.e. 53.3%) of the assessed species (i.e. 184 species) are (nearly) threatened or extinct in Belgium. A further 42.3% of bees (i.e. 161 species) are considered as Least Concern. Out of a total of 403 bee species that are recorded for Belgium, 22 species that were observed only once in a single specimen were assigned to the category Not Applicable (NA). It is unclear whether they ever had a population in Belgium. Consequently, they are considered as absent of the country. Another 36 species (i.e. 9.4%) were classified as Data Deficient, as there was not enough information to assess their risk of extinction.

By comparison, 57.1% of reptiles, 43.8 % of amphibians, 52.9% of ants, 50% butterflies, 33.8% of spiders, 30.6% dragonflies, 29.9 % of birds, 28.4% of mammals and 27.6% of vascular plants are assessed threatened in Belgium (Goffart et al. 2006; De Knijf 2006; Fichefet et al. 2008; Maes et al. 2012; Belgian Federal Government 2018c). Besides, 9.2% of bee species are considered threatened at the European scale (Nieto et al. 2014). However, no less than 57% of European bees are listed as Data Deficient, which implies that the proportion of really threatened species is highly uncertain. This proportion of threatened species could lie between as little as 4% and much as 60.7% (Nieto et al. 2014).

Considering the functional traits possibly associated with extinction risk, there is no major difference between opportunistic and specialised bees in threat status in Belgium. Besides a similar proportion of threatened species (i.e. 31-36%) among the three categories of sociality, (primitively) eusocial bees include a higher proportion of extinct species (i.e. 21.7%). Moreoever, bumblebees constitute the most impacted group with near 60% of Threatened or Near Threatened species as well as 20% of Regionally Extinct species. Finally, ground-nesting bees are more threatened (i.e. 32.5%) compared to bees nesting in existing cavities above ground (i.e. 23.6%), bees with specific nesting behaviours showing highly variable proportion of threatened species.

Regarding the spatial distribution of bees, the highest species richness is found in (i) the Condroz and Fagne-Famenne-Calestienne as well as Gaume regions, (ii) the Brussels-Capital area as well as Hageland and Droog Haspengouw, (iii) the sandy Flanders and (iv) the eastern Campine. Local diversity hotspots are found in particular habitats like calcareous grassland and heathlands. Southeastern Belgium (i.e. Fagne-Famenne, Lorraine, East canton), Hageland and Droog Haspengouw and Campine as well as the coastal dunes and East canton (albeit to a lesser extent), present a high diversity of threatened species.

The main threats identified in the literature are habitat loss and fragmentation due to agricultural intensification (e.g. changes in agricultural practices including the use of fertilisers and pesticides) and urban development, as well as climate change.

Attention must be paid to the 9.4% of Data Deficient species for which a taxonomic impediment was encountered (i.e. lack of taxonomic experts for species being recently recognized or species that are morphologically highly similar to other more widespread taxa as well as rare to very rare species in less-studied genera). For these, revisions of historical and present collections as well as an increase in taxonomic expertise and training among wild bee volunteers is necessary to resolves these impediments.

1. Background

1.1 The Belgian context

Belgium is a small and densely populated country, with 11,376,070 habitants for 30,528 km^2 in 2018 (Belgian Federal Government 2018a). Located in NW-Europe, it is a typical example of agricultural intensification and urbanization that occurred in this region during the last century. The country hosts ten geographical regions, which are from the northwest to the southeast: The Dunes, the Polders, the Sandy Loam regions, Campine, the Border Meuse Valley, the Loam region, Condroz, the Fagne-Famenne-Calestienne region, Ardenne and Lorraine (Fig. 1). Around 45% of its area is dedicated to farmland, 23% to woodland, and 21% to settlements (see Fig. 13; Belgian Federal Government 2018b).

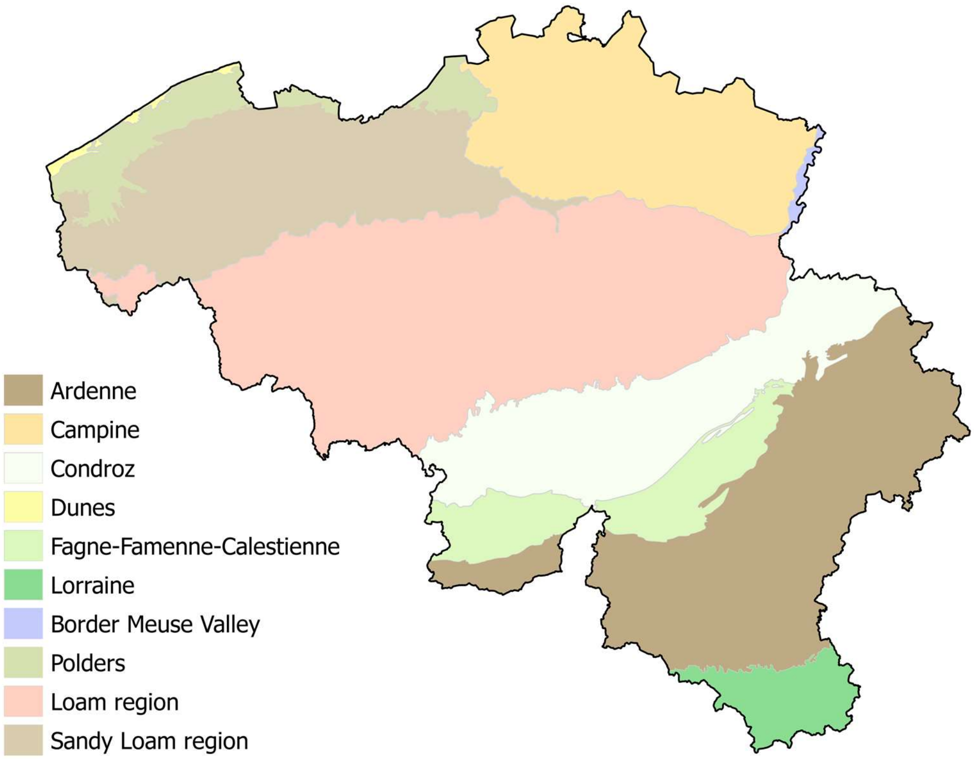

Figure 1. Geographical situation of the different ecoregions in Belgium (adapted from Goffart et al. 2006).

Belgium holds an estimated 36.300 species of micro-organisms, plants, fungi and animals (Peeters 2014). This number represents more than 20% of the total number of species described for Europe and 2% of the species known in the world. Belgian biodiversity includes 456 species of birds (Lepage 2007), 69 species of mammals (Temple & Terry 2009), 16 species of amphibians (Temple & Cox 2009), 48 species of freshwater fish (Freyhof & Brooks 2011), 69 species of dragonflies and damselflies (De Knijf et al. 2001), 93 species of butterflies (van Swaay et al. 2010) and more than 1,400 species of vascular plants (Peeters et al. 2003). In some Belgian areas (e.g. limestone regions, …) a relatively high proportion of species is of conservation interest.

Belgium has arguably one of the most highly fragmented landscapes of European countries, and no fraction of its land surface can be considered as wilderness. For centuries, most of its surface area has been used by humans to produce food, timber and fuel, and provide living space. Consequently, Belgian species are to a large extent dependent upon habitats created and maintained by human activity, particularly traditional, non-intensive forms of land management. These have created, in interaction with the different land cover types and hydrological conditions, a wide variety of so-called seminatural habitats, such as heathlands, various grassland types, shrublands, managed woodlands or coastal habitats providing suitable habitat for many species. These seminatural habitats are under heavy pressure from agricultural intensification, commercial forestry, urban sprawl, infrastructure development, land abandonment, acidification, drainage and eutrophication. Many species are directly affected by overexploitation, persecution, and the impact of invasive species. Moreoever, climate change is set to become an increasingly serious threat in the future.

Although some efforts have been made to protect and conserve habitats and species from the national and european level [i.e. near 13% of the country area is included in the Natura 2000 network (Blerot & Heyninck 2017)], biodiversity decline and the associated loss of ecosystem services (e.g. water purification, pollination, flood protection, and carbon sequestration) continue to be a major concern in the country.

1.2 Diversity and distribution of Belgian bees

The origin of bees traces back to 120 million years ago, when a group of wasps presumably shifted from a carnivorous diet to an herbivorous diet. Bees in the widest acknowledged sense constitute a monophyletic group which currently includes ~20,000 described species and occurs worldwide except in Antarctica (Michener 2007; Michez et al. 2011; Danforth et al. 2013; Ascher & Pickering 2019). A checklist collated by Rasmont et al. (2017a) showed that the European bee fauna encompasses an estimated 2051 species grouped in 77 genera. Belgium includes a relatively small part of this diversity as its climate is not optimal for most groups of bees (i.e. the highest bee diversity is found in the Mediterranean).

Bee research in Belgium has a very rich and well documented history. It started with the studies of Meunier (1888), Jacobs (1904), Ball (1914, 1920), Crèvecoeur & Maréchal (1935, 1938) and Lefeber & Petit (1970). From the 70's, the team of the University of Liège (Gembloux Agro-Bio Tech, Prof. J. Leclercq) and later the team from the University of Mons (Laboratory of Zoology, Prof. P. Rasmont) produced and published a lot of data, maps, keys and taxonomic revisions on the Belgian fauna but also worked at the continental scale and beyond the European boundaries (e.g. Europe and North America, Kerr et al. 2015). Belgian researchers specialized their work on specific bee groups: Pierre

Rasmont on bumblebees and Anthophorine bees (Rasmont 1988, 1995), Alain Pauly on Halictidae (Pauly 2019a), Michael Terzo on Xylocopinae (Terzo 2000), Sébastien Patiny on Andrenidae (Patiny 2001) and Denis Michez on Melittidae and fossil bees (Michez 2007; Michez et al. 2011). Local studies on particular habitats also contributed to the study of Belgian bees, mainly in Wallonia (Rasmont et al. 1990; Jacob-Remacle & Jacob 1990). Recently, the research programs BELBEES (Box 1) and SAPOLL (Box 2) included a larger consortium of universities (UMons, UGent, ULG, UNamur), NGO's (Natuurpunt, Natagora) as well as the Royal Belgian Institute of Natural Science (RBINS) (see Box 1). These collaborations enabled to digitize a considerable part of the historical collections of Belgian bee specimens, but also aggregated available bee records in Belgium. The last decade has seen the onset and rapid increase of citizen science through the monitoring effort of naturalist groups (exemplified by the formation of the bees and wasps study group of Natuurpunt in Flanders, "Aculea") supported by bee expert(s) at Natuurpunt and Natagora (see Box 5). They produced an important quantity of new information and data, mainly encoded and managed within the online data platform https://waarnemingen.be or https://observations.be. New entomological courses, training and field workshops are organized in Belgium and the network of bee amateurs and experts is again expanding. All these new initiatives made possible the production of a unique data base of >268,000 observations (Figure 2). From this database, a list of 403 species was established (Table 1).

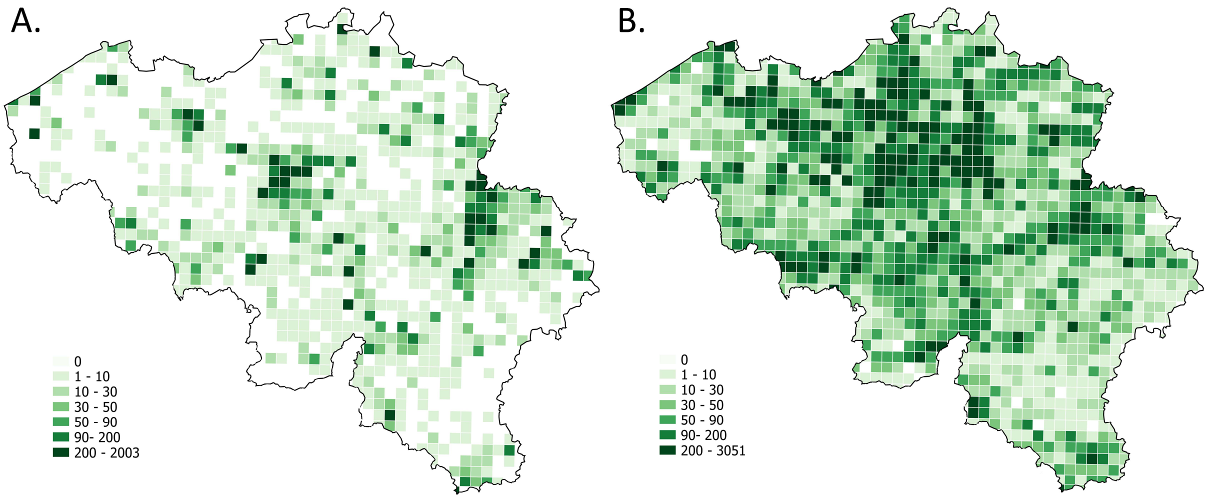

Figure 2. Investigated 5 x 5 kilometer UTM squares during the periods before 1970 (A) and after 1970 (B), with the number of observations per square. Species richness categories are quantiles with an equal number of grid cells in each category.

Bee species recorded in Belgium are divided into six families: (i) Apidae and Megachilidae form the group of long-tongued bees, (ii) Andrenidae, Colletidae, Halictidae and Melittidae represent the short-tongued bees (see Table 1, Figure 3). The most prominent and species-rich family of bees in Belgium is the Apidae family (101 species) including the honeybee (*Apis mellifera*) and bumblebees (*Bombus* spp.), while the least diverse family is the Melittidae with only 9 species (Table 1).

Halictidae and Andrenidae can be the most species diverse groups encountered in the field, especially the genera *Lasioglossum* (Halictidae) and *Andrena* (Andrenidae) (e.g. Rasmont et al. 1990).

The biodiversity of bees in Wallonia (i.e. 366 species) is higher than in the two other regions of Belgium (Table 1). This relatively high species richness can be partly explained by the higher diversity of habitats and altitudes of this area and also by the lower human density and the southernmost locations.

Table 1. Species richness in bee families in Belgium and its different regions. This compiles old and contemporary data. 22 species for which the region in which they were observed is not known (i.e. Not Applicable species) were not included in the regional counts.

Class	Order	Family	Belgium	Brussels	Flanders	Wallonia
Insecta	Hymenoptera	Andrenidae	93	59	80	81
		Apidae	101	77	92	97
		Colletidae	38	16	30	31
		Halictidae	86	55	71	82
		Megachilidae	76	32	61	67
		Melittidae	9	7	7	8
Total			403	246	341	366

Box 1 - BELBEES project (Abstract)

The BELBEES project is a conservation research project funded by the Belgian Science Policy (Belspo program BRAIN-be (Belgian Research Action through Interdisciplinary Networks)). This project develops a multidisciplinary assessment of decline of the Belgian wild bees in order to adapt mitigation management.

The general goals of the project are:

- to collect and analyze data on recent changes in wild bee populations in Belgium;
- to assess the respective roles of different assumptions on the decline to identify field action combinations needed to restore pollination service in agro-ecosystems.

Box 1 - BELBEES project (Abstract)

Apart from the overall assessment of wild bee status in Belgium, focused studies were performed into the wild bee (causes of) decline and the economic value of the ecosystem service pollination. Floral resources availabilities decreased significantly threatening most of the specialist bee species and constraining the generalist ones to shift their diet to different flower species (Roger et al. 2016a; Moerman et al. 2017; Jacquemin et al. 2018, *in prep*).

This resource shift has an impact on the bee health through the vulnerability to diseases and infections or the increased consumption of pollen and nectar (Vanderplanck et al. 2014, 2018; Moerman et al. 2015; Roger 2016b). The present main agriculture crops in Belgium do not require insect pollination. However, some large areas in Vlaams Brabant and Limburg are important fruit producer that could suffer significantly from pollinator loss (Jacquemin et al. 2017). Thistles revealed as very important resources for bumblebees (Vray et al. 2017).

Climate change appeared as a main threat against bumblebees as most of them are very sensitive to heat stress as occurring in heat waves (Martinet et al. in prep). Models show that most species might disappear in the next decades (Rasmont et al. 2015). While landscape changes had a negative impact on changes in the Belgian bumblebee fauna, land use and climate change appear as linked factors (Marshall et al. 2018; Vray 2018; Vray et al. 2019).

No population structure was found at the national scale (Belgium) (Maebe et al. 2016) nor in an international sampling for seven bumblebee species at continental scale (Europe) (Maebe et al. in prep). This indicates that there are (or have been until recently) few barriers to gene flow, even not threatened species that have shown a major reduction in geographic distribution. As well, an important result was also that there was no reduction in genetic diversity in the remaining populations of rare bumblebees in southern Belgium (Maebe et al. 2016).

A careful assessment on microbial pathogens in selected wild bee species showed that they included numerous previously hitherto unknown or underscribed taxa, with few or no connection with honey bee diseases (Schoonvaere et al. 2016). A pilot study on honeybees has been conducted to test the feasibility of adopting a biomarker-driven approach for studying insecticide-induced detoxification mechanisms in bees (De Smet et al. 2017). Results indicate that two gene expression biomarkers can potentially be used as indicators for imidacloprid-induced stress under field conditions.

Box 2 - SAPOLL project (Abstract)

The Interreg France-Wallonie-Vlaanderen SAPOLL (www.sapoll.eu) (2016-2020) project aims at initiating the creation of a cross-border action plan for pollinators with operators from Wallonia, Flanders and northern France. This plan is designed to encourage the development of actions for pollinators conservation by spreading scientific, didactic and applied contexts to all - that is to say to citizens, stakeholders, business managers and managers of natural areas. This plan is adapted to the local context of each region. It was made together with the members of the cross-border territory and exposes the goals and issues for the cross-border area as well as the actions that need to be done for pollinator conservation.

The SAPOLL project also organises additional actions that are essential for the creation and the success of the cross-border action plan. These actions facilitated the sharing of skills and the homogenisation of knowledge. Indeed, scientific knowledge, expertise in awareness raising or naturalist skills are very heterogeneous on the cross-border territory.

- Awareness raising for the general public: communication and awareness raising actions were done in order to inform as many people as possible of the pollinator decline.
- Organisation of observers networks: the naturalist network in the cross-border area was interconnected and homogenised through the animation of working groups and training courses.
- Scientific monitoring of wild pollinators: a global monitoring of pollinators was conducted on the whole cross-border territory. The area of high importance for pollination service was demarcated.

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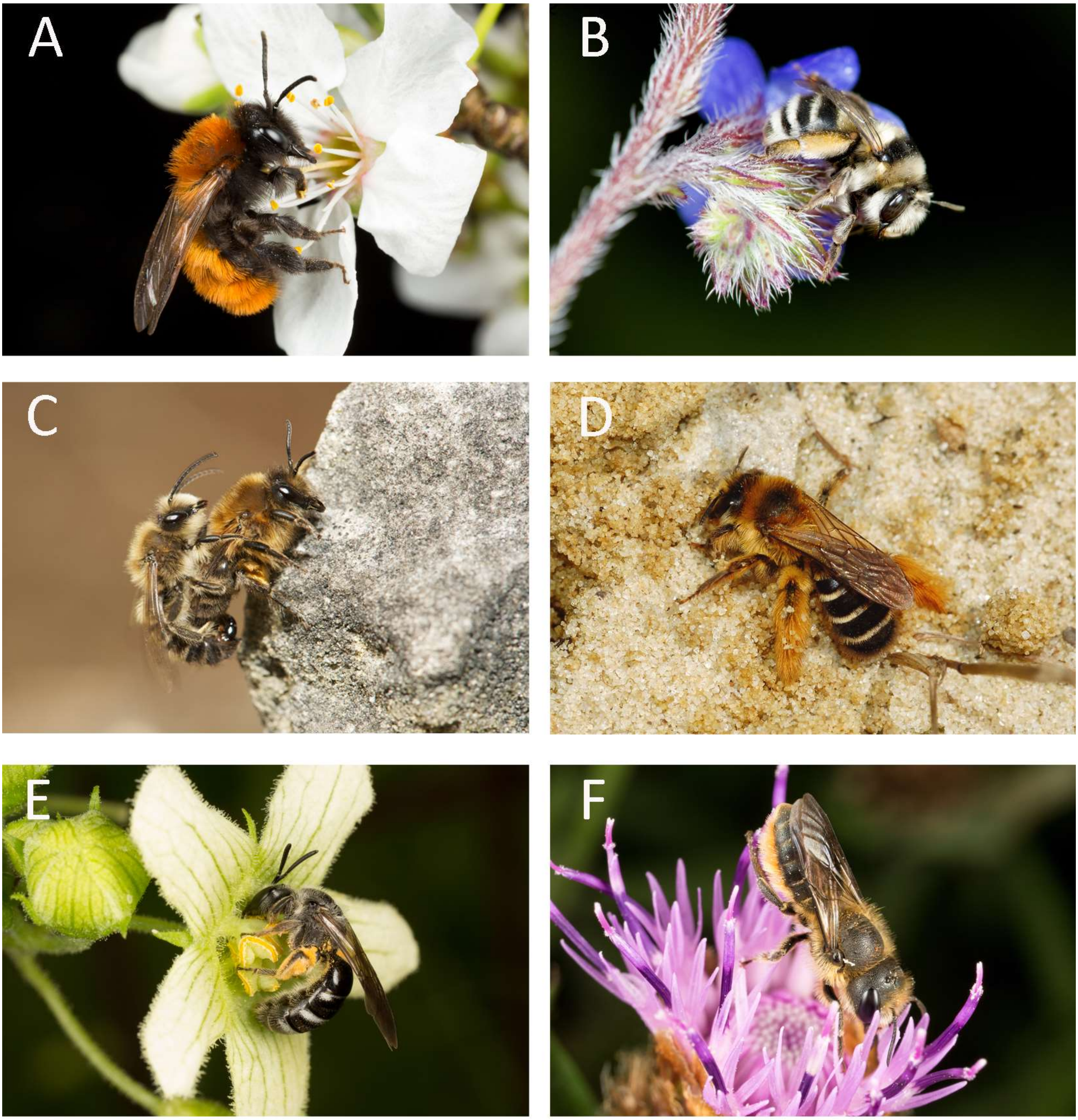


Figure 3. Bee families recorded in Belgium: **A**. Andrenidae, female of *Andrena fulva*; **B**. Apidae, female of *Anthophora aestivalis*; **C**. Colletidae, female and male of *Colletes cunicularius*; **D**. Melittidae, female of *Dasypoda hirtipes*; **E**. Halictidae, female of *Lasioglossum sexnotatum*; **F**. Megachilidae, female of *Osmia niveata*. Photo credit: Nicolas J. Vereecken.

1.3 Ecology of Belgian bees

Bee ecology can be basically characterized through their sociality, nesting requirements (including nesting sites and sometimes building material), food resources and (micro)climatic envelope. Many morphological traits are associated to these ecological characteristics. A table of IUCN Red List status of Belgian bees with their main behavioural and functional traits is available in Appendix 2.

Sociality

The degree of sociality is highly variable among bees. The majority of species (245 out of a total of 403 species, or 61% with additional 5 species which can be either solitary or primitively eucosial) is **strictly solitary species**. Fertilized females build their nest by themselves and eventually die without contact with their offspring. Each brood cell is provisioned with pollen, nectar and one egg laid by the female. The larva hatching from this egg feeds on the stocked food and will emerge as new adult after nymphosis (Falk 2015; Vereecken 2017).

The 46 social species (11.5% of the total with additional 5 species which can be either solitary or primitively eucosial) show more complexe interactions among related individuals. In the **(primitively) eusocial species**, the cycle begins with mated queens funding a nest, raising daughters (i.e. workers) who will then build and maintain the nest, collect resources and raise additional offspring (Goulson 2010). Differences in the free-living phase of the queen (non-existent in Honeybee) can be mentioned as well as the degree of differentiation between castes. Sometimes there is even only a communal nest without differentiation between queen and workers. This type of sociality is found among the most commonly known bees (i.e. from general public and science) such as the Honey Bee (Apidae) and the bumblebees (Apidae), but also among well-known species belonging to the Halictidae (i.e. *Halictus* and *Lasioglossum*).

A third major social category gathers bee species that exploit the nest and resources of other bees, a form of brood parasitism called kleptoparasitism. These **cuckoo bees** comprise a significant part of bee diversity (105 species in Belgium, or 26% of total species diversity). They do not collect pollen and nectar but rely on the resources collected by their host species. They have quite a narrow spectrum of hosts and some seem exclusively linked to a single host bee species (Nieto et al. 2014). Three of the six families (i.e. Apidae, Halictidae and Megachilidae) include kleptoparasitic species (Vereecken 2017).

Nesting requirements

Nesting behaviour of bees can be categorised in two broad groups (excluding kleptoparasite species): the **ground-nesting digger** species (197 out of a total of 403 species, or 49%) - to which the majority of Belgian species belongs - and the species that nest **aboveground or in existing underground cavities** (99 out of a total of 403 species, or 24.5%) (Michener 2007). As highlighted by Potts et al. (2005), many ground-nesting species have highly specific requirements concerning the ground texture, sun exposure and slope of the nesting sites. The first group can be exemplified by *Andrena*, *Lasioglossum* and *Colletes* species having a preference for (e.g. *Andrena fuscipes, Panurgus calcaratus*) or even a strict dependence on well-exposed sandy sites (e.g. *Andrena argentata, Colletes cunicularius*) (Vereecken et al. 2006; Falk 2015). Regarding the non-digging species, dependent on the species they use a variety of above ground cavities, for instance by excavating their galleries in plant stems, using hollow plant stems, natural or artificial holes (e.g. dead wood, walls, rock crevices, abandoned galleries of bees or rodents, …), bee hostels, … (Westrich 1989; Falk 2015; Vereecken 2017). Some *Osmia* species even nest exclusively in empty snail shells (Helicidae; *Osmia andrenoides, O. aurulenta, O. bicolor, O. rufohirta and O. spinulosa*)! Besides this, some species also collect specific materials to build their nest or line the brood cells in cavities or in the soil, such as resin, pieces of masticated leaves, cut petals or leaves and even mud and small stones (Wcislo & Cane 1996, Michener 2007; Müller 2011; Vereecken 2017). Finally, bumblebees and the honeybee are known to secrete wax by their abdomen to build nest cells (Westrich 1989; Falk 2015; Vereecken 2017).

Food resources

Wild bees rely on pollen as a source of protein and lipids during larval development and on nectar as an energy source throughout their life cycle, and sometimes also on floral oils (genus *Macropis*) (Michener 2007). Several foraging strategies can be described based on the range of plant species from which pollen is collected to feed the larvae. While some taxa (called **generalist species**) forage on a wide range of plant species (i.e. variety of plant families and genera), other bee species restrict their flower visits to closely related plant taxa (i.e. called **specialist species**) (Dötterl & Vereecken 2010). To describe the continuum in bee foraging strategies, three terms have then been formulated (from extreme specialization to extreme generalization): (i) **monolecty** (only one host plant species); (ii) **oligolecty** (within one host plant family) and (iii) **polylecty** (more than one host plant family) (Cane & Sipes 2006; Müller & Kuhlmann 2008). Subcategories were also put forward for both oligolecty (i.e. Narrow oligolecty, Broad oligolecty, Eclectic oligolecty) and polylecty (i.e. Polylecty with strong preference, Mesolecty, Polylecty *sensus stricto*) categories to accurately characterise the different degrees of host flower specialization (proposed by Cane & Sipes (2006) and modified by Müller & Kuhlmann (2008)). A third terminology followed for the present report is the one by Müller & Kuhlmann (2008): (i) **Specialised bees** which gathers monolectic and oligolectic bees (i.e. Narrow, Broad and Eclectic oligolecty) (in Belgium 87 bee species, or 21.5%, Appendix 2), (ii) **Opportunistic bees with strong preference** which gathers polylectic bees with a strong preference for one plant clade (11 species, 2.7%) and (iii) **Opportunistic bees** (184 species, 45.6%) which gathers mesolecty and polylecty *sensus stricto* subcategories. Apart from the kleptoparasites species which have not been taken into account, the foraging strategy of 16 additionnal species is unknown.

As for nectar collection, it is generally undertaken on a wider range of plant species, but this can be influenced by flower morphology (Westrich 1989). The harvest of these two food resources requires morphological adaptations, such as the shape and the size of the body and the length and structure of the proboscis/tongue (i.e. the labio-maxillary complexe) which can be elongated in order to reach deep-lying nectar in tubular flowers (Wcislo & Cane 1996; Falk 2015). While Apidae and Megachilidae contain **long-tongued species** that are able to collect nectar from flowers with long corolla tubes, species of the other families (i.e. Andrenidae, Colletidae, Halictidae and Melittidae) have a **short tongue** and mostly collect readily accessible nectar from flowers with a short or without corolla tube (Willmer 2011). Additionally, most bee species (with the exception of kleptoparasitic species) have morphological features (i.e. **corbicula on the hind legs** of *Apis* and *Bombus*; **collecting hairs on the ventral surface** of the abdomen of Megachilidae; **collecting hairs on the hind legs** of bee species of other Apidae, Colletidae, Andrenidae, Melittidae and Halictidae; and floral resources **carried back in a particular crop to be regurgitated into the nest**) allowing them to collect and transport pollen from the flowers to the nest (Westrich 1989; Falk 2015; Vereecken 2017).

It is also important to keep in mind that both food resources and nesting site and building materials have to be close enough to each other to be situated within the flight range of the bees. If this is not the case, only a partial habitat is present and the species will be absent (Westrich 1996). The maximal foraging distance will vary according to the bee species, from a little more than 100 meters for small species to several kilometres for large and good flying species (e.g. 200m for *Chelostoma rapunculi*, 2300 m for *Bombus pascuorum*) (Gathmann & Tscharntke 2002; Chapman et al. 2003; Zurbuchen et al. 2010a). Moreover, the maximal foraging distance probably overestimates the maximal distance between foraging and nesting sites needed to maintain bee populations. Indeed, an increasing distance between both habitats has an impact on the number of offspring (Zurbuchen 2010b) which is amplified by the fact that most females usually do not forage as far as their maximal range (Zurbuchen et al. 2010a). This is presumably due to the increasing time and energy investment in the actual flight with increasing distance.

Climatic enveloppe

The climatic envelope has a large impact on the occurrence of bee species and species at the edge of their bioclimatic range often only occur in sites with very specific and suitable microclimates. For instance, bee species that are at the northern limit of their range in Belgium, like *Osmia andrenoides,* will be restricted to habitats with the warmest microclimate, such as south-facing calcareous grasslands (e.g. the “Belvédère” at Han-sur-Lesse in the Calestienne region, Pauly & Vereecken (2018)). Several bee species with a southern distribution have recently been discovered in Belgium (e.g. *Hylaeus punctatus*) or are currently expanding their range in Belgium (e.g. *Panurgus dentipes*, *Halictus* *scabiosae*), probably as a result of climate warming. On the other hand, bumblebees are typically adapted to colder climates and in the future Belgian climate may become unsuitable for species like *Bombus jonellus* and *Bombus soroeensis* (Rasmont et al. 2015).

1.4 Importance of bees in pollination

The pollination (i.e. transfer of pollen from one flower to another) carried out by insects such as bees, hoverflies, butterflies… (so-called pollinators) during their flower visits (i.e. for pollen, nectar, plant oils) can fertilize plants and enable their sexual reproduction. According to Ollerton et al. (2011), the proportion of animal-pollinated plants in temperate regions is on average 78%. Given their ubiquity and tight association with flowering plants, bees are a keystone species group in natural and agricultural ecosystems.

The value of crop production for human food, the estimated value of insect pollination to this production and the vulnerability of food production to pollinator losses for the year 2010 have recently been calculated in Belgium (Jacquemin et al. 2017). The contribution of insect pollinators to human food production was estimated at 251.6 million euros (11.1 % of the total value of Belgian plant production). The area most at risk in case of pollination losses is Northern Belgium and especially the province of Limburg. The large difference between regions are linked to the concentration of fruit and pollination-dependent vegetable production in certain regions in northern Belgium while other regions are focused on animal production or on crops that are less dependent on (animal) pollination (cereals, sugar beets, potatoes, maize).

Several studies highlighted the importance of enhanced bee pollination which can lead to multiple benefits (e.g. increased production, better crop quality and shelf life, yield stability and higher commercial value for many enthomophilous crops) in the case of strawberries (Klatt et al. 2014) and apples (Garratt et al. 2014, Garibaldi et al. 2011). While some crop plants can only be pollinated by a limited number of bees (Klein et al. 2007), it has also been shown that wild pollinators (i.e. bees, hoverflies, butterflies) are responsible for a greater proportion of the pollination service than previously thought and attributed to the Honey Bee (Garibaldi et al. 2013).

1.5 Population trends of Belgian bees

The first warning about the decline of wild bee species came from Peters (1972) in Germany and from Gaspar et al. (1975) in Belgium. These authors highlighted that several bee species formerly common were disappearing, such as *Melecta luctuosa* or *Coelioxys* spp. (Gaspar et al. 1975). Simultaneously, Leclercq (1976) reported that several bumblebee species completely disappeared from his native “Pays de Herve” (Province of Liège, Belgium). As an example, *Bombus sylvarum* was very abundant everywhere in this area before the Second World War but disappeared completely in the 1960s. Ball

(1914, 1920) and Bols (1939) recorded a Belgian bumblebee fauna that comprised about 30 species. In the 1970s, it had already become impossible to observe such diversity. All these species disappeared not only from the localised areas where naturalists made observations, but also in most parts of Belgium (Rasmont & Pauly 2010; Vray et al. 2019).

While the 1980's were marked by an involvement of various researchers to study and monitor wild bees in bordering countries of Belgium, Williams (1982) was the first to clearly quantify that habitat fragmentation was the main bee threat in South-England. A first quantitative assessment of the Belgian bumblebee fauna led to the hypothesis that the main causes of the decline was the deep modification in agriculture (Rasmont 1988; Rasmont & Mersch 1988). They pointed out the great regression of leguminous crops (e.g. clovers, alfalfa and sainfoin) in the landscape, decreasing from 163.700 ha in 1908 to less than 2.500 ha in 1985. Given the fact that these disappeared bumblebee species were mostly linked to Fabaceae, the authors made the connection with this loss of resources. In addition to this regression, the landscape composition has drastically changed since the last century namely through an increase in intensively managed grasslands (with higher livestock densities and fertilisers), an increase in planted woodlands, a strong decrease of orchards and heathlands as well as an increase in urbanization and in population density leading to the expanding of settlements and gardens (Christians 1998; Barlow & Thorburn 2000; Senapathi et al. 2015; Vray et al. 2019).

In 1993, Rasmont et al. published the first comprehensive study of the status of the whole Belgian wild bee fauna (see Appendix 1). Based on a dataset of 181.894 specimens, a comparison of the fauna distribution before and after 1950 (following the statistical method from Stroot & Depiereux 1989) allowed the authors to conclude:

- Among the 360 recorded species, 91 species were in regression (i.e. 25.2%), 145 were more or less stable (i.e. 40.2%), 39 were in expansion (i.e. 10.8%), and the status of 85 species could not be determined (i.e. 23.5%);
- Compared to the short-tongued species, the long-tongued ones suffered a much steeper decline, which is indicative of a strong regression of plants with long corollae (i.e. Fabaceae, Lamiaceae, Scrophulariaceae, Boraginaceae) and namely to the demise of leguminous crops (Rasmont & Mersch 1988);
- The kleptoparasitic species also showed a strong regression, even for species that parasitize the short-tongued bees. The authors hypothesised that this strong regression indicates an absolute numerical decrease of the wild bee fauna as a whole without a decrease of the occupied area at least for the more common host species.

In 2010 the EU PF7 STEP project (*Status and Trends of European Pollinators*) was launched and represented one of the first international initiatives to evaluate wild pollinator population trends at the continental scale. This project aimed at carrying out a comprehensive assessment of the European

Union pollinators, with a special focus on bees (Potts et al. 2015). The project resulted in (i) a Red List of European Bees (Nieto et al. 2014) to support direct conservation efforts at the national and continental level; (ii) a multi-scale as well as multi-species assessment of the shifts in pollinator populations and distribution across Europe (i.e. Bommarco et al. 2012) and Belgium (i.e. Carvalheiro et al. 2013); (iii) the identification of single threat drivers (e.g. climate change, Rasmont et al. 2015; pesticides, Sandrock et al. 2014) but also the key drivers of change (González-Varo et al. 2013). In addition, reserarch conducted in the framework of the STEP project also identified the pollinators actually pollinating crops (Riedinger et al. 2015) which allows to focus mitigation measures on taxa of the highest economic importance.

1.6 Objectives of the assessment

In line with the European Red List of bees (Nieto et al. 2014), the Belgian regional Red List assessment has four main objectives:

- To contribute to national and regional conservation action plans (e.g. the SAPOLL cross-border action plan (Folschweiller et al. 2019), Brussels Bee Atlas) through the provision of an updated dataset reporting the status of Belgian bee species following the IUCN methodology.
- To identify priority geographic areas to be conserved in order to prevent further regional extinctions and to ensure that Belgian bees reach and maintain a favourable conservation status.
- To compare the risk of extinction between taxonomic and ecological groups in order to better design mitigation strategies.
- To reinforce the experts network focused on bee conservation in Belgium in order to keep assessment information up to date and to address the highest conservation priorities.

The assessment provides three main outputs:

- This summary report on the status of all 403 bee species recorded in Belgium.
- A freely available compiled database holding the baseline data for assessing the status and distribution of Belgian bees.
- A specific section will be developed on the Atlas Hymenoptera website (http://www.atlashymenoptera.net/) showcasing data in the format of species factsheets for all Belgian bees assessed in this Red List.

The data presented in this report provide a snapshot based on the knowledge available at the time of writing (i.e. database 1900 – 2017; writing and publication 2017 – 2019). The database will continue to be updated and made freely and widely available through the different web portals (i.e. https://observations.be; https://waarnemingen.be/; http://www.atlashymenoptera.net/).

The consortium of the Belbees project will ensure wide dissemination of these data and results to relevant decision makers, NGOs, scientists and practitioners to support the implementation of conservation actions on the ground.

2. Assessment methodology

2.1 Geographic scope

The geographic scope of this Red List of bees is nation-wide (i.e. Belgium) and therefore focussed on the entire territory. Assessments were conducted at the national scale but regional situations (i.e. Wallonia, Flanders, Brussels) were reviewed in case of relevant information (e.g. defining features linked habitats and distributions in each region) and/or significant differences between regions.

2.2 Taxonomic scope

The initial species list was based on Nieto et al. (2014) updated in Rasmont et al. (2017a) who listed all bee species occurring in Europe and Belgium. We followed the taxonomic position of these two publications as well as the one of Scheuchl & Willner (2016) for species groups with taxonomic uncertainties (see 3.4 "Knowledge gaps" for details). A total of 403 bee species was considered. However, the list of assessed species does not include the new species for Belgium recorded in the last 10 years or species recorded only once in Belgium. Based on this criteria 22 species were classified as Not Applicable (NA).

2.3 Data set

National and regional datasets (Table 2) were compiled from the database *Banque de Données Fauniques de Gembloux et Mons* (BDFGM). As highlighted by Vray (2018), this dataset gathers old (e.g. the Hymenoptera collection of F. J. Ball (Ball 1914, 1920) as well as recent Belgian records (e.g. data coming from university collections, scientific monitoring and NGO initiatives with naturalist platforms (https://observations.be/ and https://waarnemingen.be/). This dataset covers the whole country and has benefited from a large increase of observations since 1970 (Figure 2; Table 2).

Table 2. Number of individuals and database entries.

Type of database	Number of individuals	Number of database entries
Waarnemingen.be/observations.be	494,265	122,708
BDFGM (Rasmont P. & Haubruge E.)	255,100	127,779
DEMNA (Wallonia)	34,936	6,959
UFZ (Warncke)	6,393	6,393
RBINS	5,108	3,529
UGMD (Universiteit Gent)	1,057	1,058
UNamur	382	230
NMR (Netherlands)	298	298
Total	**797,539**	**268,954**

2.4 Assessment protocol

Bibliographic information linked to each bee species was compiled from the European assessments of bees (Nieto et al. 2014), Atlas Hymenoptera (Rasmont & Haubruge 2002) and key literature references (e.g. Rasmont et al. 1993; Scheuchl & Willner 2016; Rasmont et al. 2017a, b; Pauly 2019a).

It concerns:

- Taxonomic classification
- European Red List Categories and criteria
- Belgian distribution (i.e. map of each species)
- Habitat preferences and primary ecological requirements
- Location in main nature reserves
- Key literature references

Five workshops were held between September 2017 and Augustus 2018 to assess the status of species in the different families and genera. Following these, further email exchanges between experts helped to resolve questions and refine assessments.

Three functional traits were considered as possibly associated with extinction risk (see results). These are the host plant range, sociality and nesting behaviour (listed in Appendix 2).

First, the bee host plant range was split in three main categories following Müller & Kuhlmann in 2008: (i) **Specialised bees**, (ii) **Opportunistic bees with strong preference** (e.g. *Colletes hederae*, *Bombus confusus*) and (iii) **Opportunistic bees**. As the host plant preferences vary somewhat according to the author, we followed as far as possible a single reference (Scheuchl & Willner 2016). For the remaining species that were not included (*Andrena cinerea* and some *Lasioglossum* species) Falk (2015), Nieto et al. (2014) and Pauly (2019a) were consulted.

For the next two functional traits, information come from two databases: a database developed in the scope of the EU FP6 ALARM and EU FP7 STEP projects as well as a national database based on a wide search of European bee literature but also on researcher expertise (e.g. Westrich 1989; Moretti et al. 2009). Complement of information (see Richards 2011; Pauly 2019a) were needed for the sociality of *L. monstrificum* and *Seladonia leucahenea* for which data traits were not available.

The sociality was analysed and divided in three categories: (i) **solitary**, (ii) **primitively eusocial** (excluding the eusocial *Apis mellifera*) and (iii) **kleptoparasitic** (i.e. parasites of social and solitary species) bees.

Seven categories were used to define the nesting behaviour: (i) **Excavator - Ground**, (ii) **Excavator - Deadstems**, (iii) **Carder**, (iv) **Renter - Existing cavities above ground**, (v) **Renter - Existing cavities below ground**, (vi) **Renter - Snail shells** and (vii) **Mason**.

2.5 Importance of time scales and compared periods

The time scale proposed by the IUCN to assess a variation in population size is 10 years (or at least 3 generations). Instead, for this Red List of Belgian bees, two time periods were compared (i.e. 1900 – 1969 versus 1970 – 2017). This is because we were mainly interested in obtaining a risk assessment based on the major changes in the Belgian bee fauna that occurred during the last century. This period corresponds to the main land use changes that occurred in more recent times in Belgium (i.e. agricultural moto-mechanization and the spread of the use of chemical fertilizers between 1930 and 1970 (Mazoyer & Roudart 2006) and its increase in urbanized areas mainly since 1970-1980) and the onset of climate change (i.e. mainly since the 1970’s; IPCC 2013).

Given the absence of previous Red List versions, this work presents a baseline Red List with extinction risk assessments based on how bee species are impacted by these major land use changes as well as climate change. Next versions of the Red List may focus on risk assessments based on more recent trends. However, accurate trend calculation depends on the year-by-year generation of a sufficient number of high-quality records with large geographic coverage and/or the set-up of a monitoring network.

One aspect that has to be taken into account when comparing different time periods is the change in the number and behaviour patterns of observers through time. This leads to differences in (i) the sampling methods (e.g. sampling strategies with focus or not on hotspots and/or easily recognized species, sampling areas, sampling frequencies), (ii) the number of records (i.e. more recent data namely linked to the advent of citizen sciences) and (iii) the sampling aims (e.g. inventory of a special place, insect boxes of students, comparison with old data in a same place, research programs, looking into rare species for conservation purposes, …).

To take into account the difference in the number of records between both time periods we used the same sampling bias control as applied by Fichefet et al. (2008) for the Red List of butterflies in Wallonia. Differences in sampling method and aim were as much as possible taken into account during the species assessments. To do so, we only compared trends in areas (1*1 km UTM square) that were sampled at least once during both two time periods.

2.6 IUCN criteria: from continental (Europe) to country (Belgian) scale

Red Lists provide a classification of species according to their extinction risk in the geographic area under consideration. The IUCN Red List Categories and Criteria provide an explicit, objective framework for Red List assessments (IUCN 2012a, b), and are followed here. In national scale Red Lists, species are classified in eleven Categories based on a set of quantitative criteria which are linked to population size, structure, trends as well as geographic range (IUCN 2012a, b; Nieto et al. 2014) (Figure 4). Threatened species are classified in three Categories [i.e. Vulnerable (VU), Endangered (EN) and Critically Endangered (CR)]. A taxon is Near Threatened (NT) when it has been evaluated and does not qualify for the three before-mentioned categories but is close to qualifying for or is likely to qualify in the near future. Species that are not threatened fall in the category Least Concern (LC). Categories Regionally Extinct (RE) and Not Applicable (NA) are specifically applied for regional or national assessments (IUCN 2012b). Species that are Regionally Extinct are considered as no longer present in Belgium. Species that haven't been observed in Belgium since 1990, making it very unlikely that they are still present in the country (e.g. *B. distinguendus*), were in this way included in the RE category. As the criteria should only be applied to wild populations inside their natural range (IUCN 2012b), bee species that were only observed once with one individual were assigned to the category NA in beforehand. It is unclear for those species whether they ever had a population in Belgium. As soon as there were several individuals, observation dates or locations (5 x 5 km UTM squares) in the database, the species was considered as having had a wild population in Belgium. Given the relatively low search effort for bees, more stringent criteria such as the recommended 10 consecutive years of reproduction could not be applied.

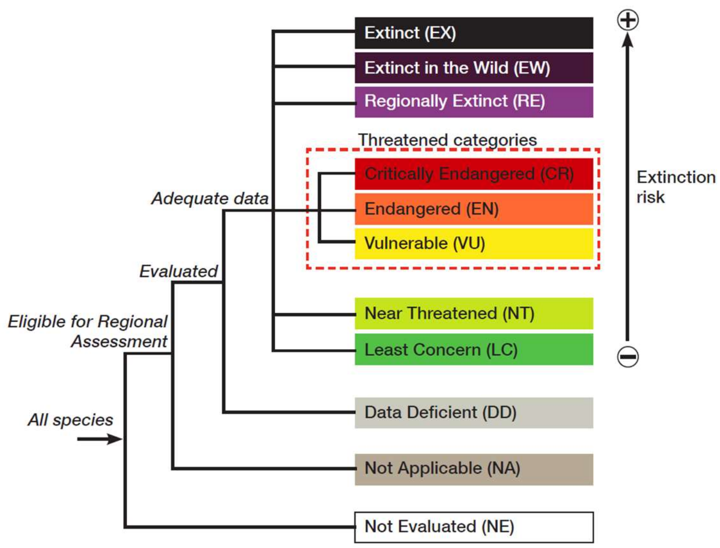


Figure 4. The IUCN Red List categories for assessments at regional scale.

As mentioned by the IUCN (2012b) and Gärdenfors et al. (2001), regional assessments should be undertaken by, firstly, applying the *IUCN Red List Category and Criteria* (IUCN 2012a) to the regional populations in order to provide a preliminary estimate of the extinction risk. This initial category is then adjusted following information about breeding and visiting populations (e.g. presence of bordering populations, conditions within the region). Based on this, the initial category of each species can be up/downgraded.

The applied methodology for this Belgian Red List of bees has previously been used for the Red List of butterflies in Wallonia (Belgium) by Fichefet et al*.* (2008). In order to assign a Category to each species, five criteria can be considered (IUCN 2012a):

A. Population size reduction
B. Geographic range
C. Small population size and decline
D. Very small or restricted population
E. Quantitative analysis of extinction risk

For this national assessment, only criteria A and B can be evaluated as appropriate data for the other categories are lacking.

Criterion A: Population size reduction between both periods (P1 et P2) based on A1 to A4

A1. Population reduction observed, estimated, inferred, or suspected in the past. This criterion supposes that all the decline causes are clearly reversible, understood and have ceased. In Belgium, these causes are multiple, not always understood and nearly always ongoing.

A2. Population reduction observed, estimated, inferred, or suspected in the past but this criterion supposes that these reduction causes may not have ceased or not be understood or not be reversible. It is most often used criterion for invertebrates (Table 3). Two indicator elements were specifically used to define A2:

A2b. An abundance index appropriate to the taxon.

A2c. Decline in area of occupancy (AOO), extent of occurrence (EOO) and/or habitat quality (HAB). The last one can't be derived from databases of species distribution but can be added following expert opinion.

A3. This criterion implies a population reduction projected, inferred or suspected in the future. This criterion is difficult to apply given a lack of studies predicting future species changes. The *Climatic Risk and Distribution Atlas of European Bumblebees* (Rasmont et al. 2015) could allow to take into account this criterion for bumblebee species at European scale but not at this national scale, given the fact that modelisations of this Atlas were made at 50 x 50 km UTM square (i.e. scale incompatibility).

A4. This criterion is based on an observed, estimated, inferred, projected or suspected population reduction in a time period including both the past and the future. It supposes that the reduction causes may not have ceased or not be understood or not be reversible. This criterion is difficult to apply for the same reason as the previous criterion.

Table 3. Summary of the criterion A with its decision rules for this Red List.

	Criterion A - Population size variation between both periods (P1 et P2)				
	POPULATION **1x1 km UTM squares**		**SURFACE** **5x5 km and 10 x10 km UTM squares**		**AREA** **10x10 km UTM squares**
Measure of decline	**Population number** (1x1 km squares) corrected for sampling bias in both periods	**OR**	**Area of occupancy** (5x5 km and 10x10 km squares) corrected for sampling bias in both periods	**OR**	**Extent of occurrence** by comparing P1/P2 and P1/All (without sampling control)
	A2b = CR<-80%<EN<-50% <VU<-30%<NT<-20%		**A2c_AOO**= CR<-80%<EN<-50% <VU<-30%<NT<-20%		**A2c_EOO**= CR<-80%<EN<-50% VU<-30%<NT<-20%

Based on the Table 3, 5 indicators allow us to assess the threat level. As settled by IUCN (2012a), the highest category resulting from each of the 5 indicators determines the global category for criterion A.

Criteron B: Geographic range based on B1 and/or B2 and its variation over time

Proposed IUCN threshold areas for B1 and B2 cannot be applied at the national scale given the very restricted geographic area. We decided to use adapted thresholds which characterise the national situation as faithfully as possible, as already done by Fichefet et al. (2008) (Table 4).

B1. Extent of occurrence (EOO) using 10x10 km UTM squares and changes between both periods.

B2. Area of occupancy (AOO) using 1x1 km and 5x5 km UTM squares and changes between both periods.

Both sub-criteria have to meet at least two of the three following conditions:

(a) Observation of population fragmentation. This sub-criterion is not used with the number of locations which is already equivalent to B2 (1x1km). For very restricted populations, the criterion C can be used. In the absence of fixed thresholds, a percentile logic was used to define the fragmentation (Table 3).

(b) Decline in (i) extent of occurrence, (ii) area of occupancy, (iii) area, extent and/or quality of habitat, (iv) number of locations or subpopulations, (v) number of mature individuals. While (iv) can be associated to (ii), the last sub-condition (v) can't be obtained from the database.

(c) Extreme fluctuations. This sub-criterion can't be obtained from the database. Nevertheless, it could be activated following an expert opinion.

Table 4. Summary of the criterion B with decision rules for this Red List.

<table>
<tr><td colspan="5">Criterion B - Population size reduced in P2</td></tr>
<tr><td>Reduced RANGE</td><td rowspan="6">AND</td><td>FRAGMENTATION</td><td rowspan="6">AND</td><td>DECLINE</td></tr>
<tr><td>Extent of occurrence (EOO) (10x10 km)
B1 = CR< 5, EN< 15, VU< 30, NT< 50 squares</td><td rowspan="3">Fragmentation index of the distribution area
Increase of the fragmentation of the distribution area
Fragmentation index of the occupied area
Increase of the fragmentation of the occupied area</td><td rowspan="4">Decline of the area of occupancy (1x1, 5x5, 10x10 km)
Decline in the number of observations (1x1, 5x5, 10x10 km)
Decline of the extent of occurrence (10x10 km)</td></tr>
<tr><td>OR</td></tr>
<tr><td>Reduced AREA</td></tr>
<tr><td rowspan="2">Area of occupancy (AOO) (1x1 and 5x5 km)
B2 = CR< 5, EN< 15, VU< 30, NT< 50 squares</td><td>Q1 (=*), P10 (=**) and P5 (=***)</td></tr>
<tr><td>(a) : at least one indicator < Q1</td><td>(b) : at least one indicator < -20%</td></tr>
</table>

Based on the Table 4, respectively 4 and 7 indicators allow us to assess the threat level with B1 and/or B2. As settled by IUCN (2012a), the highest threat category of the indicators determines the global category of criterion B. Both criteria analyses are processed and the more threatened status is taken on. The highest threat category for criteria A and B defines the final category of the bee species.

3. Results

3.1 Threat status

Consistently with the guidelines of IUCN (2016), we selected the mid-point figure to estimate the proportion of threatened species. This way, 32.8% of the species are considered threatened at the national scale (Table 5). Nevertheless, due to the 9.4% of species which are DD, this percentage is uncertain and could lie between 29.7% (if all the DD species are not threatened) and 39.1% (if all the DD species are threatened). Figure 5.A shows the proportion of each IUCN Red List Category for Belgian bees. In Belgium, 12.3% of bees were assessed as Critically Endangered (47 species), 8.4% are Endangered (32 species) and 8.9% as Vulnerable (34 species). A further 6.8% of bee species are considered Near Threatened (26 species). In addition, 11.8% (45 species) are regarded as Regionally Extinct (Table 6). Species classified as Regionally Extinct, threatened (Critically Endangered, Endangered and Vulnerable) or Near Threatened in Belgium represent 53.3% (184 species) by considering the mid-point value and are listed in Table 7.

In comparison, on the 360 bee species assessed in 1993, 25.2% were in regression (91 species), 40.2% were stable (145 species), 10.8% were in expansion (39 species), and 23.5% had an unknown status (85 species) in Belgium (Rasmont et al. 1993). At European scale 9.2% of bee species are considered threatened (Nieto et al. 2014; Fig. 5.B). This percentage is highly uncertain however, since no less than 57% of European bees are listed as DD (Fig. 5.B). As a result, the proportion of threatened species could potentially lie between 4% and 60.7% (Nieto et al. 2014; Table 5).

Table 5. Proportion of threatened species in Belgium according to the bound (i.e. lower, mid and upper bound).

	Belgium % threat	Europe % threat
Lower bound (CR+EN+VU) / (assessed – EX)	29.7%	4%
Mid-point (CR+EN+VU) / (assessed – EX – DD)	32.8%	9.2%
Upper bound (CR+EN+VU+DD) / (assessed – EX)	39.1%	60.7%

Table 6. Summary of number of bee species within each IUCN category.

IUCN Red List Categories	No. species Belgium	No. species Europe
Extinct (EX)	0	0
Extinct in the Wild (EW)	0	0
Regionally Extinct (RE)	45	0
Critically Endangered (CR)	47	7
Endangered (EN)	32	46
Vulnerable (VU)	34	24
Near Threatened (NT)	26	101
Least Concern (LC)	161	663
Data Deficient (DD)	36	1,101
Total number of species assessed	**381**	**1,942**

*This table does not include the Not Applicable species in Belgium (22).

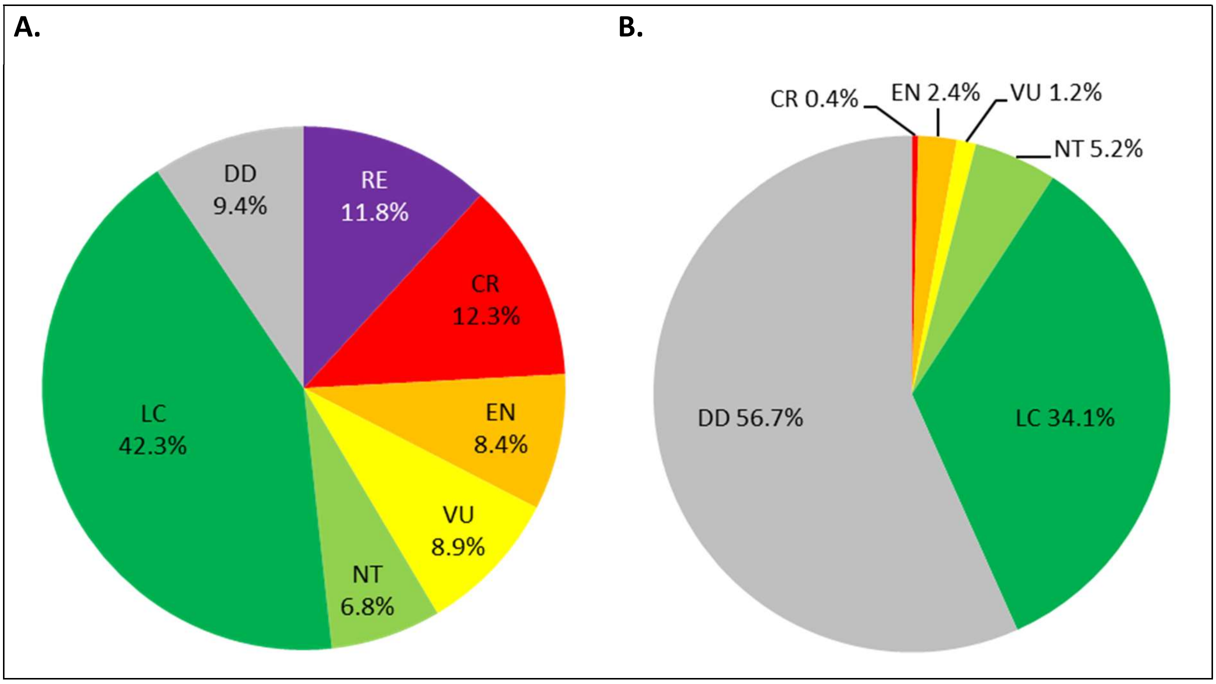


Figure 5. A. IUCN Red List status of bees in Belgium ; **B.** IUCN Red List status of bees in Europe (Nieto et al. 2014).

Osmia cornuta (Least Concern). Maxime Drossart

Table 7. Regionally Extinct and (near) threatened bee species at national scale (Belgium). As a comparison, status in the European Red List is also listed (Nieto et al. 2014).

Family	Species	Red List status	
		Belgium	Europe
Megachilidae	*Aglaoapis tridentata*	RE	LC
Andrenidae	*Andrena chrysopyga*	RE	DD
Andrenidae	*Andrena distinguenda*	RE	DD
Andrenidae	*Andrena floricola*	RE	DD
Andrenidae	*Andrena gelriae*	RE	DD
Andrenidae	*Andrena limata*	RE	DD
Andrenidae	*Andrena marginata*	RE	DD
Andrenidae	*Andrena thoracica*	RE	DD
Apidae	*Anthophora aestivalis*	RE	LC
Apidae	*Anthophora borealis*	RE	NT
Apidae	*Anthophora plagiata*	RE	LC
Apidae	*Biastes truncatus*	RE	VU
Apidae	*Bombus confusus*	RE	VU
Apidae	*Bombus cullumanus*	RE	CR
Apidae	*Bombus distinguendus*	RE	VU
Apidae	*Bombus pomorum*	RE	VU
Apidae	*Bombus subterraneus*	RE	LC
Apidae	*Bombus wurflenii*	RE	LC
Megachilidae	*Coelioxys emarginatus*	RE	LC (*C. emarginata)*
Melittidae	*Dasypoda argentata*	RE	NT
Halictidae	*Dufourea minuta*	RE	NT
Megachilidae	*Hoplitis papaveris*	RE	LC
Megachilidae	*Hoplitis villosa*	RE	LC
Colletidae	*Hylaeus pilosulus*	RE	DD
Halictidae	*Lasioglossum breviventre*	RE	EN
Halictidae	*Lasioglossum interruptum*	RE	LC
Halictidae	*Lasioglossum laeve*	RE	EN
Halictidae	*Lasioglossum lineare*	RE	DD
Halictidae	*Lasioglossum nigripes*	RE	LC
Halictidae	*Lasioglossum politum*	RE	LC
Halictidae	*Lasioglossum subfasciatum*	RE	EN
Halictidae	*Lasioglossum subhirtum*	RE	LC
Apidae	*Nomada argentata*	RE	NT
Apidae	*Nomada castellana*	RE	LC
Apidae	*Nomada emarginata*	RE	LC
Apidae	*Nomada melathoracica*	RE	LC
Apidae	*Nomada mutabilis*	RE	LC
Apidae	*Nomada pleurosticta*	RE	NT
Apidae	*Nomada rhenana*	RE	NT
Apidae	*Nomada roberjeotiana*	RE	NT
Megachilidae	*Osmia pilicornis*	RE	LC
Megachilidae	*Osmia xanthomelana*	RE	LC
Halictidae	*Rhophitoides canus*	RE	LC
Megachilidae	*Stelis minima*	RE	LC
Megachilidae	*Stelis minuta*	RE	LC

Family	Species	Red List status	
		Belgium	Europe
Apidae	*Ammobates punctatus*	CR	LC
Andrenidae	*Andrena combinata*	CR	DD
Andrenidae	*Andrena curvungula*	CR	DD
Andrenidae	*Andrena ferox*	CR	DD
Andrenidae	*Andrena nigriceps*	CR	DD
Andrenidae	*Andrena polita*	CR	LC
Andrenidae	*Andrena potentillae*	CR	DD
Andrenidae	*Andrena similis*	CR	DD
Andrenidae	*Andrena synadelpha*	CR	DD
Andrenidae	*Andrena varians*	CR	LC
Apidae	*Anthophora bimaculata*	CR	LC
Apidae	*Bombus barbutellus*	CR	LC
Apidae	*Bombus humilis*	CR	LC
Apidae	*Bombus muscorum*	CR	VU
Apidae	*Bombus ruderatus*	CR	LC
Apidae	*Bombus sylvarum*	CR	LC
Apidae	*Bombus veteranus*	CR	LC
Megachilidae	*Coelioxys afer*	CR	LC (*C. afra*)
Megachilidae	*Coelioxys conoideus*	CR	LC (*C. conoidea*)
Megachilidae	*Coelioxys quadridendatus*	CR	LC (*C. quadridentata*)
Halictidae	*Dufourea halictula*	CR	NT
Halictidae	*Dufourea inermis*	CR	NT
Apidae	*Epeolus tarsalis*	CR	NT
Halictidae	*Halictus eurygnathus*	CR	LC (*H. compressus*)
Halictidae	*Halictus quadricinctus*	CR	NT
Megachilidae	*Hoplitis anthocopoides*	CR	LC
Megachilidae	*Hoplitis ravouxi*	CR	LC
Colletidae	*Hylaeus leptocephalus*	CR	LC
Halictidae	*Lasioglossum costulatum*	CR	NT
Halictidae	*Lasioglossum quadrinotatum*	CR	NT
Halictidae	*Lasioglossum tarsatum*	CR	NT
Megachilidae	*Megachile analis*	CR	DD
Megachilidae	*Megachile genalis*	CR	DD
Megachilidae	*Megachile lagopoda*	CR	LC
Megachilidae	*Megachile maritima*	CR	DD
Megachilidae	*Megachile pilidens*	CR	LC
Apidae	*Melecta luctuosa*	CR	LC
Apidae	*Nomada mutica*	CR	NT
Apidae	*Nomada obtusifrons*	CR	NT
Apidae	*Nomada piccioliana*	CR	LC
Apidae	*Nomada sexfasciata*	CR	LC
Megachilidae	*Osmia andrenoides*	CR	LC
Halictidae	*Rophites quinquespinosus*	CR	NT
Halictidae	*Seladonia leucahenea*	CR	VU (*H. leucaheneus*)
Halictidae	*Sphecodes rubicundus*	CR	NT
Halictidae	*Sphecodes rufiventris*	CR	LC
Halictidae	*Sphecodes spinulosus*	CR	NT

Family	Species	Red List status	
		Belgium	Europe
Andrenidae	*Andrena agilissima*	EN	DD
Andrenidae	*Andrena coitana*	EN	DD
Andrenidae	*Andrena fulvida*	EN	NT
Andrenidae	*Andrena intermedia*	EN	LC
Andrenidae	*Andrena schencki*	EN	DD
Andrenidae	*Andrena tarsata*	EN	DD
Apidae	*Anthophora retusa*	EN	LC
Apidae	*Bombus cryptarum*	EN	LC
Apidae	*Bombus magnus*	EN	LC
Apidae	*Bombus ruderarius*	EN	LC
Apidae	*Bombus rupestris*	EN	LC
Halictidae	*Dufourea dentiventris*	EN	NT
Apidae	*Eucera nigrescens*	EN	LC
Halictidae	*Halictus simplex*	EN	LC
Colletidae	*Hylaeus angustatus*	EN	LC
Colletidae	*Hylaeus nigritus*	EN	LC
Halictidae	*Lasioglossum brevicorne*	EN	NT
Halictidae	*Lasioglossum prasinum*	EN	NT
Halictidae	*Lasioglossum xanthopus*	EN	NT
Megachilidae	*Megachile circumcincta*	EN	LC
Apidae	*Nomada armata*	EN	NT
Apidae	*Nomada distinguenda*	EN	LC
Apidae	*Nomada furva*	EN	DD
Apidae	*Nomada fuscicornis*	EN	LC
Apidae	*Nomada opaca*	EN	NT
Apidae	*Nomada similis*	EN	LC
Apidae	*Nomada villosa*	EN	NT
Megachilidae	*Osmia parietina*	EN	LC
Megachilidae	*Osmia rufohirta*	EN	LC
Megachilidae	*Osmia uncinata*	EN	LC
Halictidae	*Sphecodes scabricollis*	EN	DD
Apidae	*Thyreus orbatus*	EN	LC
Andrenidae	*Andrena fucata*	VU	DD
Andrenidae	*Andrena helvola*	VU	DD
Andrenidae	*Andrena lapponica*	VU	LC
Andrenidae	*Andrena nitidiuscula*	VU	LC
Andrenidae	*Andrena pandellei*	VU	LC
Apidae	*Bombus campestris*	VU	LC
Apidae	*Bombus jonellus*	VU	LC
Apidae	*Bombus norvegicus*	VU	LC
Apidae	*Bombus soroeensis*	VU	LC
Megachilidae	*Chelostoma distinctum*	VU	LC
Megachilidae	*Coelioxys alatus*	VU	LC (*C. alata*)
Megachilidae	*Coelioxys elongatus*	VU	LC (*C. elongata*)
Megachilidae	*Coelioxys mandibularis*	VU	LC
Apidae	*Eucera longicornis*	VU	LC
Halictidae	*Halictus maculatus*	VU	LC

Family	Species	Red List status	
		Belgium	Europe
Halictidae	*Halictus sexcinctus*	VU	LC
Megachilidae	*Hoplitis claviventris*	VU	LC
Colletidae	*Hylaeus rinki*	VU	LC
Halictidae	*Lasioglossum laevigatum*	VU	NT
Halictidae	*Lasioglossum minutulum*	VU	NT
Halictidae	*Lasioglossum monstrificum*	VU	NT (*L. sabulosum*)
Halictidae	*Lasioglossum pygmaeum*	VU	NT
Halictidae	*Lasioglossum quadrinotatulum*	VU	NT
Megachilidae	*Megachile alpicola*	VU	DD
Megachilidae	*Megachile leachella*	VU	LC
Mellitidae	*Melitta tricincta*	VU	NT
Apidae	*Nomada femoralis*	VU	LC
Apidae	*Nomada integra*	VU	LC
Apidae	*Nomada striata*	VU	LC
Halictidae	*Seladonia confusa*	VU	LC (*H. confusus*)
Halictidae	*Sphecodes marginatus*	VU	LC
Halictidae	*Sphecodes niger*	VU	LC
Megachilidae	*Stelis ornatula*	VU	LC
Megachilidae	*Stelis signata*	VU	LC
Andrenidae	*Andrena angustior*	NT	DD
Andrenidae	*Andrena argentata*	NT	DD
Andrenidae	*Andrena bimaculata*	NT	DD
Andrenidae	*Andrena denticulata*	NT	DD
Andrenidae	*Andrena fulvago*	NT	DD
Andrenidae	*Andrena hattorfiana*	NT	NT
Andrenidae	*Andrena labialis*	NT	DD
Andrenidae	*Andrena lathyri*	NT	DD
Andrenidae	*Andrena ovatula*	NT	NT
Andrenidae	*Andrena ruficrus*	NT	LC
Andrenidae	*Andrena wilkella*	NT	DD
Apidae	*Bombus bohemicus*	NT	LC
Apidae	*Bombus hortorum*	NT	LC
Apidae	*Bombus lucorum*	NT	LC
Apidae	*Bombus vestalis*	NT	LC
Megachilidae	*Coelioxys rufescens*	NT	LC
Apidae	*Epeolus cruciger*	NT	NT
Colletidae	*Hylaeus variegatus*	NT	LC
Halictidae	*Lasioglossum albipes*	NT	LC
Halictidae	*Lasioglossum leucopus*	NT	LC
Halictidae	*Lasioglossum rufitarse*	NT	LC
Apidae	*Melecta albifrons*	NT	LC
Apidae	*Nomada rufipes*	NT	LC
Megachilidae	*Osmia aurulenta*	NT	LC
Megachilidae	*Osmia spinulosa*	NT	LC
Megachilidae	*Stelis phaeoptera*	NT	DD

3.2 Status by taxonomic group

As described in the introduction, Belgian bees belong to different families (6) and subfamilies (12). Table 8 presents the number and percentage of species in the Red List for each of these groups. This shows that the Apidae, Megachilidae and Halictidae have a relatively high proportion of threatened species (36.7%, 36.4% and 35.9% respectively), while the Melittidae have the lowest proportion (12.5%). The Near Threatened (NT) status is mainly assigned to Andrenidae (11 species, 12.6%) and Apidae (7 species, 7%). It refers to species that are clearly declining in Belgium but not enough to meet the IUCN Red List criteria. Also, the highest proportion of Regionally Extinct species is found in the Apidae (18 species, 18%), Halictidae (10 species, 12%) and Megachilidae (8 species, 11.7%). This highlights that these are the most impacted families during the last decades and during the two time periods. It is striking that both families of long-tongued species (i.e. Apidae, Megachilidae) are among the families with the highest proportion of threatened bees (60 species, 36.6%). Moreoever, long-tongued bees are better known than short-tongued species which include less studied groups such as *Micrandrena*, *Lasioglossum* and *Hylaeus* (see 3.6 Knowledge gaps).

Regarding the sub-families, several present no threatened species (i.e. Panurginae, Xylocopinae, Colletinae, Dasypodainae) but these families contain a limited number of species and one of the two Dasypodainae species is Regionally Extinct. Some of these species forage on common yellow-flowered composites (Panurginae, Dasypodainae, some Colletinae), are unspecialised foragers (some Colletinae) and/or seem to benefit from climate change (Xylocopinae, *Colletes hederae*). Indeed, it appears that some species like *Xylocopa violacea* have expanded their distribution northward during the last decades, possibly due to climate change (Terzo & Rasmont 2014). It is likely that the increase of suburban gardens and of dead wood may also contribute to this increase.

Other sub-families contain a significant proportion of threatened species. From highest to lowest: corbiculate Apinae (pollen basket bees – *Bombus* sp. and *Apis mellifera*; 46.7% - see Box 3 and 4), not-corbiculate Apinae (without pollen baskets; 41.2%), Megachilinae (36.4%), Halictinae (33.3%), Nomadinae (30.6%), Andreninae (29.9%), Hylaeinae (23.5%), Melittinae (16.7%). Differences between these subfamilies can be explained by differences in ecological requirements ((micro)climate, host plant range, nesting requirements, sociality), resulting in different susceptibilities to land use and climate change (see point 3.4).

The Andreninae have the highest number species (17 species) belonging to the category Data Deficient followed by the Hylaeinae (10). Several reasons can be put forward to explain this high number in these two groups: taxonomic issues and confusions (e.g. in the subgenus *Micrandrena* from Andrenidae) resulting in poor knowledge, the difficulty to sample some groups/species (e.g. *Hylaeus clypearis, H. gracilicornis*) or the lack of expertise.

Table 8. Red List status at Belgian level of bees by family and subfamily (as defined by Michener et al. (2007)). Percentage of threatened species were calculated based on the mid-point figures (i.e. (CR+EN+VU) / (assessed – EX – DD) in which the Extinct (EX) status is not equivalent to the Regionally Extinct (RE) status).

Order	Family	Subfamily	Total	RE	CR	EN	VU	NT	LC	DD	% threatened	NA
Hymenoptera	**Andrenidae**		**87**	**7**	**9**	**6**	**5**	**11**	**32**	**17**	**28.6%**	**6**
		Andreninae	84	7	9	6	5	11	29	17	**29.9%**	6
		Panurginae	3	0	0	0	0	0	3	0	**0.0%**	0
	Apidae		**100**	**18**	**14**	**14**	**8**	**7**	**37**	**2**	**36.7%**	**1**
		Apinae (corbiculate)	31	6	6	4	4	4	6	1	**46.7%**	0
		Apinae (not corbiculate)	17	3	3	3	1	2	5	0	**41.2%**	0
		Nomadinae	50	9	5	7	3	1	24	1	**30.6%**	0
		Xylocopinae	2	0	0	0	0	0	2	0	**0.0%**	1
	Colletidae		**35**	**1**	**1**	**2**	**1**	**1**	**19**	**10**	**16.0%**	**3**
		Colletinae	8	0	0	0	0	0	8	0	**0.0%**	1
		Hylaeniae	27	1	1	2	1	1	11	10	**23.5%**	2
	Halictidae		**83**	**10**	**12**	**6**	**10**	**3**	**37**	**5**	**35.9%**	**3**
		Rhophitinae	6	2	3	1	0	0	0	0	**66.7%**	0
		Halictinae	77	8	9	5	10	3	37	5	**33.3%**	3
	Megachilidae		**68**	**8**	**11**	**4**	**9**	**4**	**30**	**2**	**36.4%**	**8**
		Megachilinae	68	8	11	4	9	4	30	2	**36.4%**	8
	Melittidae		**8**	**1**	**0**	**0**	**1**	**0**	**6**	**0**	**12.5%**	**1**
		Dasypodainae	2	1	0	0	0	0	1	0	**0.0%**	0
		Melittinae	6	0	0	0	1	0	5	0	**16.7%**	1
		Total	**381**	**45**	**47**	**32**	**34**	**26**	**161**	**36**	**32.8%**	**22**

Anthidium manicatum (Least Concern). Maxime Drossart

Box 3 – Belgian bumblebees (*Bombus* spp.)

Bumblebees are the best known group of wild bees in Belgium as well as in Europe (Rasmont 1988; Nieto et al. 2014; Vray et al. 2019). The Belgian bumblebee fauna has been studied for more than 100 years, starting with Meunier (1888) and particularly Ball (1914, 1920) who carried out an extensive bumblebee inventory work mainly between 1910 and 1930. After that, a detailed evaluation of species trends was produced by Rasmont & Mersch (1988), completed later by Rasmont et al. (1993; 2005) and by Vray (2018). As observed in Balls' collection (1914, 1920), 31 species of bumblebees occurred in the 1910s in Belgium but a continuing decline took place during the 20th century (i.e. between 1930 and 1970) as mentioned by Rasmont & Mersch (1998) and Rasmont et al. (1993, 2005). Several species like *B. ruderarius, B. magnus* and *B. hortorum* have shown a more recent regression (i.e. since 1990), while the list of Regionally Extinct species keeps extending (*B. confusus*, *B. cullumanus*, *B. distinguendus*, *B. pomorum, B. subterraneus, B. wurflenii*; Fig. 6.A) (Rasmont & Pauly 2010). Other species that were formerly widespread are now on the brink of extinction (e.g. *B. ruderatus*, *B. muscorum*) or geographically restricted to the (southern) Ardennes (*B. veteranus*, *B. humilis*, *B. sylvarum*), in one case including the coastal area (*B. ruderarius*). In comparison with the IUCN Red List status of *Bombus* spp. in Europe (Fig. 6.B), a higher proportion of species is threatened in Belgium (respectively 23.6% and 47%). Moreover, 13.3% are Near Threatened and 20% are Regionally Extinct. Given the large amount of available data, no species was classified as Data Deficient.

Several factors that negatively impact Belgian populations of bumblebees have been identified. Among these, habitat loss and fragmentation as well as the strong reduction of floral resources in relation with changes in agricultural practices (i.e. agricultural motorisation and mechanisation, regression of leguminous crops following the advent of chemical nitrogenous fertilizers, and pesticides) and other land use changes (e.g. increase of forest areas, urbanisation) have been pinpointed as the main drivers of bumblebee decline (Rasmont 1988; Rasmont & Mersch 1988, Goulson et al. 2005; Goulson et al. 2008; Rasmont et al. 2005; Ahrne et al. 2009; Vray 2018; Vray et al. 2019). This is exemplified by the fact that especially the late-flying bumblebee species with long tongues which are specialized on leguminous and other flowers with long corolla have disappeared or are threatened (Goulson et al. 2005). In addition, more and more studies point out the use of pesticides and climate change as additional threatening factors (e.g. Thompson 2001; Blacquiere et al. 2012; Rasmont & Iserbyt 2012; Kerr et al. 2015; Rasmont et al. 2015). Lastly, regulations against thistles in Belgium (i.e. legal requirement to remove *Carduus crispus*, *Cirsium arvense*, *C. palustre* and *C. vulgare*) seem to constitute a threat for several bumblebee species that mainly forage on these flowers for nectar (mainly *Cirsium* spp. and *Carduus* spp.) (Terzo & Rasmont 2007; Vray et al. 2017).

Box 3 – Belgian bumblebees (*Bombus* spp.)

In spite of this strong decline, some species seem to benefit (at least for now) from climate change (e.g. *B. pascuorum, B. terrestris*), from the increase of forest area (*B. hypnorum, B. sylvestris* and *B. pratorum*) (Rasmont & Mersch 1988, Rasmont & Pauly 2010; Rasmont et al. 2015; Zambra 2017) or are ubiquitous and are able to balance their diet because they forage a wide range of food plants (*B. lapidarius, B. terrestris*), including flowers in gardens. They were then assessed as Least Concern.

As highlighted by Powney et al. (2019) in Great Britain, some bumblebees seem to benefit from the widespread implementation of agri-environmental schemes designed to support them in agricultural areas. Indeed, their occupancy in these areas increased by 12% between 1980 and 2013 (Powney et al. 2019). Also in Belgium (Wallonia), *B. hortorum* (NT) locally benefits from such measures (Terzo & Rasmont 2007).

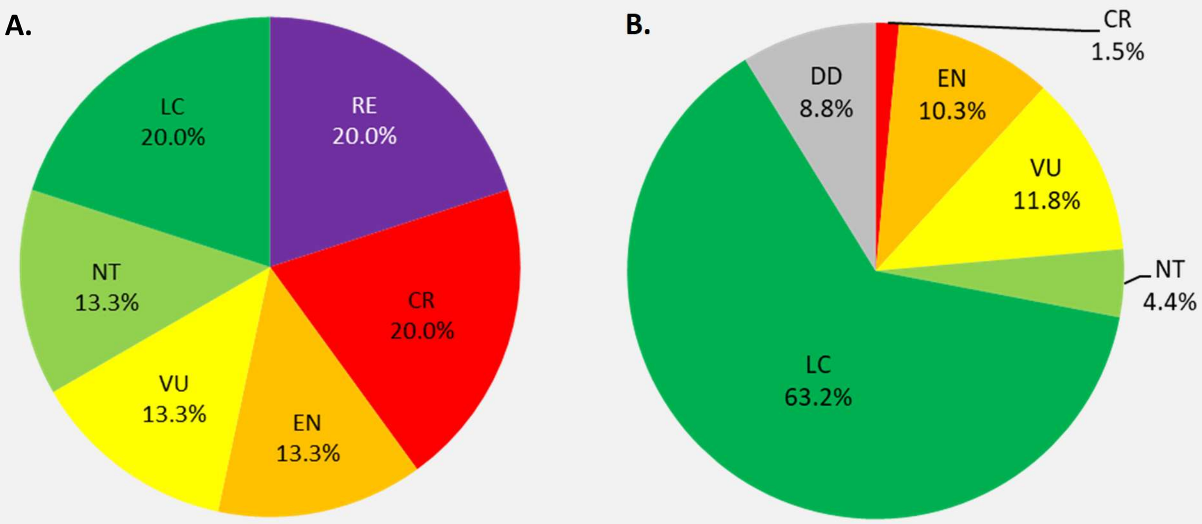


Figure 6. A. IUCN Red List status of *Bombus* spp. in Belgium; **B.** IUCN Red List status of *Bombus* spp. in Europe (Nieto et al. 2014).

Bombus sylvarum (Critically Endangered). Nicolas J. Vereecken

Box 4 – The Honey Bee (*Apis mellifera*)

The Honey Bee (*Apis mellifera*) is assessed as Data Deficient (DD) on the Belgian Red List. As mentioned by Nieto et al. (2014), this species is known to occur all over Europe (except in Faeroe Islands and Northern Scandinavia) and has numerous described sub-species across the continent. The sub-species *A. mellifera mellifera*, called the Dark European Honey Bee, originally occurred in Belgium. However, bee keepers have imported and kept other sub-species during the last 150 years, such as the Carniolian Honey Bee *A. mellifera carnica* (mainly in Flanders and along the German-border), *A. mellifera ligustica*, *A. mellifera caucasica* and *A. mellifera sahariensis* (the breeding of the last three has not been maintained) as well as the multi-hybridised Buckfast honey bee (mainly in Wallonia) coming from Devon in Great-Britain. A conservatory of the Dark European Honey Bee has been established in 2004 in Chimay.

Nowadays, the majority of beehives in Belgium are occupied by the Dark European Honey Bee, the Carniolian Honey Bee and by more or less hybridised Buckfast Honey Bees. The remaining part of "local" honey bees is then likely multi-hybridised. Some colonies are also found in the wild (mostly in holes in trees or buildings) and can either come from managed colonies (i.e. swarms) or could have recovered or conserved a feral nature. However, the wild occurrence of *Apis mellifera* in Europe is debated (Nieto et al. 2014; Moritz et al. 2007) and researches are needed to improve knowledge on genetic diversity and wild population densities of *Apis mellifera* in Belgium. Indeed, the applied selection undertaken over the last century on managed honey bee populations for particular traits (e.g. more productive, less aggressive, showing some health features, …) indicates that this species cannot be considered as natural (Nieto et al. 2014).

Apis mellifera (Data Deficient). Nicolas J. Vereecken

Box 4 – The Honey Bee (*Apis mellifera*)

While numerous studies (e.g. Van der Zee et al. 2013 and Brodschneider et al. 2018 in the scope of the COLOSS monitoring) highlighted a rise in the overwintering colony mortality, the number of hives globally increased in Europe (i.e. +5.5% between 2017 and 2018, European Commission 2019). At the national scale, the Honeybee valley platform (https://www.honeybeevalley.eu) gathered data on colony losses during the last winters (2016-17 and 2017-18) and showed contrasting situations according to the municipality. As well, the number of inventoried hives in Belgium is clearly in decline since 2010 (from 110.000 in 2010 to 60.000 in 2018) (CARI 2017; European Commission 2019).
Several drivers can be highlighted, such as the transfer of diseases, pathogens (e.g. *Nosema* spp.) and parasites (e.g. *Varroa destructor*), the floral depletion and the use of pesticides linked to the agricultural intensification, climate change, detrimental bee-keeping practices (e.g. De la Rúa et al. 2009; Blacquiere et al. 2012; Fürst et al. 2014) but also a parallel decline in the number of beekeepers across Europe (Moritz et al. 2007; Potts et al. 2010a; European Commission 2019). Finally, the arrival of the Asian hornet *Vespa velutina* could constitute a new enemy for *Apis mellifera* (Rortais et al. 2010).

3.3 Status by functional trait

Three functional traits are considered as possibly being associated with extinction risk: bee host plant range (i.e. specialised, opportunistic with strong preference and opportunistic *sensu lato*), sociality (i.e. solitary, primitively eusocial and kleptoparasitic) and nesting behaviour (i.e. Excavator - Ground, Excavator - Deadstems, Carder, Renter - Existing cavities above ground, Renter - Existing cavities below ground, Renter - Snail shells and Mason).

Bee host plant range

Using the mid-point calculation, 31.6% of opportunistic *s.l.* species and 31.2% of specialised bees are considered threatened (i.e. (CR+EN+VU)/(assessed – EX – DD)). Figure 7 shows the percentage of opportunistic (A) and specialised (B) bee species in each IUCN Red List Category. Regarding Belgian opportunistic bees (n= 173), 12.1% are Critically Endangered, 7.5% are Endangered and 8.7% are Vulnerable. A further 6.4% of bee species are Near Threatened. In addition, 10.4% are already Regionally Extinct at this national scale (Fig 7.A). Considering the specialised bees (n=82), 13.4% are Critically Endangered bees, 8.5% are Endangered and 7.3% are Vulnerable. A further 9.8% of bee species are Near Threatened. In addition, 9.8% are already Regionally Extinct at this national scale (Fig 7.B). Between these both main categories, opportunistic bees with strong preference (n=10) include 7 threatened or already extinct species (i.e. 3 RE, 1 CR, 2 EN, 1 VU; Appendix 2). In addition to bees assessed as Not Applicable in these three previous categories (i.e. 22 species), 12 species were not considered in this analyse given the lack of knowledge concerning their host plant range.

Taken together, this shows there is no major difference between opportunistic and specialised bees in threat status in Belgium.

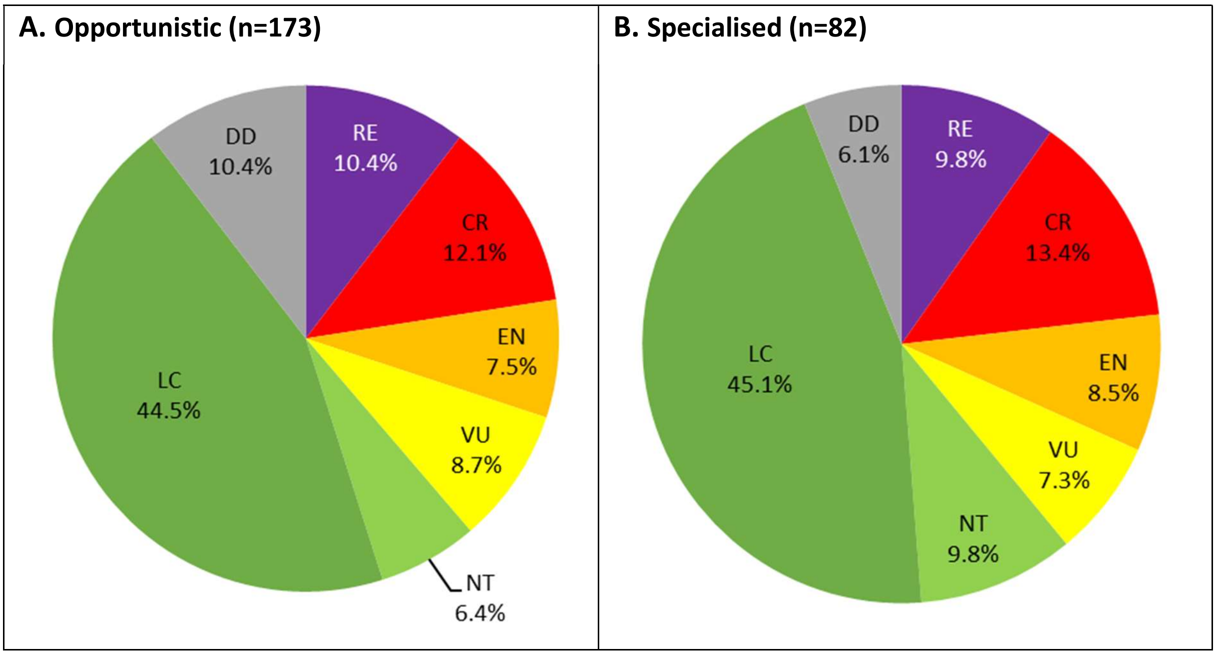
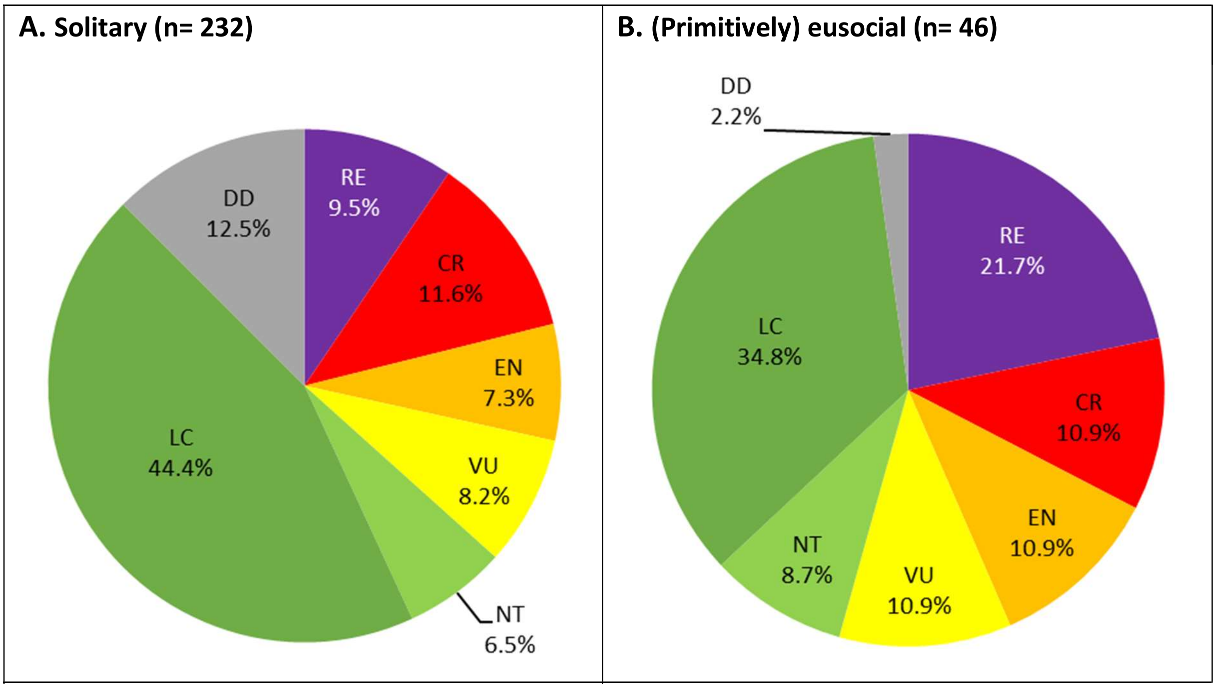


Figure 7. IUCN Red List status of bees in Belgium according to the main host plant ranges: opportunistic (A) and specialised (B). This figure does not include the Not Applicable (A. 11 species; B. 5 species) as well as kleptoparasitic species.

Sociality

In addition to bees assessed as Not Applicable in these three previous categories (i.e. 22 species), 2 species were not considered in this analyse given the lack of knowledge concerning their sociality (i.e. *Halictus eurygnathus*, *Seladonia submediterranea*). *Apis mellifera* were also not been included in this analysis given its high degree of eusociality. As some bee species can be solitary or primitively eusocial according to the environmental context, they were then considered in both groups (i.e. *Halictus rubicundus*, *H. sexcinctus*, *Seladonia confusa* and *S. tumulorum*).

Overall, 31% of solitary species, 33.3% of primitively eusocial species and 36% of kleptoparasitic bees are considered threatened in Belgium. Figure 8 shows the percentage of solitary (A), primitively eusocial (B) and kleptoparasitic species (C) in each IUCN Red List Category. Regarding Belgian solitary bees (n=232), 11.6% are Critically Endangered, 7.3% are Endangered and 8.2% are Vulnerable. A further 6.5% of bee species are Near Threatened. In addition, 9.5% are already Regionally Extinct at national scale (Fig 8.A). Considering social bees (n=46), 10.9% are Critically Endangered, 10.9% are Endangered and 10.9% are Vulnerable. A further 8.7% of bee species are Near Threatened. In addition, 21.7% are already Regionally Extinct at national scale (Fig 8.B). Lastly for the kleptoparasitic bees (n=104), 13.5% are Critically Endangered, 9.6% are Endangered and 11.5% are Vulnerable. A further 6.7% of these bee species are Near Threatened. In addition, 12.5% are already Regionally Extinct at national scale (Fig 8.C).



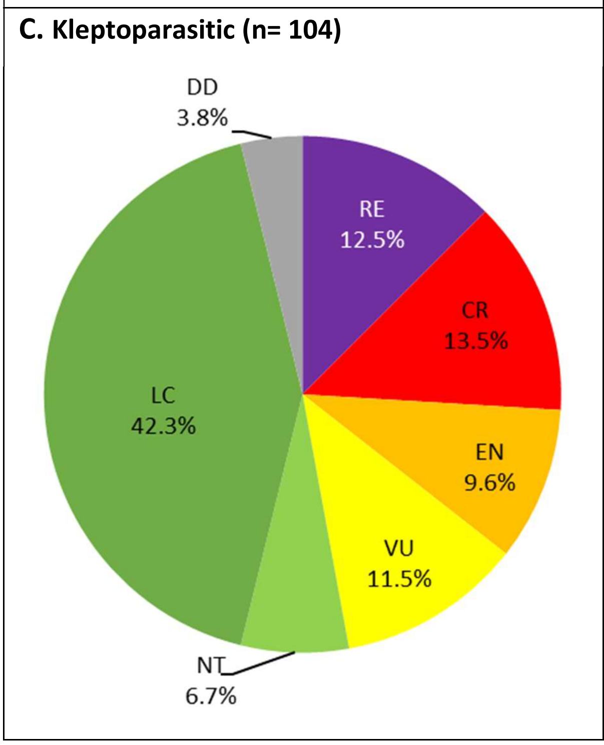


Figure 8. IUCN Red List status of bees in Belgium according to their sociality: solitary species (A), primitively eusocial species (B) and kleptoparasitic species (including solitary and social parasites) (C). This figure does not include the Not Applicable species (A. 18 species; B. 4 species; C. 1 species).

The group of primitively eusocial bees gathers the highest proportion of compiled threatened bees and extinct species (Fig 8.B) among which especially bumblebees seem highly threatened (see Box 3; Fig 6A). Indeed, 46.6% of species this group are threatened, 13.3% assessed as Near Threatened and 20% already extinct (Regionaly Extinct). Kleptoparasitic bees gather a reduced proportion of Data Deficient species (i.e. 3.8%; Fig 8.C) compared to solitary species (i.e. 12.5%; Fig 8.A). It gives us a more accurate estimation of the cuckoo bees decline which seems to be related to the decline of their hosts.

Nesting behaviour

In addition to the bees assessed as Not Applicable for the Red List (i.e. 22 species), 2 species were not considered in this analyse given the lack of knowledge concerning their nesting behaviour (i.e. *Bombus cullumanus*, *Seladonia submediterranea*). In total, 32.5% of ground-nesting bees (i.e. Excavator – Ground) and 23.6% of species nesting in existing cavities above ground (i.e. Renter - Existing cavities above ground) are considered threatened in Belgium. Other minor specific nesting behaviours gathering less species show variable proportion of threatened species: 33.3% of species nesting existing in cavities below ground (i.e. Renter - Existing cavities below ground), 83.3% of carder bees and 40% of species nesting in snail shells are considered threatened.

Figure 9 shows the percentage of bees in each IUCN Red List Category in relation with the two main nesting behaviours: Excavator - Ground (A) and Renter - Existing cavities above ground (B). For ground nesting bees (n=185), 12.4% are Critically Endangered, 7.6% are Endangered and 9.2% are Vulnerable. A further 7.6% of bee species are Near Threatened. In addition, 12.4% are already Regionally Extinct at national scale (Fig 9.A). Considering bees nesting in existing cavities above ground (n=67), 4.5% are Critically Endangered, 9% are Endangered and 6% are Vulnerable. A further 3% of bee species are Near Threatened. In addition, 7.5% are already Regionally Extinct at national scale (Fig 9.B). As for minor very specific nesting behaviours, they exhibit a large proportion of (near) threatened or extinct species: bees nesting in existing cavities below ground (n=9 of which 3 RE, 2 CR, 1 VU, 1 NT), carder bees (n=6 of which 4 CR, 1 EN), bees nesting in snail shells (n=5 of which 1 CR, 1 EN, 2 NT). These minor specific nesting behaviours represent 23 species among which 20 are already extinct, threatened or near threatened.

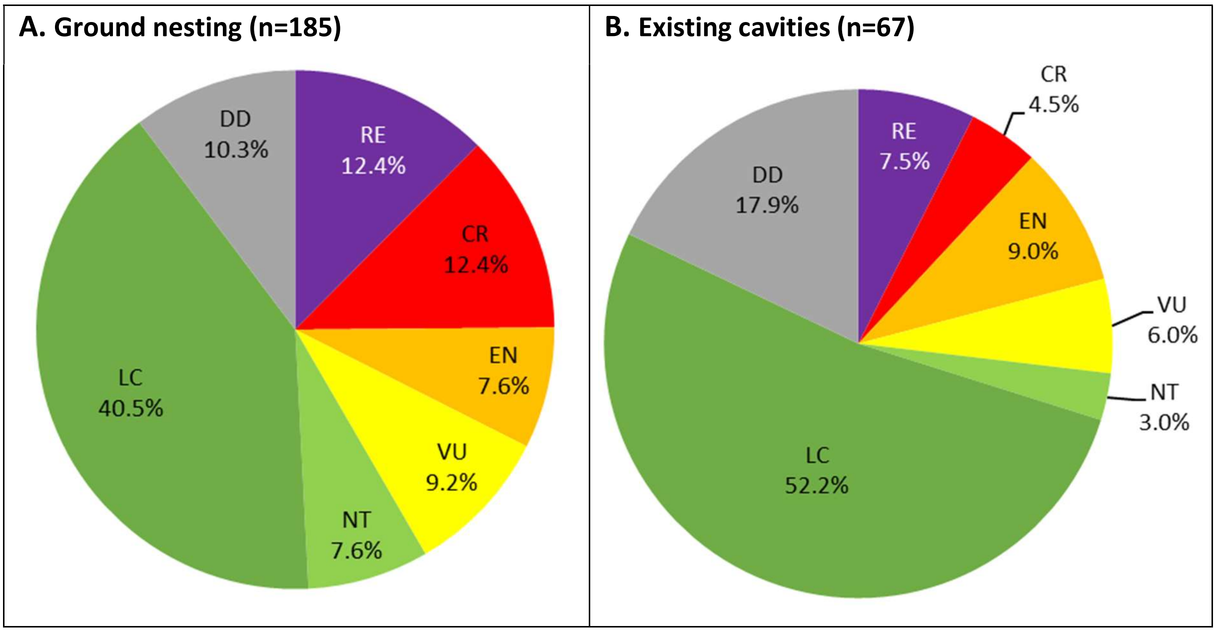


Figure 9. IUCN Red List status of bees in Belgium according to the two main nesting behaviours: in ground (A) and in existing cavities above ground (B). This figure does not include the Not Applicable species (A. 12 species; B. 8 species) as well as kleptoparasitic species.

It has to be noted that bees nesting in cavities above ground seem to be less well-known and have the highest proportion of Data Deficient species (i.e. 17.9%; Fig 9.B).

3.4 Spatial distribution of species

Species richness

The geographic distribution of bee species richness in Belgium is shown in Figure 10 and is based on all 403 bee species observed between 1980 and 2016 (i.e. comprising Regionally Extinct as well as Not Applicable species). Several main hotspots, based on cumulated species richness, can be delimited on this map. Firstly, southern Belgium, and particularly the Condroz to the south of Liège and the limestone regions of Fagne-Famenne-Calestienne and Gaume (i.e. south of the Lorraine region). Secondly, Brussels-Capital area (i.e. partly due to the long tradition of survey and the large sampling during the last years, Figure 2) as well as Hageland and Droog Haspengouw (i.e. astride between Flemish Brabant and Limburg). Thirdly the sandy Flanders close to Gent, and finally the eastern Campine around Maasmechelen. Other local areas with relatively high species richness are associated with particular habitats such as calcareous grasslands and heathlands (i.e. in the Campine, Southern sandy-silty Flanders and Eastern canton). Also, Belgian hotspots of bee diversity or of rare bees mentioned by Pauly (2019a) (i.e. Mount Saint Pieter; calcareous grasslands of Han-sur-Lesse and Treignes; the natural reserve of Torgny, western and eastern polders and the sandy heathlands of Kalmthout and Blaton) are included in these high-diversity areas. Globally, in Belgium, bee richness declines gradually towards the northwest and at the highest altitudes in the Ardennes.

As mentioned above, some regions benefited from larger samples (Figure 2), which induces a sampling bias. Indeed, several species-rich regions (e.g. Limburg) have relatively few observations compared to others (e.g. large areas such as Brussels and the Flemish Brabant or small localities such as Blaton, Mount Saint Pieter, La Calamine, De Panne, Het Zwin). Also, several areas which are less sampled (e.g. Ardenne, West Flanders) have the lowest known species richness (Figure 2, 10).

Halictus quadricinctus (Critically Endangered). Kurt Geeraerts

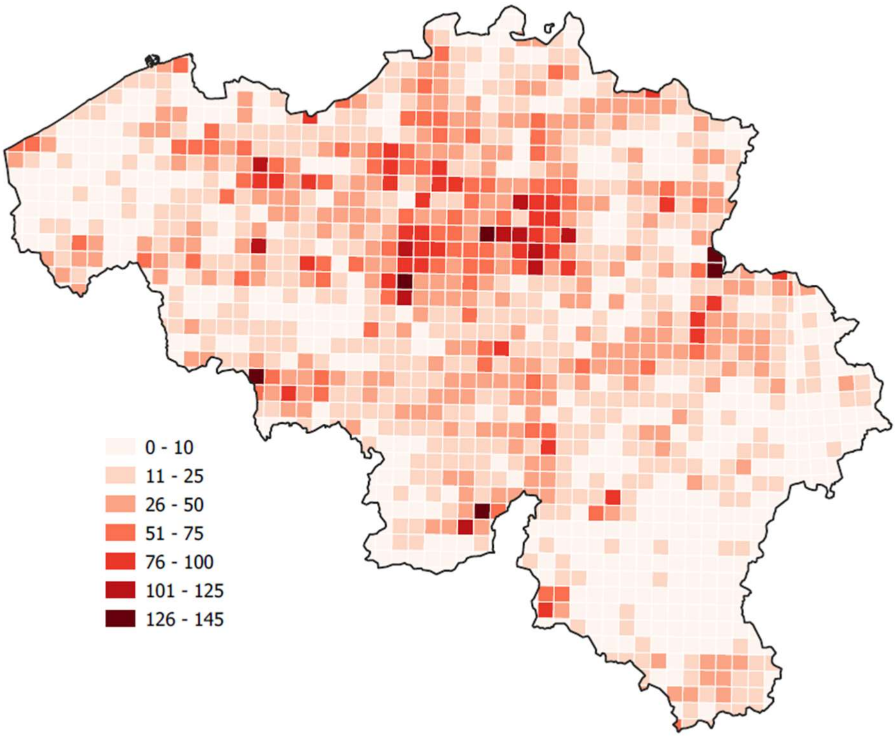


Figure 10. Species richness of Belgian bees (considering data from 1980 to 2016; 5 * 5 kilometre UTM squares). Species richness categories are arbitrary and were design to stand-out the most species-rich squares.

While a number of Belgian bee species occur all over the country (e.g. *Bombus pascuorum*, *Andrena fulva*), others display a limited geographic distribution associated with the distribution of particular habitats and host plants (Fig 11). Examples are *Colletes halophilus* which is restricted to coastal areas where it nests in sandy areas and forages on *Aster tripolium* growing in nearby salt marshes. *Rophites quinquespinosus* is currently restricted to calcareous grasslands in nature reserves in the Fagne-Famenne-Calestienne where it forages on Lamiaceae (Fig 11) (Pauly 2019a).

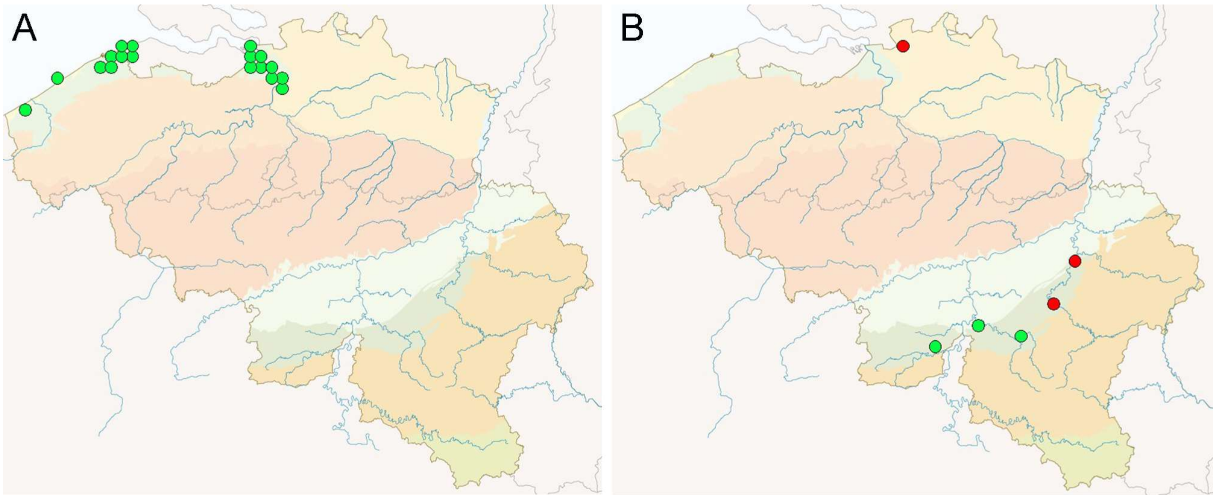


Figure 11. Distribution of *Colletes halophilus* (A) and *Rophites quinquespinosus* (B) in Belgium. Occurences only before 1970 are represented in red and those after 1970 in green, per 5 x 5 kilometre UTM squares (DFF 5.1.0; Barbier et al. 2015).

Distribution of threatened species

The richness pattern of threatened bee species in Belgium is presented in figure 12. The Belgian Red List includes 113 threatened species (i.e. VU, EN, CR species), with the greatest concentration in Campine, Hageland and Droog Haspengouw as well as southeastern Belgium (i.e. Fagne-Famenne and Lorraine), and to a lesser extent in the west of the coastal dune and East canton. This pattern globally overlays the species richness pattern (Fig 12). Threatened species seem then linked to specific habitats, such as calcareous grasslands, heathlands and coastal dunes.

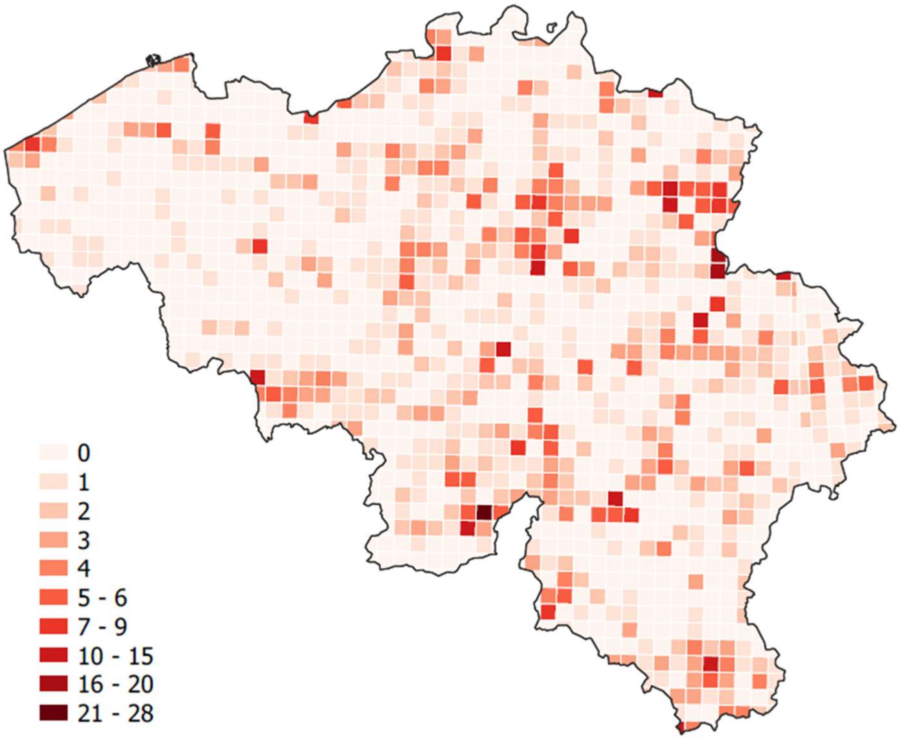


Figure 12. Distribution of threatened bees in Belgium, based on the number of threatened species recorded between 1980 to 2016; 5 * 5 kilometre UTM squares). Species richness categories are quantiles with an equal number of grid cells in each category.

Table 9 presents the different Red List status of each bee species as well as their known occurrence at the regional level (i.e. Brussels, Flanders, Wallonie), based on current knowledge (i.e. sampling effort is not the same in all 3 regions). As already mentioned in the table 1, 246 bee species were listed in Brussels, 341 in Flanders and 366 in Wallonia. 15 of the species recorded in Brussels are Regionally Extinct (6.1%), 21 Critically Endangered (8.5%), 18 are Endangered (7.3%) and 21 are Vulnerable (8.5%). For Flanders, 28 species are Regionally Extinct (8.2%), 39 are Critically Endangered (11.4%), 27 are Endangered (7.9%) and 33 are Vulnerable (9.7%). For Wallonia, 41 species are Regionally Extinct (11.2%), 45 are Critically Endangered (12.3%), 31 are Endangered (8.4%) and 34 are Vulnerable (9.3%).

Table 9. Regional occurrence of threatened bee species and species that went extinct in Belgium since 1900.

Family	Species	Red List status in Belgium	Occurrence in Brussels	Occurrence in Flanders	Occurrence in Wallonia
Megachilidae	*Aglaoapis tridentata*	RE		Yes	Yes
Andrenidae	*Andrena chrysopyga*	RE		Yes	Yes
Andrenidae	*Andrena distinguenda*	RE	Yes		
Andrenidae	*Andrena floricola*	RE		Yes	
Andrenidae	*Andrena gelriae*	RE		Yes	Yes
Andrenidae	*Andrena limata*	RE			Yes
Andrenidae	*Andrena marginata*	RE		Yes	Yes
Andrenidae	*Andrena thoracica*	RE		Yes	Yes
Apidae	*Anthophora aestivalis*	RE	Yes	Yes	Yes
Apidae	*Anthophora borealis*	RE		Yes	
Apidae	*Anthophora plagiata*	RE	Yes	Yes	Yes
Apidae	*Biastes truncatus*	RE			Yes
Apidae	*Bombus confusus*	RE	Yes	Yes	Yes
Apidae	*Bombus cullumanus*	RE	Yes	Yes	Yes
Apidae	*Bombus distinguendus*	RE	Yes	Yes	Yes
Apidae	*Bombus pomorum*	RE	Yes	Yes	Yes
Apidae	*Bombus subterraneus*	RE	Yes	Yes	Yes
Apidae	*Bombus wurflenii*	RE	Yes	Yes	Yes
Megachilidae	*Coelioxys emarginatus*	RE			Yes
Mellitidae	*Dasypoda argentata*	RE			Yes
Halictidae	*Dufourea minuta*	RE	Yes	Yes	Yes
Megachilidae	*Hoplitis papaveris*	RE	Yes	Yes	Yes
Megachilidae	*Hoplitis villosa*	RE		Yes	Yes
Colletidae	*Hylaeus pilosulus*	RE			Yes
Halictidae	*Lasioglossum breviventre*	RE			Yes
Halictidae	*Lasioglossum interruptum*	RE			Yes
Halictidae	*Lasioglossum laeve*	RE		Yes	Yes
Halictidae	*Lasioglossum lineare*	RE	Yes		Yes
Halictidae	*Lasioglossum nigripes*	RE		Yes	Yes
Halictidae	*Lasioglossum politum*	RE			Yes
Halictidae	*Lasioglossum subfasciatum*	RE			Yes
Halictidae	*Lasioglossum subhirtum*	RE			Yes
Apidae	*Nomada argentata*	RE		Yes	Yes
Apidae	*Nomada castellana*	RE			Yes
Apidae	*Nomada emarginata*	RE	Yes		Yes
Apidae	*Nomada melathoracica*	RE		Yes	Yes
Apidae	*Nomada mutabilis*	RE			Yes
Apidae	*Nomada pleurosticta*	RE			Yes
Apidae	*Nomada rhenana*	RE	Yes	Yes	Yes
Apidae	*Nomada roberjeotiana*	RE	Yes	Yes	Yes
Megachilidae	*Osmia pilicornis*	RE			Yes
Megachilidae	*Osmia xanthomelana*	RE		Yes	Yes
Halictidae	*Rhophitoides canus*	RE		Yes	
Megachilidae	*Stelis minima*	RE		Yes	Yes
Megachilidae	*Stelis minuta*	RE		Yes	Yes

Family	Species	Red List status in Belgium	Occurrence in Brussels	Occurrence in Flanders	Occurrence in Wallonia
Apidae	*Ammobates punctatus*	CR	Yes	Yes	Yes
Andrenidae	*Andrena combinata*	CR	Yes	Yes	Yes
Andrenidae	*Andrena curvungula*	CR			Yes
Andrenidae	*Andrena ferox*	CR		Yes	Yes
Andrenidae	*Andrena nigriceps*	CR		Yes	Yes
Andrenidae	*Andrena polita*	CR	Yes	Yes	Yes
Andrenidae	*Andrena potentillae*	CR			Yes
Andrenidae	*Andrena similis*	CR	Yes	Yes	Yes
Andrenidae	*Andrena synadelpha*	CR		Yes	Yes
Andrenidae	*Andrena varians*	CR	Yes	Yes	Yes
Apidae	*Anthophora bimaculata*	CR	Yes	Yes	Yes
Apidae	*Bombus barbutellus*	CR	Yes	Yes	Yes
Apidae	*Bombus humilis*	CR	Yes	Yes	Yes
Apidae	*Bombus muscorum*	CR	Yes	Yes	Yes
Apidae	*Bombus ruderatus*	CR	Yes	Yes	Yes
Apidae	*Bombus sylvarum*	CR	Yes	Yes	Yes
Apidae	*Bombus veteranus*	CR	Yes	Yes	Yes
Megachilidae	*Coelioxys afer*	CR		Yes	Yes
Megachilidae	*Coelioxys conoideus*	CR		Yes	Yes
Megachilidae	*Coelioxys quadridendatus*	CR		Yes	Yes
Halictidae	*Dufourea halictula*	CR	Yes	Yes	Yes
Halictidae	*Dufourea inermis*	CR		Yes	Yes
Apidae	*Epeolus tarsalis*	CR		Yes	
Halictidae	*Halictus eurygnathus*	CR		Yes	Yes
Halictidae	*Halictus quadricinctus*	CR	Yes	Yes	Yes
Megachilidae	*Hoplitis anthocopoides*	CR			Yes
Megachilidae	*Hoplitis ravouxi*	CR		Yes	Yes
Colletidae	*Hylaeus leptocephalus (bisinuatus anc.)*	CR	Yes	Yes	Yes
Halictidae	*Lasioglossum costulatum*	CR			Yes
Halictidae	*Lasioglossum quadrinotatum*	CR	Yes	Yes	Yes
Halictidae	*Lasioglossum tarsatum*	CR		Yes	Yes
Megachilidae	*Megachile analis*	CR		Yes	
Megachilidae	*Megachile genalis*	CR			Yes
Megachilidae	*Megachile lagopoda*	CR	Yes	Yes	Yes
Megachilidae	*Megachile maritima*	CR	Yes	Yes	Yes
Megachilidae	*Megachile pilidens*	CR		Yes	Yes
Apidae	*Melecta luctuosa*	CR	Yes	Yes	Yes
Apidae	*Nomada mutica*	CR			Yes
Apidae	*Nomada obtusifrons*	CR			Yes
Apidae	*Nomada piccioliana*	CR		Yes	Yes
Apidae	*Nomada sexfasciata*	CR	Yes	Yes	Yes
Megachilidae	*Osmia andrenoides*	CR			Yes
Halictidae	*Rophites quinquespinosus*	CR		Yes	Yes
Halictidae	*Seladonia leucahenea*	CR		Yes	Yes
Halictidae	*Sphecodes rubicundus*	CR		Yes	Yes
Halictidae	*Sphecodes rufiventris*	CR		Yes	Yes
Halictidae	*Sphecodes spinulosus*	CR	Yes	Yes	Yes

Family	Species	Red List status in Belgium	Occurrence in Brussels	Occurrence in Flanders	Occurrence in Wallonia
Andrenidae	*Andrena agilissima*	EN	Yes	Yes	Yes
Andrenidae	*Andrena coitana*	EN	Yes		Yes
Andrenidae	*Andrena fulvida*	EN	Yes	Yes	Yes
Andrenidae	*Andrena intermedia*	EN		Yes	Yes
Andrenidae	*Andrena schencki*	EN	Yes	Yes	Yes
Andrenidae	*Andrena tarsata*	EN	Yes	Yes	Yes
Apidae	*Anthophora retusa*	EN	Yes	Yes	Yes
Apidae	*Bombus cryptarum*	EN	Yes	Yes	Yes
Apidae	*Bombus magnus*	EN	Yes	Yes	Yes
Apidae	*Bombus ruderarius*	EN	Yes	Yes	Yes
Apidae	*Bombus rupestris*	EN	Yes	Yes	Yes
Halictidae	*Dufourea dentiventris*	EN		Yes	Yes
Apidae	*Eucera nigrescens*	EN		Yes	Yes
Halictidae	*Halictus simplex*	EN	Yes		Yes
Colletidae	*Hylaeus angustatus*	EN			Yes
Colletidae	*Hylaeus nigritus*	EN			Yes
Halictidae	*Lasioglossum brevicorne*	EN		Yes	Yes
Halictidae	*Lasioglossum prasinum*	EN		Yes	Yes
Halictidae	*Lasioglossum xanthopus*	EN	Yes	Yes	Yes
Megachilidae	*Megachile circumcincta*	EN	Yes	Yes	Yes
Apidae	*Nomada armata*	EN		Yes	Yes
Apidae	*Nomada distinguenda*	EN	Yes	Yes	Yes
Apidae	*Nomada furva*	EN		Yes	Yes
Apidae	*Nomada fuscicornis*	EN	Yes	Yes	Yes
Apidae	*Nomada opaca*	EN		Yes	
Apidae	*Nomada similis*	EN	Yes	Yes	Yes
Apidae	*Nomada villosa*	EN	Yes	Yes	Yes
Megachilidae	*Osmia parietina*	EN		Yes	Yes
Megachilidae	*Osmia rufohirta*	EN			Yes
Megachilidae	*Osmia uncinata*	EN	Yes	Yes	Yes
Halictidae	*Sphecodes scabricollis*	EN		Yes	Yes
Apidae	*Thyreus orbatus*	EN		Yes	Yes
Andrenidae	*Andrena fucata*	VU	Yes	Yes	Yes
Andrenidae	*Andrena helvola*	VU	Yes	Yes	Yes
Andrenidae	*Andrena lapponica*	VU	Yes	Yes	Yes
Andrenidae	*Andrena nitidiuscula*	VU		Yes	Yes
Andrenidae	*Andrena pandellei*	VU		Yes	Yes
Apidae	*Bombus campestris*	VU	Yes	Yes	Yes
Apidae	*Bombus jonellus*	VU	Yes	Yes	Yes
Apidae	*Bombus norvegicus*	VU	Yes	Yes	Yes
Apidae	*Bombus soroeensis*	VU	Yes	Yes	Yes
Megachilidae	*Chelostoma distinctum*	VU		Yes	Yes
Megachilidae	*Coelioxys alatus*	VU		Yes	Yes
Megachilidae	*Coelioxys elongatus*	VU	Yes	Yes	Yes
Megachilidae	*Coelioxys mandibularis*	VU		Yes	Yes

Family	Species	Red List status in Belgium	Occurrence in Brussels	Occurrence in Flanders	Occurrence in Wallonia
Apidae	*Eucera longicornis*	VU	Yes	Yes	Yes
Halictidae	*Halictus maculatus*	VU	Yes	Yes	Yes
Halictidae	*Halictus sexcinctus*	VU	Yes	Yes	Yes
Megachilidae	*Hoplitis claviventris*	VU		Yes	Yes
Colletidae	*Hylaeus rinki*	VU		Yes	Yes
Halictidae	*Lasioglossum laevigatum*	VU	Yes	Yes	Yes
Halictidae	*Lasioglossum minutulum*	VU			Yes
Halictidae	*Lasioglossum monstrificum*	VU		Yes	Yes
Halictidae	*Lasioglossum pygmaeum*	VU	Yes	Yes	Yes
Halictidae	*Lasioglossum quadrinotatulum*	VU	Yes	Yes	Yes
Megachilidae	*Megachile alpicola*	VU	Yes	Yes	Yes
Megachilidae	*Megachile leachella*	VU		Yes	Yes
Mellitidae	*Melitta tricincta*	VU	Yes	Yes	Yes
Apidae	*Nomada femoralis*	VU	Yes	Yes	Yes
Apidae	*Nomada integra*	VU	Yes	Yes	Yes
Apidae	*Nomada striata*	VU	Yes	Yes	Yes
Halictidae	*Seladonia confusa*	VU	Yes	Yes	Yes
Halictidae	*Sphecodes marginatus*	VU		Yes	Yes
Halictidae	*Sphecodes niger*	VU	Yes	Yes	Yes
Megachilidae	*Stelis ornatula*	VU		Yes	Yes
Megachilidae	*Stelis signata*	VU		Yes	Yes

3.5 Major threats to bees in Belgium

Several causes are pointed out by experts to explain the bee decline. While many studies confirm the negative impact of many drivers, some drivers could potentially benefit to particular bees and represent an opportunity for biodiversity, depending on the context and human management (e.g. urbanisation, quarries).

Habitat and floral resources losses and modifications

The first cause of bee decline is fragmentation, loss and alteration of their habitat, resulting partly from a reduced availability of open semi-natural areas due to agricultural intensification, urbanisation, and increased afforestation (Williams 1986; Rasmont & Mersch 1988; Carvell 2002; Goulson et al. 2008; Williams & Osborne 2009; Ahrné et al. 2009; Le Féon et al. 2010; Potts et al. 2010b; Ollerton et al. 2014).

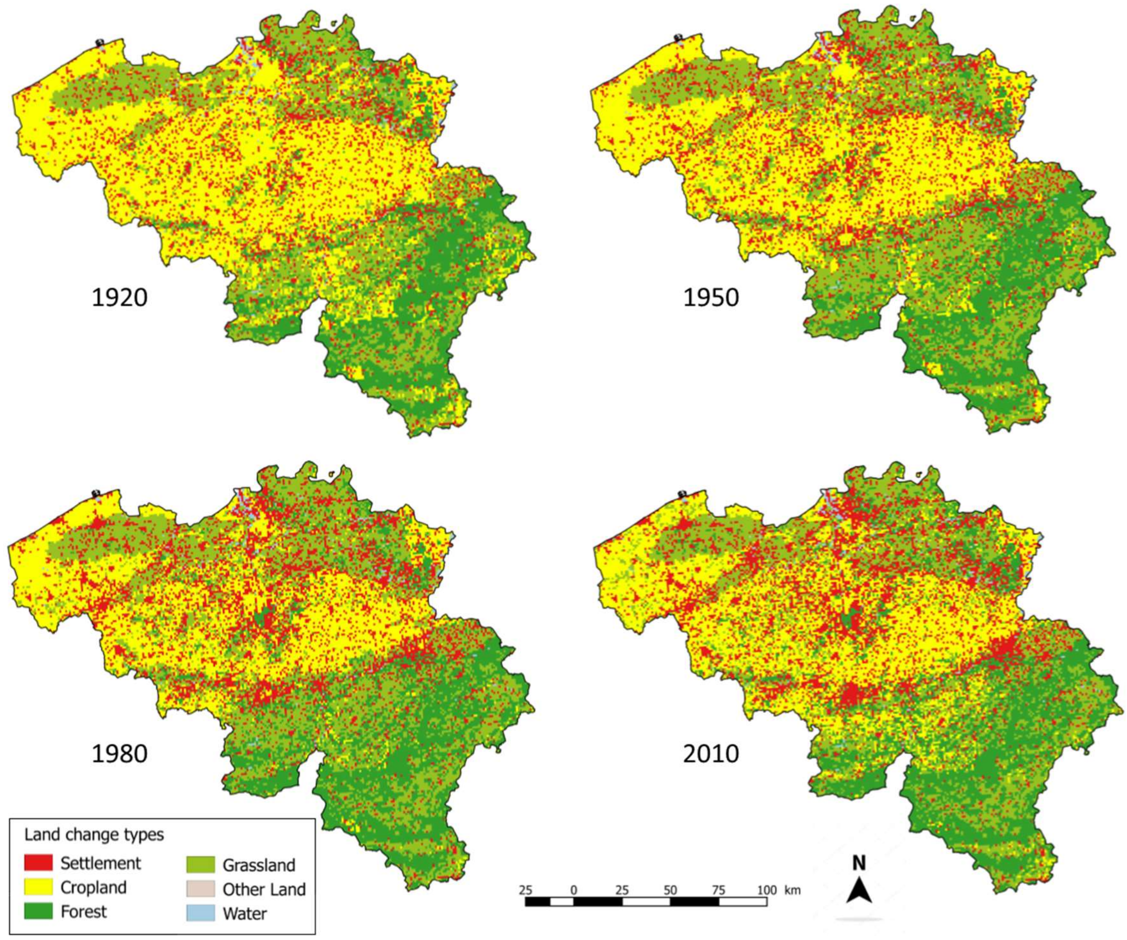


Figure 13. Comparison of the land use in 1920, 1950, 1980 and 2010 in Belgium (Fuchs et al. 2013, 2014).

Agricultural intensification

Many of the environmental threats to bees are associated with changes in agricultural practices that occurred after the First World War and especially after the Second World War (Fig. 13). The development of agricultural mechanisation and chemical fertilizers led to an extreme simplification and homogenization of agricultural landscapes and to a complete restructuration of agricultural processes, such as: removal of hedges and trees, loss of uncultivated areas, small and diversified crops turned intolarge monocultures, extensive pasture with low livestock densities turned into intensive pastures with stocking regimes that are damaging to grasslands, and flower-rich hayfields with a in late mowing date turned into early and frequently mowed almost monospecific grasslands for intensive silage production (Christians 1998; Mazoyer & Roudart 2006, Vulliamy et al. 2006). These land use changes strongly reduced the availability of bee nesting sites and floral resources. Moreover, the spread of nitrogenous chemical fertilisers led to the replacement of leguminous (Fabaceae) crops, known to be very important for long-tongued species such as bumblebees, by other crops (e.g. sugar beet, corn) that do not constitute a food resource for these species (Rasmont & Mersch 1988, Goulson & Darvill 2004, Goulson et al. 2005, Rasmont et al. 2005, Carvell et al. 2006, Rasmont 2008). As highlighted by Rasmont et al. (2005), the regression of bees seems especially linked to the loss of long corolla plants (i.e. Fabaceae, Lamiaceae, Scrophulariaceae, Boraginaceae). Like for bumblebees (see Box 3), the strong regression of leguminous crops and flower-rich haymeadows and pastures rich in long corolla plants could explain the decline of the whole guild of wild bees specialized on Fabaceae and other long corolla plants in Belgium (Rasmont 1988; Rasmont & Mersch 1988; Rasmont et al. 2005). Moreover, the resulting atmospherous nitrogen deposits are also responsible for the eutrophication of natural environments and associated homogenization of the flora (Rasmont 2008).

Urbanisation

Like in other European countries, urbanization and urban sprawl are one of the largest changes in land use in Belgium since the mid-20th century (Fig 13; Antrop 2004, European Environment Agency 2016). Urbanization is known to significantly reduce the availability of favourable habitats to many bees (e.g. Ahrne et al 2009, Deguines et al. 2016). However, some studies showed that gardens and urban parks may be beneficial to certain bees if they provide sufficient floral resources and nesting sites (Tommasi et al. 2004, McFrederick & LeBuhn 2006, Osborne et al. 2008; Garbuzov & Ratnieks 2014, Normandin et al. 2017; Pauly 2019b, c), especially in intensive farming areas or woodland areas (Winfree et al. 2007, Samnegård et al. 2011, Diaz-Forero et al 2013, Baldock et al. 2015). Settlements represent 8.9% (269.902 ha) of the land use in Belgium (Fig. 13), more precisely 5.8 % (98 515 ha) in the Walloon Region, 12.3% (166 489 ha) in the Flanders Region and 30.34% (4 897 ha) in the Brussel-Capital Region (Belgian Federal Government 2018b). Although a comprehensive study on urban bees and the impact of the urban landscape mosaic is still lacking, several general recommendations can be formulated based on examples from other temperate countries. For example, the mosaic of impervious surfaces and urban green spaces could be enhanced through qualitative private gardens and public greens areas, benefitting from suitable management measures (e.g. late mowning, limited use of pesticides), which could provide floral resources (e.g. flowered meadows, qualitative and native flowering plants, shrubs and trees, flowering hedges), nesting sites (e.g. modular pavements with unbound joints, non-artificialized surfaces), linear landscape structures allowing dispersion (e.g. hedges). As an example, some *Lasioglossum* species (e.g. *L. nitidulum, L. morio and L. laticeps*) could be favoured by urbanisation through the availability of nesting sites (e.g. joints in old walls) (Pauly 2019a, c). Ongoing studies in Brussels are likely to provide more detailed and evidence-based recommendations from our regions, with a potential to replicate the surveys across several of the important cities in Wallonia (e.g. Mons, Charleroi, Liège, Namur) and Flanders (e.g. Ghent, Antwerp, Hasselt).

Afforestation and wood plantation

Forest cover increased during the last century in Walloon (i.e. 396.792 ha in 1910; 556.200 ha in 2016) and Flemish (i.e. 122.469 ha in 1910; 148.185 ha in 2016) Regions (not in Brussels Region; 1955 ha in 1910 and 1735 ha in 2016), and it is still increasing today, especially in the Walloon region (Fig 13;

Blerot & Heyninck 2017). A high forest density generally does not favor a large diversity of bees (e.g. Winfree et al. 2007, Diaz-Forero et al. 2013), probably because most species prefer more open and flower-rich landscapes such as borders and clearings (Pauly 2019a) but also meadows and heathland (Pittioni & Schmidt 1942, Reinig 1972, Rasmont 1988). Open areas, forest edge and clearings offer stable habitats with nesting sites (e.g., trunks, dead wood, underground cavities, …) as well as flower resources (i.e. wood plants and numerous shrubs like *Prunus sp.*, *Cytisus scoparius*, *Rubus sp.*, *Salix sp.*, …) for some bee species (Pauly 2019a). However, less than 10% of forest edges in Wallonia are qualitative enough for biodiversity (i.e. edge hem and cord measuring 5m for each) (Pauly 2019a). Several forest-linked bee species seem to have been impacted, such as *A. lapponica* (VU)*, Osima uncinata* (EN) or *Andrena ferox* (CR). Moreover, changes in woodland management (i.e. from coppice wood to dense high trees and the establishment of coniferous plantations leading to less and less small open areas in the woodlands) seem to represent one of the main factor of the disappearance of some bee species, such as *O. pilicornis* (BWARS 2019).

Heathland and moors are also important habitats for several species (Moquet et al. 2017; Pauly 2018). However, they declined sharply in Belgium and in other European countries as a result of changes in land management. The extensive grazing of heathland mainly by sheep during the 18th and 19th centuries, which limited the recolonization by trees, was replaced by drainage and enrichment of the soil with fertilizers to make them suitable for agriculture or by commercial timber plantations of conifers during the 20th century (Aerts & Heil 1993, Webb 1998). In the South-East of Belgium, coniferous plantations dominate the landscape in most regions. Their undergrowth being unfavorable for the development of a herbaceous flora, they are highly unfavorable to bees.

Other land use changes

Other habitat modifications (i.e. modifications, alterations, destructions) have also an important impact on bees. As already mentioned, some particular habitats of bees are highly impacted by human activities (e.g., urbanisation, forestry, industry). This is notably marked for sandy areas (i.e. coastal dunes; Flanders and Campine district; outcrops in Wallonia in Picardy-Brabant and along the Meuse districts) which constitute precious but highly threatened habitats for a significant part of Belgian fauna and entomofauna (Leclercq et al. 1976; Pauly 2019a). Coastal dunes (west; Fig 12) present a relatively high number of threatened species (e.g. *Lasioglossum prasinum* (EN); *Lasioglossum tarsatum* (CR)), most likely linked to the high habitat alterations and destructions, mainly resulting from urbanisation and shrub encroachment due to abandonment of grazing. As well, the remaining sand dunes of the interior of Flanders (i.e. close to Gent, Speelbos, Molsbergen) present a high inteterest to be conserved, just as the larger sandy areas of heathland in for instance Kalmthout (Pauly 2019a).

Box 4 – When human activity can positively impact on biodiversity - Quarrying

Biodiversity can be hosted in some human mining and quarrying activities. Quarries can namely lead to the creation of uncommon and favourable habitats for bees in Belgium (e.g. sandy surfaces, chalk grasslands, nutrient-poor meadows), as long as they don't destroy highly valuable bee habitat such as calcareous grassland in the first place. More than 25 quarries in Wallonia are included in the LIFE in Quarries project (http://www.lifeinquarries.eu) which aims to develop in a sustainable way their capacity for maintaining rare biodiversity, namely species like sand martin, lizards, wall lizards, natterjack toads or Characeae (i.e. algae typical of nutrient-poor environments). Several actions undertaken can benefit bees: (i) maintenance of dry and flower-rich grasslands; (ii) dynamic management of pioneer grasslands, (iii) creation and refreshing of loose cliffs and (iv) maintenance of sunny rockfaces. As highlighted by Remacle (2005; 2006) and Lemoine (2015), sandpits and quarries represent very interesting replacement spaces for ground nesting bees (i.e. majority of Belgian wild bees – see ecology of bees) and their associated kleptoparasitic bees. While Jacob-Remacle & Jacob (1990) already highlighted the interest of these quarry establishments in Wallonia (i.e. 72 bee species observed in 5 sandpits in Belgian Lorraine), many studies confirmed this assessment (e.g. 2 protected bee species observed in the quarry of Loën in Wallonia (Colart 2009); 124 bee species sampled in 24 chalk quarries in Lower Saxony in Germany (Krauss et al. 2009); 123 bee species sampled in one chalk quarry in the Netherlands (province of Zuid-Limburg), among which 41 species on their national Red List (Raemakers & Faasen, 2012)).

Specific management (i.e. avoiding reforestation or use as rubbish tip (Pauly 2019a) of old quarries is essential to conserve this particular biodiversity. It is also important to design or adapt management plans of quarries and sandpits that are still in use to allow spontaneous biodiversity in at least part of the sites (Remacle 2005). On this point, we can mention as exemple the integrated management of the sandpit of Hamel (France, Nord department) for bees, the management of the old quarry of "Haut des Loges" (Etalle, Province of Luxembourg) converted in a natural reserve by the *Ardenne & Gaume* association (Jacob & Remacle 2005) and the attention paid to bees in belgian CBR quarries (HeidelbergCement group) (Colart 2009).

Pesticides

Agricultural intensification also resulted in the development and widespread use of pesticides. By their application, phytophamaceutical products (i.e. herbicides, fungicides, insecticides, growth regulators and additives, soil disinfectant (Lievens et al. 2012) seem to impact directly or indirectly on bees (e.g. Devillers & Pham-Delègue 2003; Brittain & Potts 2011). Their uses are numerous and varied with a large range of potential users (i.e. farmers, public administrations, rail network managers, private individuals, …) (Lievens et al. 2012).

With over 5 kg per ha of agricultural land per year, Belgium is ranked as the fourth country in the EU-28 in 2014 for the use of these products, after Malta, Cyprus and Netherlands (Eurostat 2018; Wallonie Environnement SPW 2018). While the concentration of active substances (i.e. active ingredient without formulating agent) has been reduced following the European norms (i.e. 358 in 1995, 260-270 after 2010), the sold quantities of active substances have decreased by half between 1995 and 2010 (i.e. respectively 10.872t to 5.472t) but increased again by 2015 (i.e. 6.648t) (UCL – ELI – ELIM 2017). In Belgium, sales of active substances mostly concern related to fungicides and herbicides and mainly professional users (UCL – ELI – ELIM 2017).

As most studies of the toxicological impacts of pesticides have been conducted on the honey bee and, to a lesser extent commercial *Bombus*, the consequences for wild bees are still poorly known (Nieto et al. 2014). Since the 2000s, more and more studies have targeted wild bees and have revealed negative effects of pesticides. It seems that pesticides can impact several aspects of bees' ecology, such as the foraging behaviour (Morandin et al. 2005, Mommaerts et al. 2006, Feltham et al. 2014), the sociality (Brittain & Potts 2011), the colony productivity (Gels et al. 2002), as well as the development and queen production in bumblebees (Whitehorn et al. 2012; Woodcock et al. 2017). Among the range of pesticides impacting bees, the most well-known are pyrethroids and neonicotinoids (Thompson & Hunt 1999, Goulson 2013). Neonicotinoids are neurotoxic pesticides causing paralysis and death of insects (Tomizawa & Casida 2005; Gradish et al*.* 2010 for commercial *Bombus* in the US). It has been shown that sub-lethal doses of both neonicotinoids Imidachloprid and thiamethoxam (the aforementioned in conjunction with the DMI fungicide propiconazole) affect respectively the foraging behaviour of commercially reared *Bombus terrestris* in the field and colony iniatition of this same species (Elston et al. 2013; Godfray et al*.* 2014; Woodcock et al. 2017). The acute toxicity of neonicotinoids is compounded by their long persistence in the soil (Goulson et al. 2015), where several bee species nest, and their accumulation in floral resources (Krupke et al. 2012; Woodcock et al. 2016). Two other less known pesticides, diflubenzuron and teflubenzuron, are also among the most toxic for bumblebees and yet widely used (Mommaerts et al. 2006). This is also the case of deltamethrin, which is well known for its high toxicity to bees (e.g. Moncharmont et al. 2003, Dai et al. 2010).

Climate change

In recent years, climate change is considered as a significant driver of bumblebee decline (Williams et al. 2007; Iserbyt & Rasmont 2012; Rasmont & Iserbyt 2012; Bartomeus et al. 2013; Kerr et al. 2015; Rasmont et al. 2015). Species that were initially common and widespread are now regressing, even in favourable habitats. We can understand this climate change effect in two distinct processes.

Firstly, extreme events such as heat waves, which seem to have an important impact on the flower resources availability and on the bumblebee populations even when in a favourable habitat (Iserbyt &

Rasmont 2012; Rasmont & Iserbyt 2012; Ploquin et al. 2013; Herrera et al. 2014). A rapid mortality was observed in experimental condition from 40°C or higher, as during heat waves (Martinet et al. 2015). Sub-lethal effects have also been observed on colonies at 33°c (Gérard et al. 2018; Vanderplanck et al. 2019). In addition, droughts can indirectly affect bumblebee colonies by impacting on vegetation and then reducing the floral resources availability (Brochet 1977; Thomson 2016; Ogilvie et al. 2017). Also, floods can impact bees nesting in or on the ground, namely bumblebees (Goulson et al. 2015).

Secondly, gradual and continuous increases of temperature also have dramatic impacts on bumblebees (Kerr et al. 2015; Rasmont et al. 2015). It results in geographical distribution changes and more specificaly in spatial shifts toward the North or in a concentration of the species range (Bartomeus et al. 2013; Aguirre-Gutiérrez et al. 2016). These modifications are highlighted by Rasmont et al. (2015) in the "*Climatic Risk and Distribution Atlas of European Bumblebees"* which predicts the disappearance of the majority of the remaining Belgian bumblebee fauna as well as a reduction of the range for most European bumblebee species by 2050 and/or 2100.

At the same time as the demise of more bee species with a more northern distribution, it can be expected that southern bee species will extend their geographic range north. This already seems to be ongoing with the appearance and/or spread of a number of species for which Belgium is on the northern or northwestern limit of their geographic range, such as *Megachile rotundata*, *Hylaeus punctatus* or *Halictus scabiosae* but comprehensive analyses are lacking. This seems to be the case for *Colletes hederae* which has undergone a rapid expansion towards the north during the 2000's (Roberts et al. 2011).

3.6 Knowledge gaps

Taxonomic impediment

The Red List of Belgian bees resulted in 9.4% of species being Data Deficient (Fig. 5.A, page 32). These mainly include species from the genera *Andrena*, *Hylaeus* and a few *Nomada*, *Sphecodes* and *Lasioglossum* species. Data deficient species fall into the three following categories.

1. The first category includes species being recently recognized taxonomically, which have or had an uncertain species status for a long time, or which have been split off from a former species complex, and for which the collection material has not been revised due to the lack of taxonomic experts. As a result, the historical distribution is unknown and if the taxonomic revision is recent also the present distribution may be unclear. Examples of this category are *Hylaeus dilatatus* and *H. spilotus* (*H. annularis* was recently renamed as *H. dilatatus*, while the former *H. spilotus* was recently renamed as *H. annularis*, see Notton & Datte 2008), *Hylaeus gredleri* (split from *H. brevicornis*, Dathe 1980), *Hylaeus incongruus* (recently described and originally included in *Hylaeus gibbus*, Straka and Bogusch 2011), *Andrena pilipes* (split from *A.*

nigrospina, Schmid-Egger and Scheuchl 1997; Scheuchl and Willner 2016) and *Nomada baccata* (not always recognized as a separate species from *N. alboguttata*, Sann et al. 2010).

2. A second category consists of species that are morphologically very similar to widespread taxa. For some species groups, the lack of taxonomic expertise prevents unequivocal identification of these species (e.g. *Andrena apicata* and *A. batava*). Most notable cases are the species of the *Micrandrena* subgenus. At the present time there is no Belgian specialist able to identify these species with certainty. As a result, they are also relatively understudied by the volunteers doing wild bee inventories, which generates undersampling and lack of data. This lack of expertise and of reference collections currently prevents us from assessing the Red List status of all *Micrandrena* except for the two most abundant species (*Andrena minutula* and *A. subopaca*).
3. The third category includes rare to very rare species in less-studied genera (*Hylaeus, Lasioglossum*, *Sphecodes*) for which the few seemingly erratic observations did not allow to make an assessment (e.g. *Lasioglossum fratellum* / *L. subfulvicorne*).

A revision of historical and present collections by foreign experts and an increase in taxonomic expertise and further capacity building among wild bee volunteers in Belgium will be necessary to resolve these issues. It could namely allow to (dis)confirm the presence of some species in Belgium for which revision of specimens is needed (e.g. *Andrena rufula*, *Coelioxys echinata, Megachile apicalis, Lasioglossum pauperatum*, *L. smeathmanellum*).

Threats

As highlighted by Williams et al. (2010), traits such as body size, foraging range, and food storage capacity, are highly different between bee species and thus also the potential sensitivity for direct or indirect effects of pesticides. Evidence and wide-ranging field scale studies are needed. Concerning this, UMONS (i.e. Laboratory of zoology) is taking part in the pan-european PoshBee project (www.poshbee.eu; 2018 – 2023). It represents an assessment, monitoring and mitigation of stressors on the health of bees (i.e. Honeybees, Bumblebees, wild bees). The partner consortium (i.e. 42 partners in 14 European countries) will namely "*provide the first pan-European quantification of the exposure hazard of chemicals to managed and wild bees*" and "*determine how chemicals alone, in mixtures, and in combination with pathogens and nutrition, affect bee health*" at the biological level (i.e. field observations) but also experimental scale (i.e. laboratory experiments).

Finally, research is needed to evaluate consequences of phenological shifts of bees in Belgium. Indeed, this could cause desynchronization between plants and pollinators and clear fitness losses in solitary bees (Schenk et al. 2018). A preliminary study seems indicate a strong average forward shift in the flight period in Belgium between 1983 and 2016, mainly driven by climate change (Duchenne et al. *in prep*).

4. Conservation measures

4.1 Biodiversity change in Belgium and in Europe

Evolution of the bee diversity in Belgium

As mentioned above, our study has benefitted from a consistent bee recording history over the last century. Two assessments of bee diversity have been published previously (before the advent of the IUCN and its IUCN Red List methodology): (i) Leclercq et al. in 1980 and (ii) Rasmont et al. in 1993. The latter constitutes the first comprehensive assessment of the complete Belgian wild bee fauna up to 1991. The authors revealed that 25% (i.e. 91 species) of species were already in decline or even extinct at that time (Rasmont et al. 1993; see Appendix 1). To allow a clear comparison, we inferred IUCN categories from the available trends reported in Rasmont et al. (1993) (Table 10; Appendix 3). While only 4 species were considered as Regionally Extinct (RE) in 1993, this proportion has increased tenfold by 2017. However, many rare species were assessed as Data Deficient by Rasmont et al. (1993) due to a lack of knowledge. Without doubt, some of these were already threatened or extinct at that time, which can explain the large difference between both periods.

Table 10. Summary of number of bee species within each IUCN category. IUCN categories for Rasmont et al. (1993) were inferred based on trends reported in that work: "RE" corresponding to an observed estimator since 1950 equal to 0; "threatened categories" were gathered and corresponding to species in relative regression with a highly negative trend (-***); "NT" corresponding to species in relative regression with a negative trend (-*); "LC" corresponding to species in relative expansion (+) and status quo (=); "DD" corresponding to species with an expected estimator <5 for the "since" period.

IUCN Red List Categories	No. species Belgium (Rasmont et al. 1993)	No. species Belgium (Present study)	
Extinct (EX)	0	0	
Extinct in the Wild (EW)	0	0	
Regionally Extinct (RE)	4	45	
Critically Endangered (CR)	81	47	113
Endangered (EN)		32	
Vulnerable (VU)		34	
Near Threatened (NT)	7	26	
Least Concern (LC)	183	161	
Data Deficient (DD)	71	36	
Total number of species assessed	**346**	**381**	

However, the number of threatened (i.e. CR, EN, VU; 113 species), regionally extinct and nearly threatened (i.e. NT; 26 species) species strongly increased since 1993. As a result, the proportion of (nearly) threatened or extinct species has doubled over the last 25 years. This regression phrenomenon seems to reach all the categories, which is especially worrying. Also, the assessment of 12% of species assessed as Least Concern in 1993 has resulted in an upgrading of their threat status in this work (i.e. Near Threatened, Threatened or Regionally Extinct).

Regarding the status by taxonomic group, Rasmont et al. (1993) emphasized a faster decline of Apidae species and Megachilidae to a lesser extent (i.e. long-tongued bees; respectively 53.5% and 30.9%). Except for Melittidae which includes only 9 species, this Red List assesses that this decline was accentuated for all the families by taking into account the proportion of threatened species but also Regionally Extinct ones, such as for Apidae (Tables 8 and 11).

Table 11. Inferred Red List status of bees by taxonomic family and subfamily (as defined by Michener et al. (2007)) in Rasmont et al. (1993). Percentage of threatened species were calculated based on the mid-point figures (i.e. (CR+EN+VU) / (assessed – EX – DD) in which the Extinct (EX) status is not equivalent to the Regionally Extinct (RE) status). N.M refers as bee species not mentioned in Rasmont et al. 1993.

Order	Family	Subfamily	Total	RE	Threatened	NT	LC	DD	% threatened (1993)	N.M	% threatened (2019)
Hymenoptera	**Andrenidae**		**76**	**0**	**12**	**0**	**50**	**14**	**19.4%**	**17**	**28.6%**
		Andreninae	73	0	11	0	49	13	**18.3%**	17	**29.9%**
		Panurginae	3	0	1	0	1	1	**50.0%**	0	**0.0%**
	Apidae		**91**	**4**	**38**	**1**	**28**	**20**	**53.5%**	**10**	**36.7%**
		Apinae (corbiculate)	26	4	16	0	5	1	**64.0%**	5	**46.7%**
		Apinae (not corbiculate)	17	0	8	1	6	2	**53.3%**	2	**41.2%**
		Nomadinae	46	0	14	0	16	16	**46.7%**	2	**30.6%**
		Xylocopinae	2	0	0	0	1	1	**0.0%**	1	**0.0%**
	Colletidae		**30**	**0**	**2**	**1**	**17**	**10**	**10.0%**	**8**	**16.0%**
		Colletinae	7	0	0	1	4	2	**0.0%**	2	**0.0%**
		Hylaeniae	23	0	2	0	13	8	**13.3%**	6	**23.5%**
	Halictidae		**72**	**0**	**11**	**3**	**46**	**12**	**18.3%**	**14**	**35.9%**
		Rhophitinae	4	0	0	0	2	2	**0.0%**	1	**66.7%**
		Halictinae	68	0	11	3	44	10	**19.0%**	13	**33.3%**
	Megachilidae		**70**	**0**	**17**	**2**	**36**	**15**	**30.9%**	**6**	**36.4%**
		Megachilinae	70	0	17	2	36	15	**30.9%**	6	**36.4%**
	Melittidae		**7**	**0**	**1**	**0**	**6**	**0**	**14.3%**	**2**	**12.5%**
		Dasypodainae	1	0	0		1		**0.0%**	1	**0.0%**
		Melittinae	6	0	1		5		**16.7%**	1	**16.7%**
		Total	**346**	**4**	**81**	**7**	**183**	**71**	**29.5%**	**57**	**32.8%**

Considering functional traits, Rasmont et al. (1993) reported a high proportion of declining kleptoparasitic species, which is congruent with our results. In addition, we now also observe an increasing proportion of threatened species in the other ecological groups of (see 3.2 and 3.3). Compared to their analysis, we can namely highlight a more pronounced regression of bees nesting in the ground (i.e. 15.7% of threatened species in 1993; 32.5% of threatened species in the present Red List) and bees nesting in cavities above ground (i.e. 10.7% of threatened species in regression in 1993; 23.6% of threatened species in the present Red List). In addition, our results indicate in general a similar decline in opportunistic and specialised bees (i.e. respectively 31.6% and 31.2% of threatened species) as well as in the three categories of sociality (i.e. 31%, 33.3% and 36% of threatened species for solitary, primitively eusocial and kleptoparasite respectively). In this respect also the relatively high proportion of Regionally Extinct (i.e. varying from 7.5% for bees nesting in cavities above ground to 21.7% for primitively eusocial bees) and Near Threatened (i.e. varying from 3% for bees nesting in cavities above ground to 9.8% for specialised bees) species in all functional group also has to be considered. Lastly, especially bees having very specific nesting needs (i.e. bees nesting in existing cavities below ground, bees nesting in deadstems, carder bees, bees nesting in snail shells; 27 species) seem to be severely impacted with 12 threatened species, but also 3 Regionally Extinct and 5 Near Threatened species.

Assessments of the bee decline in Europe

Even if the comparison of National Red Lists or Red Data Books of Bees can be tricky, a simple comparison of the percentages of regionally extinct and threatened species of the Belgian Red List with those of other European countries shows that the Belgian bee fauna can be considered as one of the most threatened in Europe, together with that of the Czech Republic, Ireland, Germany, Netherlands and Switzerland (Table 12). In addition to these countries, Powney et al. (2019) highlighted an overall decline in bees (i.e. 25%) and syrphids (i.e. 24%) between 1980 and 2013 in Great Britain. In their study related to the European butterflies, Maes et al. (2019) indicated that the large number of Red Listed butterfly species could be linked to (i) high anthropogenic pressure (e.g. Czech Republic, Konvicka et al. 2006) and/or (ii) high nitrogen deposition in these countries (e.g. Netherlands, WallisDeVries & van Swaay 2017; Belgium, Maes & Van Dyck 2001, Maes et al. 2012) which presents a threat for the terrestrial biodiversity in Europe (Dise et al. 2011). In line with this, Rasmont et al. (2008) already highlighted a negative impact of nitrogen deposition on both nutrient-poor biotopes and the related bee fauna.

Table 12: National species diversity and red List status in European countries. "Npsec"= number of recorded species according to IUCN data (*except for Hungary, Begium, Slovenia (specific checklists) and Netherlands (recent Red List)); "NRLspec"= Number of species on national red list; "%threatened" = Proportion of threatened species based on Nspec/NRLspec (given that NDD species are not known for all Red Lists); "NREspec"= Number of species assessed as Regionnally Extinct (RE) and "NDDspec"= Number of species assessed as Data Deficient (DD). Criteria used for the Red Lists assessments: IUCN = IUCN criteria, NC= national criteria, NM= not mentioned.

Country	Nspec	NRLspec	%threatened	NREspec	NDDspec	Reference of the Red list
Czech Republic	600	242	40.3%	108	N.M	Farkac et al. (2005) IUCN
Germany	585	194	33.2%	39	15	Westrich et al. (2008; 2011) NC
Netherlands	331*	110	33.2%	46	2	Reemer (2018) NC, *
Switzerland	633	192	30.3%	67	N.M	Amiet (1994); Cordillot & Klaus G (2011) IUCN
Ireland	101	30	29.7%	3	16	Fitzpatrick et al. (2006) IUCN
Belgium	403*	113	28.0%	36	45	Drossart et al. (2019) IUCN; *Rasmont et al. (2017b)
Sweden	283	54	19.1%	13	3	Gärdenfors (2010) IUCN
Slovakia	586	105	17.9%	0	0	Feráková et al. (2001) IUCN
Finland	244	43	17.6%	7	0	Rassi et al. (2010) IUCN
Poland	490	84	17.1%	15	111	Głowaciński et al. (2002) IUCN
Great Britain	237	35	14.8%	10	2	Shirt (1987); Falk (1991) NM
Norway	192	26	13.5%	12	N.M	Kålås et al. (2010) IUCN
Moldova	127	10	7.9%	N.M	N.M	Timuş et al. (2017) IUCN
Belarus	124	3	2.4%	1	0	Prischchepchik (2008) NM
Latvia	195	4	2.1%	N.M	N.M	Spuris (1998); Patiny et al. (2009) NC
Italy	897	16	2%	5	N.M	Quaranta et al. (2018)IUCN
Malta	49	1	2.0%	0	3	Schembri & Sultana (1989) IUCN
Denmark	261	5	1.9%	2	2	Windt & Pihl (2010) IUCN
Slovenia	563*	10	1.8%	N.M	N.M	Gogala (2019) IUCN; *Gogala (2014)
Hungary	704*	12	1.7%	N.M	N.M	Sárospataki et al. (2005) IUCN; *Jozan (2011)
Spain (mainland)	1008	8	0.8%	N.M	16	Verdú et al. (2011) IUCN
Lithuania	295	2	0.7%	1	N.M	Rašomavičius (2007) IUCN
Estonia	179	0	0.0%	5	16	CNCEAS (2008) NM

The biodiversity decline in Belgium

Apart from some highly threatened taxa (e.g. reptiles (57.1%), amphibians (43.8%), ants (52.9%)), the percentage of threatened bee species in Belgium is similar to that of other groups (e.g. beetles (24.3%), mammals (28.4%), nesting birds (29.9%), spiders (33.8%)) (Belgian Federal Government 2018c). However, when compared to, e.g. beetles (9%), mammals (6.7%), nesting birds (5.1%) and spiders

(1.5%) a larger proportion of bee species is classified as Regionally Extinct (Belgian Federal Government 2018c).

Concerning other insects, some regional Red Lists are already available in Belgium. Fichefet et al. (2008) and Maes et al. (2012) applied IUCN criteria at a smaller regional level for butterflies (respectively in Wallonia, South Belgium; and in Flanders, North Belgium). They report that 33.6% (34 species out of 103 assessed species) of butterflies in Wallonia and 37.5% (18 species out of 68 assessed species) in Flanders are threatened according to mid-point calculation. For their study, Maes et al. (2019) combined both regional Red Lists into a Belgian Red List by opting for the lowest extinction risk category of the two regions as the Belgian Red List category. As a result, 50% (55 species out of 112 assessed species) of butterflies are considered threatened following the mid-point value (i.e. substracting 2 DD species). Moreover, a high proportion of butterfly species in these Red Lists is Regionally Extinct (i.e. 17.8% (18 species) in Wallonia and 29.4% (20 species) in Flanders). The majority of threatened butterfly species are linked to semi-natural habitats under pressure (i.e. dry and wet heathlands, nutrient-poor grasslands and deciduous forests) and mostly found in the coastal dune (west) and Campine ecoregion (northeast) in Flanders (Maes et al. 2012). A correlation can also be seen between threatened butterfly species in Wallonia and their habitats: 78% of the butterfly species closely linked to calcareous grasslands are threatened as well as 50% of the forest and wet meadows butterfly species (Fichefet et al. 2008).

Concerning Odonata, Goffart et al. (2006) and De Knijf (2006) performed a Red List assessment for Wallonia and Flanders respectively. In Wallonia (57 evaluated species), 46.4% (26 species; based on the mid-point figure) are threatened and 5.2% (3 species) Regionally Extinct. The majority of threatened species are linked to habitats under pressure (i.e. running water, oligotrophic and mesotrophic pools) and mostly occur in the south (i.e. Fagne-Famenne region, Ardennes and Lorraine region) (Goffart et al. 2006). In Flanders (64 evaluated species), 29.3% (17 species; based on the mid-point figure) are threatened and 9.4% (6 species) Regionally Extinct (De Knijf 2006). Similarly as for butterflies, the two Red Lists can also be combined into a Belgian Red List following the same conservative measure of Maes et al. (2019). On the 69 dragonfly species observed in Belgium, 30.6 % (19 species out of 69 assessed species) are then considered threatened at the Belgian level following the mid-point value (i.e. substracting 7 DD species).

However, because these Red List were produced several years ago and of nature restoration actions undertaken for instance within the scope of LIFE projects, we may hope that the situation has meanwhile improved for these two groups in Belgium.

Lastly, the Belgian Federal Government (2018c) highlights that 423 vascular plant species out of 1530 native species are threatened (i.e. 27.6%) in Belgium, with a higher proportion in Wallonia (i.e. 31.9%) than in Flanders (i.e 18.7%). Habitat destruction and eutrophication are inferred to explain this decline. These drivers especially impacts habitat specific and localized plants (Wallonie Environnement SPW 2008). This global phenomenon could be linked to bee decline, as already reported by Powney et al. (2019), who showed that 55% of pollinators (i.e. bees and syrphids) in decline are associated with specific habitats (i.e. uplands) in Great Britain.

4.2 Nature conservation strategy at European and Belgian scale

In 2011, the European Union adopted a strategy to protect and improve the biodiversity status in Europe by 2020. Six targets addressing the main drivers of biodiversity loss have been highlighted (Table 13). Twenty focused and time-bound actions were integrated to ensure that ambitions were fully accomplished by covering the main drivers of biodiversity decline and by reducing the strongest pressures on nature. A mid-term review of these targets was conducted in 2015 (European Union 2015).

Table 13. EU Biodiversity Strategy to 2020 (European Union 2011). Target 4 was not mentioned because not related to bee conservation.

Target 1: Fully implement the "Birds" and "Habitats" Directives	Action 1: Complete the establishment of the Natura 2000 network and ensure good management Action 2: Ensure adequate financing of Natura 2000 sites Action 3: Increase stakeholder awareness and involvement and improve enforcement Action 4: Improve and streamline monitoring and reporting
Target 2: Maintain and restore ecosystems and their services.	Action 5: Improve knowledge of ecosystems and their services in the EU Action 6: Set priorities to restore and promote the use of green infrastructure Action 7: Ensure no net loss of biodiversity and ecosystem services
Target 3: increase the contribution of agriculture (A) and forestry (B) to maintaining and enhancing biodiversity	Action 8: Enhance direct payments for environmental public goods in the EU Common Agricultural Policy Action 9: Better target Rural Development to biodiversity conservation Action 10: Conserve Europe's agricultural genetic diversity Action 11: Encourage forest holders to protect and enhance forest biodiversity Action 12: Integrate biodiversity measures in forest management plans
Target 5: Combat Invasive Alien Species	Action 15: Strengthen the EU Plant and Animal Health Regimes Action 16: Establish a dedicated instrument on Invasive Alien Species

Target 6: Help avert global biodiversity loss	Action 17: Reduce indirect drivers of biodiversity loss Action 18: Mobilise additional resources for global biodiversity conservation Action 19: 'Biodiversity proof' EU development cooperation Action 20: Regulate access to genetic resources and the fair and equitable sharing of benefits arising from their use

Since 2006 (update in 2013), a Belgian national biodiversity strategy was also implemented containing 15 prioritary key objectives (and 85 operational objectives) meeting CBD (i.e. Convention of Biological Diversity), European and International requirements (Belgian NFP-CBD 2013a) (Table 14).

Table 14. Belgium's National Strategy to 2020, objectives and their equivalent in the EU strategy 2020 (Belgian NFP-CBD 2013a).

National Objectives	**EU strategy 2020**
Objective 1: Identify and monitor priority components of biodiversity in Belgium	
Objective 2: Investigate and monitor the effects of threatening processes and activities and their causes	T6 Act. 17c
Objective 3: Maintain or restore biodiversity and ecosystem services in Belgium to a favourable conservation status	T1 Act. 1bc; T2 Act. 6& 7; T5
Objective 4: Ensure and promote the sustainable use of components of biodiversity (General; Sustainable products, Consumption and production policies; Agriculture; Fishery in marine and inland waters; Wise use of wetlands; Forestry; Hunting; Tourism and leisure)	T3; T3A; T3A Act. 9 & 10; T3B Act. 11 & 12; T4 Act. 13 & 14; T4; T6; T6 Act. 17a
Objective 5: Improve the integration of biodiversity concerns into all relevant sectoral policies	T1 Act. 3b; T2 Act. 5; T5; T6 Act. 17c
Objective 6: Promote and contribute to an equitable access to and sharing of benefits arising from the use of genetic resources - ABS	T6 Act. 20
Objective 7: Improve and communicate scientific knowledge on biodiversity and ecosystem services	T2 Action 5
Objective 8: Involve the community through communication, education, public awareness and training	T1 Action 3a;b
Objective 9: Strengthen the biodiversity-related regulatory framework and ensure the implementation of, compliance with and enforcement of biodiversity related legislations	T1 Action 3c
Objective 10: Ensure a coherent implementation of / and between biodiversity-related commitments and agreements	
Objective 11: Ensure continued and effective international cooperation for the protection of biodiversity	T6 Act. 19
Objective 12: Influence the international agenda within biodiversity-related conventions	T6

Objective 13: Enhance Belgium's efforts to integrate biodiversity concerns into relevant international organisations and programmes	
Objective 14: Promote the commitment of cities, provinces and other local authorities in the implementation of the Biodiversity Strategy 2020	
Objective 15: Ensure the provision of adequate resources for biodiversity	T1 Act. 2; T6 Act. 18

This Belgium's National Biodiversity Strategy to 2020 gathers goals and actions of the different existing strategies developed at the four levels of government in Belgium (i.e. federal and regional levels; summarized in Belgian NFP-CBD 2013a) and integrates the main objectives (i.e. targets) of the European biodiversity strategy. It represents the first document applicable at the federal as well as the regional level.

Target 1 - *targeting threatened and rare species*: Natura 2000 constitutes the biggest network of protected areas worldwide, covering 18% (950.000 km²) of the total area of the European Union and 12.7% (3883km²) of Belgium (Blerot & Heyninck 2017). These sites were chosen following the developed list of European threatened species and habitats (based on the Birds and Habitats Directives). Each European member state is bound to propose a list of sites allowing to ensure protection of natural habitats, wild fauna and flora on its territory (Blerot & Heyninck 2017). This European and national habitat protection, comprising the associated management measures, is likely beneficial for bees. However, not a single bee species was specifically included in the Habitats Directive. The recently European red list of bees, despite the fact that many bee species are considered Data Deficient, provides an opportunity to specifically include wild bees in European nature conservation (Nieto et al. 2014). Conservation actions could then be designed to specifically target threatened bee species (e.g. LIFE bees).

Beneficial actions for bees in the framework of this European target could be namely applied at the national scale through the key objective 3 (i.e. operational objectives 3.1 and 3.4). The Action Plan currently developed with the Interreg SAPOLL project (see Folschweiller et al. 2019) comes within the scope of the operational objective 3.4 (i.e. "*Develop and implement action plans so as to ensure the maintenance or rehabilitation of our most threatened species to a favourable conservation status*"). Implementation of this cross-border action plan for wild pollinators is then needed.

At the regional scale, protected areas (i.e. RND – national natural reserves; RNA – certified natural reserves; ZHIB – wet areas of biological intest; RF – forest reserves) cover an area of 0.9% in Wallonia (15.600 ha) compared to nearly 3% in Flanders (i.e. 40.000 ha). While protection of 5% of the total area could ensure an adequate flora and fauna conservation, an augmentation of protected natural reserves is needed in Wallonia (i.e. aiming at the protection of more than 50.000 ha or 3% of the territory) (Dufrêne 2018). Military camps namely represent remarkable natural areas with a great faunistic and floristic diversity, of which 7.000 ha have already been integrated in the Natura 2000 network and benefit from appropriate management within the scope of the LIFE Natura2MIL (e.g. Elsenborn, Lagland, Marche-en-Famenne in Wallonia). An additional regional protection is then needed in Wallonia, as in Flanders in which military camps represent 25% of protected areas (Dufrêne 2018). A protection linked to bee hotspots (see 3.4; namely heathlands, calcareous grasslands, coastal dunes)) could then be applied in order to preserve the species richness as well as threatened species. Moreoever, roadsides (e.g. shoulders, ditches, enbankments) constitue great biological passageways, covering around 20.000 ha in Wallonia and 25.000 ha in Flanders (Wallonie Environnement SPW 2012; Underwood et al. 2017). Maintenance measures like extensive mowing and prohibition of pesticides contribute to the conservation of diversity in roadsides.

Target 2 - *targeting common species providing services*: Ecosystem services can be grouped into (i) support services which enable essential ecosystem functions (e.g. hydrologic cycle, photosynthesis, oxygen production, …), (ii) regulation services (iii) supply services and (iv) cultural services (Belgian NFP-CBD 2013a). Insect pollination is highly important for the reproduction of wild and cultivated plants. Jacquemin et al. (2017) mapped the dependency of crops on pollinators in Belgium. They highlighted that the part of plant production for human food dependent on pollination represents a value of 251.6 million euros in Belgium in 2010, which corresponds to 11.1% of the total value of plant production in terms of quantity and quality (Jacquemin et al. 2017). A high spatial variability is present, with Flanders being more dependent on pollinators (especially the southern part of Limburg and eastern Flemish Brabant with a pollination value of, respectively, 108.8 million euros and 46.8 million euros and a rate of vulnerability > 20% for both (i.e. ratio between the insect pollination economic value and the total production economic value)) than Wallonia. This contrast is mostly due to the differences in crops between Provinces. While Limburg and Flemish Brabant are the main regions for fruit production (i.e. apple, pears, cherries), Hainaut and West Flanders for instance are dominated by cereals (Jacquemin et al. 2017).

Beneficial actions for bees of this European target could be namely applied at the national level through the key objective 3 (i.e. operational objective 3.3), 5 (i.e. operational objective 5.11) and 7 (i.e. operational objectives 7.2, 7.4, 7.6). The study of Jacquemin et al. (2017) comes within the scope of the operational objective 7.4 (i.e. "*Mapping ecosystem services in Belgium and assessing their values*"). More research is needed improve our knowledge on biodiversity and ecosystem services to carry out adapted conservation measures.

Target 3: Agricultural lands represent 45% of Belgium's surface area, woodlands 23% (Belgian Federal Government 2018b). Agricultural changes and modifications represent one of the major driver of bee decline (see 3.5 Major threat to bees).

Benefitial actions for bees of this European target could be namely applied at the national level through key objective 4 (i.e. operational objectives 4c.1-8) and should be connected with the key objective 3. Measures have urgently to be taken to mitigate the negative impact of intensive agriculture on bees (e.g. consideration of bees in agroenvironmental measures (i.e MAE in Wallonia) such as the reduction of pesticides or the setting-up of floral strips). The entire bee biodiversity as well as species needs could also be taken into account in woodland management (i.e. operational objectives 4f.1 & 2). A serious transformation of agriculture and sylviculture is needed to achieve targets 1 & 2. A part of the recommended actions (see 5.1) aims to mitigate bee decline in these areas.

Target 5: Invasive alien species (especially plants and insects) can directly or indirectly impact native bees. Impacts of alien plants seem to vary according the plant taxa (e.g. melliferous or not), the functional traits of the bees (e.g. specialist or generalist species) as well as the ecological context (e.g. flower-rich or flower-poor environment) (Stout & Morales 2009). While some bee species might suffer from these invasions (e.g. replacement of native host plants of specialist species, or low diet quality of invasive plants for some generalist bees, Roger et al. 2016a)), other bees could incorporate with benefit invasive plants in their diet (e.g. opportunistic generalist species, such as *Bombus terrestris* and *Bombus pascuorum* (Kleijn & Raemakers 2008; Roger et al. 2016a)). Several studies highlighted that the removal of a valuable diet resource (e.g. *Buddleia davidii, Impatiens glandulifera*, *Senecio inaequidens*) in forage-depleted environments could negatively impact these generalist bees (e.g. Rasmont et al. 1990; Saad et al. 2009; Drossart et al. 2017; Davis et al. 2018). Moreover, invasion of alien plants could also indirectly impact on bees through their competition with native plants, especially for specialist bees that display low diet plasticity (e.g. for nutrients, light, ware, space, pollination) (Chittka & Schürkens 2001; Müller et al. 2006; Stout & Morales 2009).

Direct and indirect impacts of invasive insects on bees are numerous and varied (Stout & Morales 2009). Main impact of invasive insects could be linked to (i) the competition for resources and nesting sites; (ii) transmission of pathogens and (iii) reproductive disruption through interspecific mating (Goulson 2003; Traveset & Richardson 2006; Morales 2007). Indirect impacts could also occur on native bees through modification of plant communities induced by invasive insects. Stout & Morales (2009) highlighted that worldwide circa 20 bee species (mainly *Apis mellifera, Bombus* spp, *Osmia* spp, *Megachile* spp, …) have been introduced out of their native range, namely as part of economical

activities. For example, *Megachile sculpturalis* currently constitutes a new invader in Europe (Geslin et al. 2017). This species could be the first alien bee to invade Belgium.
Benefitial actions for bees of this European target could be namely applied at the national level through the key objective 3 (i.e. operational objective 3.7) and 5 (i.e. operational objective 5.7) of Belgium's National strategy (Table 14).

4.3 Conservation of bee species in the European Union and Belgium

In the European Union, the LIFE projects (LIFE + Nature and Biodiversity) aim at restoring target habitats of species (i.e. through the Birds and Habitat Directives) in Natura 2000 sites to halt biodiversity loss. Among the three main pollinator groups (i.e. bees, hoverflies, butterflies), only butterflies are directly targeted in projects which aim at the restoration of populations of threatened butterflies as well as their habitats (e.g. LIFE papillons, LIFE Nardus). Nevertheless, also other LIFE projects (e.g. LIFE Helianthème, LIFE Bocage, LIFE Herbage, LIFE Pays Mosan, LIFE in Quarries) are beneficial to pollinators through the restoration of natural, semi-natural and even anthropic habitats (e.g. calcareous lawns, meadows, pastures, quarries, …), of which many are of prime importance for wild bees. As already mentioned (i.e. point 4.2 – target 1), the integration of bees and hoverflies in the Natura 2000 species lists could allow specific conservation actions for these groups.

Moreoever, the European Commission proposed on the 1 June 2018 the first-ever EU initiatives to address the decline of wild pollinators. Thanks to growing research at the European (i.e. European Red Lists of bees and butterflies, ALARM and STEP projects) and national (e.g., Rasmont et al. 2005; Biesmeijer et al. 2006; Vray 2018) level, our understanding of their trends, threats they face and consequences of their loss has improved. This has resulted in increasing pollinator initiatives in the EU Member states (Underwood et al. 2017). Three priorities were set by EU and its Member states to tackle the pollinator decline: (i) Improving knowledge of pollinator decline, its causes and consequences; (ii) Tackling the causes of pollinator decline and (iii) Raising awareness, engaging society-at-large and promoting collaboration (European Commission 2018).

In Belgium, the study of wild bees is mainly undertaken by academic institutions (e.g. UMONS, UGENT, ULB, ULiège Gembloux Agro-Bio Tech, …) as well as two non-governmental nature organisations (Natuurpunt, Natagora).

Since 2016, the Interreg "France-Wallonie-Vlaanderen" SAPOLL project aims to develop a cross border action plan for wild pollinators (Folscwheiller et al. 2019; www.sapoll.eu). Including local actors in each region, this plan is adapted to regional context and regulations. It is also based on scientific studies at the regional scale (i.e. in the scope of BELBEES). Within SAPOLL, partners namely aim the above-mentioned bee inventory effort through (i) sampling campaigns in under-sampled areas in Belgium;

and (ii) mobilizing naturalist networks to recruit new entomologists specialized in wild bees (by means of training, working group animations, citizen science (for more information see box 5)). An atlas of the cross-border area for bumblebees (*Bombus*) is also planned. While bumblebees constitute the best studied group in Belgium and Northern France, the knowledge on the other groups is less complete and additional inventories are needed to better understand their ecology and current geographical distribution.

A second Interreg project "Vlaanderen-Netherlands" (Meer natuur voor pittig fruit) has been launched in 2016 and gathers 5 regional landscape/nature organisations (3 Flemish and 2 Dutch), the Province of Vlaams-Brabant and an international research institute for fruit farming. It focuses on increasing wild bee populations orchards and benefits from the collaboration of more than 100 fruit farmers as well as land and water managers around farms (i.e. municipalities, water boards).

These Interreg projects also include a raising awareness through varied actions for citizens (e.g. encourage the bee-friendly gardens with bee hostels and natural nesting sites in soil, cross-border traveller exhibition, information species sheets on common bees, events, …). In recent years, public awareness has markedly grown through public and NGO initiatives and campaigns (e.g. bee hotels, general public "bee" events like "Week van de bij" in Flanders, "Semaine de l'abeille & des pollinisateurs" in Wallonia) (Underwood et al. 2017).

Box 5 – The arrival of citizen science in Belgium

The last decades have seen a large increase in citizen science data in Belgium, as in other countries (e.g. UK (Roy et al. 2016)). This recent rise through the monitoring of emblematic insect groups (e.g. butterflies, bees) as well as the volunteers' interest in this research task is due to the fact that the development of several new knowledge dissemination and species occurrence recording tools for naturalists. First is the creation of online platforms where naturalists can post their observations, even directly in the field using apps, and in return get a real-time overview of which species are recorded and their distribution. Most commonly used in Belgium is the naturalist platform (https://observations.be (FR) and https://waarnemingen.be (NL)), which is used by tens of thousands of users. A team of administrators guards the data quality by record validation, mostly through pictures. A recent advance is an automatic species identification tool based on machine learning using validated pictures. In parallel, digital photograpy partially replaces the need for collection since pictures can increasingly be used to communicate and validate observations. Fueled by the above there has also been a steady demand for and increase in expertise of wild bee field and picture-based recognition among naturalists, supported by bee specialists.

Box 5 – The arrival of citizen science in Belgium

This knowledge is rapidly spread through common activities (often by the Aculea working group) and social media. This has also resulted in the publication of new identification keys and even field guides for the broader public in the last years. Those keys are well-illustrated and written in Dutch and French, thus reducing the distance between professional taxonomists and naturalists.

In spite of significant biases in records (for instance towards the more striking species, and species that are identifiable in the field), citizen science seems very effective to map the occurrence of rare as well as invasive species (Dickinson et al. 2010; Ward 2014). Moreover, it can also provide useful data on the occurrence of common species, as proved with this Red List.In the last few years and more recently within the scope of collaborative projects (i.e. BELSPO-project BELBEES; Interreg France-Wallonie-Vlaanderen SAPOLL project), two of the biggest nature conservation organizations in Belgium (i.e. Natuurpunt and Natagora) have mobilized their volunteers (e.g. through the working group *Aculea* in Flanders) to increase the number of observations of pollinators (i.e. especially in syrphids and bees) in under-sampled areas. Indeed, involving volunteers allows a larger sampling of data at larger scale and with a finer resolution (Hochachka et al. 2012). Collected data coming from citizen science in Belgium have been included in the dataset used to produce this Red List (Table 2).

Several action plans and initiatives have been proposed and undertaken by governments at different levels in Belgium (i.e. federal, regional, local). However, most of them are focussed on the honeybee (*Apis mellifera*), at least in Wallonia and Flanders, and none is focusing on the conservation of wild bees. However, indirect measures (e.g. protected areas, mass flower crops, agri-environment schemes, …) initiated for other threatened groups (e.g. birds) tend to benefit to pollinators (Nieto et al. 2014).

Belgium

The Belgian federal authority acts at different levels to preserve bees, mainly honeybees. Two successive bee plans have been developed: the first (2012-2014) aimed to establish a federal and national “Bee” governance allowing the implementation of tangible actions (see www.info-abeilles.be; Cuypers 2013); the second one (2017-2019) aims to help beekeepers as much as possible, improving knowledge on honeybee decline, better risk management as well as mobilising concerned actors (Auwers 2017). As highlighted by Underwood et al. (2017), policy competence for most relevant areas linked to the conservation of wild pollinators depends on regional governments, which have not yet developed regional strategies focused on wild pollinators (but see next chapters).

In parallel, a federal working group (i.e. the “Pollinators Working Group”, previously the “Bee Working Group”) was founded in 2012 and gathers federal, regional and local authorities and entities. It constitutes an expert group created and mandated by the Coordination Committee for International

Environmental Policy to inform and advise on policies affecting pollinators and pollination. It gathers scientific experts, civil society organisations, government administrations, universities and associations. A list of additional actions/measures for bees (i.e. wild and honey bees) was elaborated by this working group in 2012:

- Development of a permanent monitoring tool for wild bees;
- Development of a honey bee tool, such as "honey bee, sentinel of health and environement";
- Development of an integrated tool of a monitoring of bees' exposure to neonicotinoids;
- Developing a legal protection for endangered wild bee species in Flanders and Brussels;
- Consideration of bees in agroenvironmental measures (MAE);
- Establishing a Bee Coalition (i.e. developing a stable WG "bees").

Given the favourable context (e.g. gain of attention for pollinators; Belgium being a member of the Coalition of the Willing on Pollinators, future Common Agricultural Policy (CAP) and the regional/federal elections, …), a pollinator strategy will be formulated compiling ongoing and new actions/measures for pollinators in 2019. Main axes of the new action list will be (i) a favourable common agricultural policy, (ii) the conservation of natural areas for pollinators, (iii) an extensive management and green network in favour of pollinators, (iv) a better beekeeping policy, (v) education and awareness.

Within the scope of the Common Agricultural Policy (CAP) beyond 2020, the working group has also recommended in particular to:

- Incorporate in the rules on conditionality all the basic legal requirements that are part of the EU regulatory framework providing safeguards for the environment andbiodiversity.
- Encourage the inclusion of the conservation and sustainable use of pollinators in the possible eco-schemes proposed by the Member States.
- Implement the pollinator indicator that is in development under EU Pollinators Initiative.

Lastly, the NAPANprogram (2018-2022) is a national action plan which aims at reducing the pesticide use as well as their impact on environment and health through implemented actions by federal and regional authorities (i.e. regional action plans in Wallonia, Flanders ans Brussel-Capital). Pesticide use in public areas are then planned to be banned in the three Regions according to their action plan and timeframe (e.g. ban of pesticide use in amenity areas from 2019 in Wallonia; prohibition of pesticides uses in 2015 in Flanders for public places offering a public service to vulnerable groups like hospitals, schools, churches, …) but many towns have already either stopped the use of pesticides or significantly reduced their use (Underwood et al. 2017).

At the Flemish level

The Flemish Region has adopted a program for beekeeping (i.e. Bijenteeltprogramma 2017 – 2019) which aims to improve conditions for apicultural production and commercialization of beehive products (Auwers 2017). In parallel, Natuurpunt (i.e. the largest Flemish nature conservation organization) undertakes every year several local (i.e. small-scale) wild bee projects aiming to (1) make general inventories of wild bees or search for a specific bee species (e.g. *Andrena hattorfiana*) (often in collaboration with volunteers – see below); (2) suggest recommendations for wild bee-friendly management based on these inventories, and (3) increase knowledge and awareness of wild bees of the public and local administrations. Several municipalities and provinces have then been inventoried (e.g., Aalst, Merelbeke, Beersel, Leuven, Zaventem, some sites in Flemish Brabant and in Limburg, …), namely in the scope of the Interreg SAPOLL project during which more data have been gathered in East- and West-Flanders. For instance, 109 bee species were discovered in a joint effort of professionals and volunteers in Leuven (i.e. an urban area) (D'Haeseleer 2014). Moreover, several intensively mown nutrient-poor lawns were transformed in extensive flower-rich haymeadows. A similar project led in Beersel has resulted in the discovery of 141 wild bee species (D'Haeseleer et al. 2015; Veraghtert et al. 2017). Like for the city of Leuven, a blueprint for wild bee-friendly management of the bee hotspots in the township was made. The investigated areas for all inventories combined include townships, nature reserves, green areas but also companies, orchard landscapes, sown flower strips, recreational areas, gardens, ... These result in both a better knowledge of the current distribution of wild bees in Flanders (more information at natuurpunt.be, section "publicatie"), but in at least several cases also in real management actions for wild bees (only a few of municipalities used the toolkit of recommandations propoposed (Underwood et al. 2017)).

At the Walloon level

The Walloon Region has launched in 2011 the MAYA plan which aims to protect bees and other pollinators in order to positively impact on the environment, biodiversity and our food (Marot 2015). This plan primilary focusses on honeybees as well as wild pollinators in a lesser extent and is designed for citizens, beekeepers, municipalities but also provinces. Through its actions, the MAYA plan promotes (i) the augmentation of the food resources availability (e.g. creation of flowering meadows, use of 2/3 of melliferous plants in hedges and plantation of orchards); (ii) the implementation of late mowing; (iii) the research on diseases, viruses and contaminations resulting from the use of pesticides; (iv) the training support for new beekeepers and (v) the development of wild bee-friendly managements. The Provinces as well as 211 municipalities are involded in this plan.

Moreoever, samplings and bee inventories are undertaken in the Walloon Region by the Zoology lab (UMONS) (e.g. in terrils, natural reserves, agricultural areas) and the Agroecology lab (ULB) in the

Walloon Brabant (20 sites, orchard/arable pilot project monitored by CRA-W) and in the Luxembourg Province (15 sites, LIFE Herbages project).

At the Brussels-Capital level

Historical bee data of the twenty last years were compiled at this regional scale in the scope of the BRUBEES project financed by Brussels Environment. It also aimed to raise awareness of citizens (i.e. citizen sciences), firemen and green space managers.

Structured surveys conducted since 2015 by the Agroecology lab (ULB) are yielding their first results, illustrating that certain categories of urban green spaces such as community gardens (i.e. urban agriculture) are of particularly high conservation value in urban areas. Standardized samplings by the Agroecology lab have also been undertaken in parallel of the BELBEES project in Brussels (40 sites, urban wild bees). Based on the BRUBEES project experience, the WildBnB project (2018-2020) aims to produce an atlas of the bees of Brussels-Capital Region as well as a regional Red List. This project is led by the Agroecology lab (ULB) with active collaboration by IRSNB/RBINS, Natuurpunt and Natagora.

Box 6 - Regulatory framework for wild bee conservation in Belgium

Wallonia

The law of the Nature Conservation of the 12th July 1973, updated with the Decree of the 6th December 2001 (appendix IIb) includes a list of 47 species of wild bees which are strictly protected. The publication of this Red List highlights the necessity to bring this list of protected species up to date. While some of these protected species were assessed as Least Concern (LC) (i.e. *Andrena fuscipes, Anthidium punctatum, Colletes cunicularius, Dasypoda hirtipes, Epeoloides coecutiens, Macropis spp., Nomada obscura, Osmia bicolor, Panurgus spp. and Trachusa byssina*), others were assessed as Regionally Extinct (RE) (i.e. *Andrena marginata, Anthophora aestivalis, Anthophora plagiata, Bombus distinguendus*) since they seem to have disappeared from this country. This protection implies a ban on sampling, disrupting or destroying specimens, as well as having, carrying, exchanging, collecting, selling or buying sampled/ pinned specimens, but also altering sites where populations of these species occur (Goffart et al. 2006).

Flanders

No bee species occurring is currently under legal protection. A regional Red List has firstly to be produced and be evaluated by INBO (Instituut voor Natuur- en Bosonderzoek). After that, threatened species can potentially be added to the list of protected species in Flanders.

Brussels-Capital

No bee species is currently under legal protection.

5. Recommendations

5.1 Recommended actions

The scientific results of the BELBEES project (Rasmont et al. 2019) show a tangible impact of current human practices on wild bees in Belgium. This includes factors such as habitat loss, pesticides, food resource depletion and climate change. We should thus adapt our practices at several levels (regional, federal and European) in order to reduce the negative impact of human practices on wild bees. We could even imagine that some fields of action, such as agriculture, could become leverages for wild bees' conservation. To do so, new regulations, promotion of good practices that already exist and new management practices (farming, public spaces, industries, green spaces, …) are needed. Plus, awareness raising and promotion of good practices are needed to stimulate and valorise the actions taken. Finally, scientific research and wild bee inventories and monitorings have to be maintained or implemented in Belgium in order to fill the remaining knowledge gaps.

The next recommendations are of great importance for wild bee conservation. As already mentioned, a first study on the pollination service in Belgium (Jacquemin et al. 2017) concluded that the majority of crop production in Belgium does not depend on wild pollinators. Nevertheless, this study also estimates the value of the pollination service for pollination-dependent crops at 251 million euros per year in Belgium which issubstantial. This is especially the case for provinces like Flemish Brabant and Limburg. The further recommendations are thus essential to durably maintain food quality and food security in Belgium.

Recommended actions for wild bees' conservation in Belgium

The following recommendations are a synthesis from two main sources: the BELBEES final report (Rasmont et al. 2019) and the SAPOLL action plan (Folschweiller et al. 2019). More precisely, we had a close look at the scientific results of BELBEES, a recent project (2014-2018) that tackled the causes of wild bee decline in Belgium. From the outcomes of this project we proposed conservation actions for wild bees that are in coherence with the action plan for wild pollinators of Belgium and north of France (SAPOLL project).

First, we will summarize the consequences of factors causing wild bee decline and address the associated conservation measures that are needed. These will be followed by more specific recommendations (action 1-5) and complementary actions such as awareness raising and scientific monitoring (action 6-7).

1. Floral resources depletion

Scientific studies show a shift in floral resources exploited by Belgian wild bees (Roger et al. 2016a) with possible nutritional impacts (diets quality and quantity, health and development – Vanderplanck et al. 2014, 2018; Moerman et al. 2015; Roger 2016b; Drossart al. 2017) and also inducing changes in the plant-bee's networks (Jacquemin et al. in prep). It appears that some generalist bee species such as bumblebees may be able to compensate and shift their diet if suitable flower resources are available (Moerman et al. 2017). However, generalist species might be impacted if they have to shift to poor-nutrient resources, such as Asteraceae (Vanderplanck et al. 2018). In regard, specialist species seem less able to shift their diet and are more threatened by the disappearance of their floral resources (Jacquemin et al. 2018).

Thus, it is critically important to increase the floral resources availability and quality in the landscape in order to provide for the nutritional needs of wild bees and to improve their health and resilience to other decline factors.

More precisely, we recommend the following actions:

- **Restoration of (semi-)natural habitats and small-scale landscape elements that provide floral resources in the landscape**. It is important to increase the proportion of areas and habitats that provide flower resources (see actions n°26 to 32 from Folschweiller et al. 2019) on a landscape scale in order to enhance the resilience and maintenance of wild bee communities, and provide a source of wild pollinators for adjacent croplands. This is especially important in areas that suffer great variations in flower resources through space and/or time, such as agricultural areas with crops or orchards (Quinet et al. 2016) or natural areas like heathlands (Moquet et al. 2017; Pauly 2018).

- **Promote the best resource plants for wild bees in (sub)urban areas**. This can be done through a list, or database, of recommended plants taking into account their importance for specialist and generalist bees, their nutritional value, the local context (i.e. climate and soil) and land use (i.e. public areas, municipal flowerbeds, agricultural areas, citizen's gardens, …). This could lead to a beneficial change in flower resources, especially in urban or suburban landscapes. Plus, this would be a good support to encourage an adequate local plant production (i.e. indigenous, high-quality and non-treated plants - see action n°22 from Folschweiller et al. 2019).

- **Improve the availability of flowering plants that benefit to some target bee species that are declining, rare or ecologically important**. This can be done through programs to restore population of indigenous plants that declined during last century, through ecological or agricultural measures such as MAE schemes as well as through cities, green spaces and garden flowering. The flower resources have to be enhanced in quantity and quality (flower species choices) and availability (adapted to the bee's phenology and geographical range).

- **Promote good practices for the management of flowering plants in all types of areas**. This would allow spontaneous and managed flowering plants to express their whole potential as food resources for wild bees (quantity, quality and availability). This implies to adapt management practices such as pesticides use, mowing and pruning calendars and to integrate wild bees' requirements in all green spaces managements (actions n° 21 to 32 in Folschweiller et al. 2019).

- **Review the law regarding thistle removal**. Thistles are important plants for wild bees (Pauly & Coppée 2017) and particularly for bumblebee males (Vray et al. 2017). The current laws making thistle removal mandatory could negatively affect the bumblebee populations that are already threatened by global environmental changes. We thus recommend to abrogate or limit the law to some thistle species and/or to some specific areas such as crop hedges (see action n°24 in Folschweiller et al. 2019).

2. Habitat fragmentation

The Belgian landscape dramatically changed during last century, especially through drivers like urbanisation, industrialisation and agricultural intensification with severe impacts on land use and degree of fragmentation. These landscape changes in Belgium were shown to have a negative effect on bumblebees' assemblages (Vray 2018, Vray et al. 2019) and we suspect that other wild bees, with smaller dispersion abilities or higher habitat requirements, are probably even more at risk. At this stage more studies are still needed to better understand the effects of habitats fragmentation on wild bees. Nevertheless, in this context it is important to maintain some key elements for wild bees' conservation: (i) to provide all ecological requirements within the flight range of bees (resource plants, nesting sites, nesting material in a suitable microclimate); (ii) to maintain population connectivity.

These first results bring us to strongly recommend to improve the wild bee habitat availability and quality in the landscape to provide nesting (nesting sites, nesting material, …) and floral resources to bees and to allow bee communities to thrive in the Belgian landscape. We also recommend to ensure wild bee population connectivity to avoid any future genetic pauperization and to improve wild bee resilience to other decline factors.

More precisely, we recommend the following actions:

- **Protect and restore (semi-)natural wild bee habitats**. Attention must be paid to key (semi-)natural habitats on which bees, and pollinators in general, are highly dependent (e.g. uplands, nutrient-poor grasslands, dry and wet heathlands, deciduous forests…) through protection, suitable management and restoration actions (see actions n° 26 to 32 from Folschweiller et al. 2019). This would allow to create safe areas (no pesticides use, adapted management practices, …) providing ecological requirements to wild bees (flower and nesting resources). A list of interesting habitats, taking into account the geographic region, the plant and bee communities associated, … would be of great help in order to prioritise habitat conservation for wild bees. As an example, Svensson et al. (2000) investigated the habitat preferences of nest-seeking bumblebees in an agricultural landcape in Sweden. They seemed to prefer forest and field boundaries as well as open uncultivated areas and landscapes. Quality and connectivity of these preserved habitats should be included in their management plans. Indeed, several studies highlighted the importance of hedgerows and artificial linear landscape features for bees (i.e. bumblebees but also less common species) and plants which depend on them for pollination in intensive agricultural landscapes (Cranmer et al. 2012; Morandin & Kremen 2013). As well, many studies (e.g. Mallinger et al. 2016) emphasized the importance of diverse landscapes, such as flower-rich grasslands and orchards, for bees by providing food resources throughout the entire foraging period and other species' requirements (e.g. nest sites). Also, we suggest to create natural reserves in Belgium in sites hosting wild bee communities of regional or national importance.

- **Increase the suitability of urban and agricultural areas for wild bees**. These places have a potential for hosting wild bee communities and an adequate management could act as a leverage for wild bee conservation on a large part of the Belgian territory. As a general rule preserving undisturbed elements in the landscape such as hedgerows, micro-reliefs and embankments and respecting the spontaneity of wildlife will help providing natural nesting and flower resources. Also a general management of risks for wild bees (pesticides, mowing and pruning calendar…) and improvement of floral resources offer can have a positive effect on wild bees. Finally, bee-friendly practices need to be implemented and tested in urban areas (differential management, melliferous planting, …) and in agriculture (agro-ecology, precision agriculture, flowering crops like leguminous grops, crop rotations, flower margins, …).

- **Have a dynamic conservation approach for wild bees**. Indeed, bees are able to disperse by flying and seem to be able to quickly colonize new habitats fitting their floral and nesting requirements. In the current context of global change (climate and landscape), a dynamic conservation of wild bees through time (e.g. climatic sanctuaries) and space (e.g. urban wildernesses moving around the city) seems necessary for their sustainable conservation in Belgium. This dynamic conservation infers to identify the future protection areas and to plan bee conservation. Dynamic conservation also implies to better understand wild bee dispersal abilities in the landscape to contribute to habitats connectivity and thus allow gene flow between populations (see action n°2 from Folschweiller et al. 2019).

3. Disease emergence

Metagenomic surveys targeting bee pathogens have been conducted on wild bees in Belgium and highlighted the fact that wild bee pathogens are very poorly known. Also, wild bees carry very specific sets of viruses and parasites such as microsporidias and trypanosomes (Schoonvaere et al. 2016). More research is needed to better describe the pathogenosphere of wild bees and to study the pathogenicity of newly described viruses and parasites.

These first results bring us to strongly recommend to apply the precaution principle regarding diseases in managed and wild bee species in order to limit diseases transmission and propagation.

More precisely, we recommend the following actions:

- **Study the pathogenicity of wild bee parasites and viruses in bumblebees, *Osmia* spp., and other wild bees**. In order to do so, more research should be performed on these diseases (see action n° 3 from Folschweiller et al. 2019).

- **Evaluate the effect of management practices on disease prevalence in wild bee populations**. Indeed, we currently lack information regarding the effect of some management practices on the prevalence of some diseases in wild bee populations. Measures that increase the proximity of pollinators (such as proximity of hives, insect hostels, …) might enhance the risk of infection and disease transmission (see action n° 3 from Folschweiller et al. 2019). Sanitary rules might come out of such evaluations and allow the improvement of wild bee management practices.

- **Implement the observation and monitoring of the pollinator trade in Belgium**. The trade of managed pollinators such as honey bees (*Apis mellifera*) and more recently bumblebees (*Bombus terrestris, Bombus* sp.), *Osmia* spp. (*Osmia cornuta, Osmia bicornisi*) and *Mechachile rotundata*) is increasing in the world and in Europe. The movement of these managed pollinators breed in other countries will inevitably bring along the genetic contamination of local populations and new diseases in Belgium. Invasive species (e.g. potentially *M. sculpturalis* in Belgium) can also represent a vector of novel pathogens for native species (Stout & Morales 2009). Since we are currently not able to screen for the diseases of wild bee species, we recommend to apply the precaution principle by monitoring the importation of pollinators in Belgium (keep records of the trades and organize traceability of the bees) and to elaborate pest controls in parallel (see action n° 25 from Folschweiller et al. 2019).

4. Pesticide development and fertilizers

Lethal effects of pesticides used in Belgium are egenerally tested on honey bees (*Apis mellifera*) but there still is a lack of knowledge regarding their effect on bumblebees and other wild bees as well as on their sublethal and chronic effects. Exploratory studies exist but more researchis needed on the effect of pesticides on bumblebees and other wild bees, for instance through the development of biomarkers. Moreoever, few studies have addressed the impact of cocktails of agrochemicals on bees which could interact synergetically (Goulson et al. 2015).

These preliminary results bring us to strongly recommend to apply the precaution principle and to limit wild bee exposure to pesticides in order to avoid sublethal and lethal negative effects and to enhance the health and resilience of wild bee populations to other causes of decline.

Plus, multiple effects (e.g. photochemical smog, acidification, eutrophication) can be caused by a single nitrogen atom via the series of chemical transformations that it undergoes throughout its progression in the environment (called "nitrogen cascade") (Galloway & Cowling 2002; Galloway et al. 2003; Gruber & Galloway 2008). Since 1950, the sudden increase in the concentration of available nitrogen induced changes in the specific composition, productivity, dynamic and diversity of ecosystems (Matson et al. 2002; Guber & Galloway 2008; Tylianakis et al. 2008). In particular, the eutrophication of ecosystems has led to the disappearance of former oligotrophic biotopes and their replacement by current eutrophic biotopes (Robinson & Sutherland 2002; Rasmont et al. 2005; Rasmont 2008). At the same time, the pollinating fauna dependent on these plant species (e.g. bumblebees, solitary bees) would also appear to be negatively influenced (Rasmont et al. 1993; Rasmont et al. 2005). However, the impact of eutrophication on bees is still poorly understood, although this issue could be a major cause of the decline in apifauna (Rasmont 2008; Le Féon et al. 2010).

More precisely, we recommend the following actions:

- **Develop biomarkers for pesticide intoxications for bees**. The development of a specific biomarker in honey bees (*Apis mellifera*) would allow us to monitor the pesticide exposure risks in Belgium. In parallel, studies on pesticide toxicity and biomarker development are essential to understand the effect of pesticide mixes and pesticide molecules on solitary bees and bumblebees (see action n°3 from Folschweiller et al. 2019).

- **Test the relative diagnostic potential of solitary and social bee species to track the presence of pesticides in the environment**. Preliminary results by the Agroecology lab (project URBEESTRESS, funded by Bruxelles Environnement and in collaboration with UGent) indicate that solitary bees that collect pollen in bee hotels can be reliably used to monitor the presence of pesticides across urban green spaces in urban environments; parallel experiments in Wallonia led by CRA-w and Agroecology lab suggest that honeybees and solitary bees are complementary for this analytical approach and should therefore be used together to provide a more detailed evaluation of pesticide residues in the environment. Finally, the Agroecology lab has also led a pilot study (ToxiFlore, funded by Bruxelles Environnement and in collaboration with UGent) providing evidence of the presence of pesticides in leaves, flowers and pollen of horticultural plants available in garden shops to the public. This might therefore represent another route of exposition to pesticides for wild bees in urban habitats.

- **Promote good sanitary practices and adapt the regulatory framework for pesticides use**. Currently some first measures could be implemented on the field to reduce the risks for pollinators through the control of pesticide use. This would imply to change the regulatory framework of currently used pesticides, veterinary products and biocides (see action n°21 from Folschweiller et al. 2019).

- Promote alternatives for pesticides to farmers and other land managers. New management practices are needed in agricultural areas and green spaces in order to stop, or greatly limit the pesticides use in Belgium (see action n°21 from Folschweiller et al. 2019). In agricultural areas we recommend to accompany farmers into a transition toward different farming practices (ex: crop diversification, agroforestry, agroecology, organic farming, …). In non-agricultural areas (ex: road edges, public green spaces, citizen's gardens, …) adapted practices need to be more broadly applied (organic treatments, differentiated management, …).

- **Study the impact of nitrate inputs in different anthropogenic systems.** Following the European Directive (91/676/EEC) concerning the protection of waters against pollution caused by nitrates from agricultural sources, strategies to reduce nitrate inputs were settled and applied by federal and regional authorities in Belgium (i.e. 277kg/ha in 1990 to 165kg/ha in 2008 in arable lands, Belgian Federal Government 2008). However, few studies focussed on direct impact of these inputs with long residence time (from decades to centuries according to the soil type, Galloway et al. 2003) on pollinators (e.g. bees, Le Féon et al. 2010). In order to do so, more research should be performed on this topic.

5. Climate change

The current studies on climate change focused on global warming scenarios (Rasmont et al. 2015) as well as punctual extreme temperature events like heat waves. The consequences of these climate displays on wild bees' ecology, morphology and physiology (heat-stress resistance, phenological shifts, body size changes, …) are resulting research domains. Also, we need to better understand the interactions with other global changes such as landscape change (Marshall et al. 2018) and habitat fragmentation. Climate change should then be studied in a dynamic way (i.e. integrating other environmental factors). Nevertheless, some functional consequences have already been shown on plant-pollinators networks (Schleuning et al. 2016), heat-resistance (Martinet et al. in prep), body size (Gérard et al. 2018) … As a general trend, specialist species or species with a narrow climatic niche seem to be more at risk.

These results bring us to strongly recommend to support programs for climate change mitigation and to take actions to reduce climatic risks for wild bees.

More precisely, we recommend the following actions:

- **Study further the effects and mechanisms of climate change (in synergy with other global changes) on wild bees**. A better understanding of the effects and mechanisms of climate change - and its' synergies with other decline factors - is crucial to implement mitigation measures for wild bees (see action n°3 from Folschweiller et al. 2019). Further research is needed on wild bees and host plants phenological shifts. Furthermore, modelling the future climatic wild bees' sanctuaries would help to better plan sustainable wild bees' conservation (see action n°2 from Folschweiller et al. 2019).

- **Focus on reducing all the other causes of decline for wild bees**. Climate change is a global issue for which mitigation cannot be totally managed at Belgian scale. In this context, focusing on other decline causes (i.e. floral resources depletion, habitat regression, pesticides, diseases, …) that can be managed at the national level is important. For example, Vanderplanck et al. (2019) showed that a high-quality diet reduces the impact of heatstress on *Bombus terrestris*. For more information on how to achieve this goal, you can refer on the previous paragraphs and to the SAPOLL action plan for wild pollinators (Folschweiller et al. 2019).

6. Awareness raising and promotion of good practices

In previous paragraphs we suggested different measure or actions to achieve wild bees' preservation in Belgium. These measures can be implemented at various scales, with different actors and need to evolve as our knowledge on wild bee conservation improves. To do so, the planning of actions is necessary, for instance through national or regional action plans (e.g. the Action Plan developed in the scope of the Interreg SAPOLL project- Folschweiller et al. 2019). In parallel, information (naturalist, scientific and technical) needs to be spread among people that are willing to take adequate actions for wild bee conservation.

This context brings us to consider the valorization of scientific results and dissemination of information as essential in order to initiate targeted field actions.

More precisely, we recommend the following actions:

- **Support dissemination of scientific research in general audience**. Scientific results need to be shared and made understandable for society actors and stakeholders. Technical or financial supports (partnerships between universities and associations for instance) would improve the dispersion of scientific results amongst the civil society (see action n°10 from Folschweiller et al. 2019).

- **Raise awareness among the broad public**. Raising awareness amongst citizens is necessary for a large scale understanding of the pollinators' decline issue which is crucial to bring everyone to take actions. This can be done through various media such as citizen science programs, conferences, films and movies, social or outdoor events, … (see action n°10 from Folschweiller et al. 2019). The content of the citizen science message should evolve in consideration with the context and the target audience.

-**Promote biodiversity and wild bees in school programs**. Schools would certainly be the most efficient gateway to raise awareness amongst Belgian citizens (see action n°10 from Folschweiller et al. 2019). Also, basic pollinator courses should be available for future professionals having a link with land management such as farmers, landscape gardeners, horticulturists, … in order to help them integrate pollinators issues and adapt their practices in favor of wild bees (see action n°17 from Folschweiller et al. 2019).

- **Support the elaboration and promotion of good practice guidelines**. Indeed, good technical support is needed in order to bring people and professionals to take actions for pollinators (e.g. see Vereecken et al. 2017; Gosselin et al. 2018). These documents should provide information that are adapted to their context (profession, administrative and bioclimatic region, …) (see actions n°17 and 18 from Folschweiller et al. 2019). These good practices guidelines would be of greater impact if accompanied by some exemplary pilot projects (e.g. experimental farms, ideal garden for wild bees, …) (see actions n°34 and 35 from Folschweiller et al. 2019).

- **Support the development and implementation of a pollinator indicator**. A simple and comprehensive pollinator indicator would allow to rate and follow the health and evolution of pollinator communities within the Belgian territory. It would also help prioritize actions or adapt managements and would facilitate communication toward local stakeholders and decision makers.

7. Scientific monitoring and wild bees' monitoring

All previous recommendations rely on a general context of scientific survey and wild bee inventory and monitoring in order to keep improving our knowledge on wild bees and their decline. The scientific monitoring should be a long term, standardized and organized monitoring. Plus, wild bee fauna databases need to be connected, managed and made available.

These facts bring us to recommend standardized monitoring of wild bees to allow a precise follow-up of populations health and decline. We also suggest an efficient and coordinated management of wild bee databases to allow the sustainability of wild bee inventories and monitoring and the progresses of research.

More precisely, we recommend the following actions:

- **To organize wild bee data collection, digitization and distribution in concertation at the country scale**. In order to standardize bee inventories at the regional or national scale, concertation between stakeholders is necessary (see action n°7 and 8 from Folschweiller et al. 2019). Some factors such as exchange format, protocols and data management need to be commonly applied.

- **Ensure the durability of wild bee databases in Belgium**. Currently wild bee databases are managed by different structures and people. At present time data sharing takes place in the framework of specific projects and is not permanent or financially sustainable. Wild bee databases would be more consistent and lasting with country scaled data management and subventions.

- **Engage a transition toward open data for a better data valorization**. Wild bee conservation would benefit from the data sharing that could bring more sustainability and create more research and collaboration opportunities. It could lead to more scientific publications in relation with Belgian wild bees, or help taking wild bees into consideration in management projects by local actors.

- **Develop a bee monitoring programme on the regional or national level**, based on a standardized protocol applied on a representative number of locations. The occurrence records resulting from bee inventories that presently constitute the wild bee database(s) are suitable for assessing (changes in) the distribution of our wild bee species, but do not allow to monitor changes in the abundance of common bee species. Common bee and total bee abundance might have declined greatly over the past decades (as is the case for other insect groups) but there are not data available to test this, while it is also of very high importance for the pollination service which depends on a high enough abundance of mainly generalist and common bee species.

5.2 Future work

Mobilising a network of national bee experts in the scope of the BELBEES project, this Red List greatly benefitted from the contribution of NGO partners of the Interreg SAPOLL project (i.e. Natagora, Natuurpunt) which lead and animated the Belgian naturalist networks and citizen sciences programs (www.observations.be/www.waarnemingen.be) over the past 10 years. This work also greatly benefitted from the spatial data made available by the global database developed in the scope of the BELBEES project. However, the compilation of data for this Red List has revealed a number of knowledge gaps (see 3.6 Gap in knowledge). Significant geographic and taxonomic biases have been identified, namely in the quality of data available on the distribution and status of species.

As mentioned in the previous point (see 5.1 Recommendations), key challenges for the future are to improve knowledge, raise awareness, continue wild bee inventories (comprising data quality) as well as data openness and dissemination, and setting up bee monitoring. Based on these, conservation actions could be developed as solid a scientific basis as possible (Nieto et al. 2014).

It is hoped that by presenting this assessment, regional research will be stimulated to provide new data and to further improve data quality (Nieto et al. 2014). The Red List of Threatened Species constitutes a powerful tool for conservation planning, management, monitoring and decision making (Rodrigues et al. 2006). It is namely used to guide management of natural resources, national development policies and legislation as well as multilateral agreements (e.g., the Convention on International Trade in Endangered Species of Wild Fauna and Flora (i.e. CITES)) (Rodrigues et al. 2006).

Coelioxys alatus (Vulnerable). Kurt Geeraerts

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7. Appendix

Appendix 1: Red List status of Belgian bees. Legal protection status in Wallonia are mentioned as well as bee trends in 1991 ("-" for species in relative regression / "=" for species in relative status quo / "+" for species in relative expansion / "DD" for Data Deficient species; Rasmont et al. 1993). Red List status at European scale are also indicated.

Taxonomy	Protected in Wallonia	Trends in 1991 (Rasmont et al. 1993)	IUCN Red List Category (Belgium)	IUCN Red List Criteria (Belgium)	IUCN Red List Category (Europe)	IUCN Red List Criteria (Europe)
ANDRENIDAE						
Andrena agilissima	Yes	-	EN	A2bc; B2ab(iv)	DD	
Andrena alfkenella	No	Not mentioned	DD		DD	
Andrena angustior	No	+	NT	A2bc	DD	
Andrena anthrisci	No	DD	DD		LC	
Andrena apicata	No	=	LC		DD	
Andrena argentata	No	=	NT	A2bc; B1ab(iii)	DD	
Andrena assimilis	No	Not mentioned	NA		DD	
Andrena barbareae	No	Not mentioned	NA		DD	
Andrena barbilabris	No	+	LC		DD	
Andrena bicolor	No	+	LC		LC	
Andrena bimaculata	No	DD	NT	A2c	DD	
Andrena carantonica	No	+	LC		DD	
Andrena chrysopus	No	Not mentioned	DD		DD	
Andrena chrysopyga	No	-	RE		DD	
Andrena chrysosceles	No	+	LC		DD	
Andrena cineraria	No	=	LC		LC	
Andrena cinerea	No	Not mentioned	LC		DD	
Andrena clarkella	No	=	LC		DD	
Andrena coitana	No	=	EN	B1ab(i,ii,iv) +2ab(i,ii,iv)	DD	
Andrena combinata	No	-	CR	A2bc	DD	
Andrena curvungula	Yes	=	CR	A2c; B1ab(i,ii,iv) +2ab(i,ii,iv)	DD	
Andrena decipiens	No	Not mentioned	NA		DD	
Andrena denticulata	No	-	NT	A2c	DD	
Andrena distinguenda	No	Not mentioned	RE		DD	
Andrena dorsata	No	=	LC		DD	
Andrena falsifica	No	=	DD		DD	
Andrena ferox	No	DD	CR	B1ab(i,ii,iv) +2ab(i,ii,iv)	DD	
Andrena flavipes	No	+	LC		LC	
Andrena florea	No	=	LC		DD	

Taxonomy	Protected in Wallonia	Trends in 1991 (Rasmont et al. 1993)	IUCN Red List Category (Belgium)	IUCN Red List Criteria (Belgium)	IUCN Red List Category (Europe)	IUCN Red List Criteria (Europe)
Andrena floricola	No	Not mentioned	RE		DD	
Andrena fucata	No	+	VU	A2bc	DD	
Andrena fulva	No	+	LC		DD	
Andrena fulvago	No	=	NT	A2bc	DD	
Andrena fulvata	No	Not mentioned	NA		DD	
Andrena fulvida	No	-	EN	A2c; B1ab(i,ii,iii, iv) +2ab(i,ii,iii,iv)	NT	
Andrena fuscipes	Yes	=	LC		DD	
Andrena gelriae	No	DD	RE		DD	
Andrena gravida	No	=	LC		DD	
Andrena haemorrhoa	No	+	LC		LC	
Andrena hattorfiana	No	=	NT	A2bc; B1ab(i,iii) +2ab(i,iii)	NT	
Andrena helvola	No	+	VU	A2c	DD	
Andrena humilis	No	=	LC		DD	
Andrena intermedia	No	DD	EN	B1ab(iii) +2ab(iii)	LC	
Andrena labialis	Yes	=	NT	A2bc	DD	
Andrena labiata	No	=	LC		DD	
Andrena lapponica	No	=	VU	B1ab(ii,iii,iv) +2ab(ii,iii,iv)	LC	
Andrena lathyri	No	=	NT	A2b	DD	
Andrena limata	No	DD	RE		DD	
Andrena marginata	Yes	-	RE		DD	
Andrena minutula	No	+	LC		DD	
Andrena minutuloides	No	=	DD		DD	
Andrena mitis	No	=	LC		DD	
Andrena nana	No	DD	DD		LC	
Andrena nanula	No	Not mentioned	NA		DD	
Andrena nigriceps	No	DD	CR	B1ab(ii,iii,iv) +2ab(ii,iii,iv)	DD	
Andrena nigroaenea	No	+	LC		LC	
Andrena nigrospina	No	Not mentioned	DD		LC (*A. pilipes*)	
Andrena nitida	No	+	LC		LC	
Andrena nitidiuscula	No	DD	VU	B1ab(iii) +2ab(iii)	LC	
Andrena nitidula	No	Not mentioned	NA		DD	
Andrena niveata	No	DD	DD		DD	
Andrena nycthemera	No	DD	LC		DD	
Andrena ovatula	No	-	NT	A2c	NT	
Andrena pandellei	No	=	VU	B2ab(iii)	LC	

Taxonomy	Protected in Wallonia	Trends in 1991 (Rasmont et al. 1993)	IUCN Red List Category (Belgium)	IUCN Red List Criteria (Belgium)	IUCN Red List Category (Europe)	IUCN Red List Criteria (Europe)
Andrena pilipes	No	-	DD		LC	
Andrena polita	No	=	CR	A2bc; B1ab(i,ii,iii,iv) +2ab(i,ii,iii,iv)	LC	
Andrena potentillae	No	DD	CR	B1ab(iii) +2ab(iii)	DD	
Andrena praecox	No	=	LC		LC	
Andrena propinqua	No	Not mentioned	DD		DD	
Andrena proxima	No	=	LC		DD	
Andrena pusilla	No	Not mentioned	DD		DD	
Andrena rosae	No	-	LC		DD	
Andrena ruficrus	No	=	NT	A2b	LC	
Andrena schencki	No	-	EN	A2bc; B1ab(i,ii,iii,iv) +2ab(i,ii,iii,iv)	DD	
Andrena semilaevis	No	=	DD		DD	
Andrena similis	No	=	CR	A2bc; B1ab(i,ii,iv) +2ab(i,ii,iv)	DD	
Andrena spreta	No	=	DD		DD	
Andrena strohmella	No	=	DD		LC	
Andrena subopaca	No	+	LC		DD	
Andrena synadelpha	No	+	CR	A2bc; B1ab(i,ii,iii,iv) +2ab(i,ii,iii,iv)	DD	
Andrena tarsata	No	-	EN	A2bc	DD	
Andrena thoracica	No	DD	RE		DD	
Andrena tibialis	No	=	LC		LC	
Andrena trimmerana	No	Not mentioned	DD		DD	
Andrena vaga	No	=	LC		LC	
Andrena varians	No	=	CR	A2bc	LC	
Andrena ventralis	No	=	LC		DD	
Andrena viridescens	No	Not mentioned	LC		DD	
Andrena wilkella	No	=	NT	A2c	DD	
Panurgus banksianus	Yes	=	LC		LC	
Panurgus calcaratus	Yes	-	LC		LC	
Panurgus dentipes	Yes	DD	LC		LC	
APIDAE						
Ammobates punctatus	Yes	-	CR	A2bc; B1ab(i,ii,iii,iv) +2ab(i,ii,iii,iv)	LC	
Anthophora aestivalis	Yes	-	RE		LC	
Anthophora bimaculata	Yes	-	CR	A2bc; B1ab(i,ii,iii,iv) +2ab(i,ii,iii,iv)	LC	

Taxonomy	Protected in Wallonia	Trends in 1991 (Rasmont et al. 1993)	IUCN Red List Category (Belgium)	IUCN Red List Criteria (Belgium)	IUCN Red List Category (Europe)	IUCN Red List Criteria (Europe)
Anthophora borealis	No	Not mentioned	RE		NT	
Anthophora furcata	No	-	LC		LC	
Anthophora plagiata	Yes	-	RE		LC	
Anthophora plumipes	No	+	LC		LC	
Anthophora quadrimaculata	No	-	LC		DD	
Anthophora retusa	Yes	-	EN	A2c	LC	
Apis mellifera	No	Not mentioned	DD		DD	
Biastes truncatus	No	DD	RE		VU	B2ab(i,ii,v)
Bombus barbutellus	No	-	CR	A2bc; B1ab(i,ii,iii,iv)	LC	
Bombus bohemicus	No	+	NT	A2bc	LC	
Bombus campestris	No	-	VU	A2bc	LC	
Bombus confusus	No	-	RE		VU	A2c+3c+4c
Bombus cryptarum	No	Not mentioned	EN	A2bc	LC	
Bombus cullumanus	No	DD	RE		CR	A2c
Bombus distinguendus	Yes	-	RE		VU	A2c
Bombus hortorum	No	-	NT	A2bc	LC	
Bombus humilis	Yes	-	CR	A2bc; B1ab(i,ii,iii,iv)	LC	
Bombus hypnorum	No	+	LC		LC	
Bombus jonellus	Yes	-	VU	A2bc	LC	
Bombus lapidarius	No	-	LC		LC	
Bombus lucorum	No	Not mentioned	NT	A2bc	LC	
Bombus magnus	No	Not mentioned	EN	A2bc	LC	
Bombus muscorum	Yes	-	CR	A2bc	VU	A2c
Bombus norvegicus	No	DD	VU	B1ab(i,ii) +2ab(i,ii)	LC	
Bombus pascuorum	No	+	LC		LC	
Bombus pomorum	No	-	RE		VU	A2c
Bombus pratorum	No	+	LC		LC	
Bombus ruderarius	No	-	EN	A2bc	LC	
Bombus ruderatus	No	-	CR	A2bc; B1ab(i,ii,iii,iv)	LC	
Bombus rupestris	No	-	EN	A2bc	LC	
Bombus soroeensis	No	-	VU	A2bc	LC	
Bombus subterraneus	No	-	RE		LC	
Bombus sylvarum	Yes	-	CR	A2bc; B1ab(i,ii,iii,iv)	LC	
Bombus sylvestris	No	+	LC		LC	
Bombus terrestris	No	Not mentioned	LC		LC	
Bombus vestalis	No	-	NT	A2bc	LC	
Bombus veteranus	Yes	-	CR	A2bc	LC	

Taxonomy	Protected in Wallonia	Trends in 1991 (Rasmont et al. 1993)	IUCN Red List Category (Belgium)	IUCN Red List Criteria (Belgium)	IUCN Red List Category (Europe)	IUCN Red List Criteria (Europe)
Bombus wurflenii	No	DD	RE		LC	
Ceratina cyanea	No	=	LC		LC	
Epeoloides coecutiens	Yes	DD	LC		LC	
Epeolus cruciger	Yes	=	NT	A2c	NT	
Epeolus tarsalis	No	Not mentioned	CR	B1ab(i,ii,iii) +2ab(i,ii,iii)	NT	
Epeolus variegatus	Yes	=	LC		LC	
Eucera longicornis	Yes	=	VU	A2bc; B1ab(i,iii) +2ab(i,iii)	LC	
Eucera nigrescens	Yes	=	EN	A2bc; B1ab(i,iii)	LC	
Melecta albifrons	No	+	NT	A2c	LC	
Melecta luctuosa	Yes	-	CR	A2bc; B1ab(i,ii,iii,iv)	LC	
Nomada alboguttata	No	=	LC		LC	
Nomada argentata	No	DD	RE		NT	
Nomada armata	No	=	EN	B1ab(i,ii,iii) +2ab(i,ii,iii)	NT	
Nomada baccata	No	DD	DD		NT	
Nomada bifasciata	No	-	LC		LC	
Nomada castellana	No	DD	RE		LC	
Nomada conjungens	No	=	LC		LC	
Nomada distinguenda	No	-	EN	A2bc; B1ab(i,ii,iii) +2ab(i,ii,iii)	LC	
Nomada emarginata	No	=	RE		LC	
Nomada fabriciana	No	=	LC		LC	
Nomada facilis	No	Not mentioned	LC		LC	
Nomada femoralis	No	-	VU	A2bc	LC	
Nomada ferruginata	No	=	LC		LC	
Nomada flava	No	+	LC		LC	
Nomada flavoguttata	No	=	LC		LC	
Nomada flavopicta	No	-	LC		LC	
Nomada fucata	No	-	LC		LC	
Nomada fulvicornis	No	=	LC		LC	
Nomada furva	No	DD	EN	A2bc; B1ab(i,ii,iii,iv) + 2ab(i,ii,iii,iv)	DD	
Nomada fuscicornis	No	-	EN	A2bc; B1ab(i,ii,iii,iv) + 2ab(i,ii,iii,iv)	LC	
Nomada goodeniana	No	-	LC		LC	
Nomada guttulata	No	DD	LC		LC	
Nomada integra	No	-	VU	A2bc	LC	
Nomada lathburiana	No	=	LC		LC	
Nomada leucophthalma	No	-	LC		LC	
Nomada marshamella	No	=	LC		LC	

Taxonomy	Protected in Wallonia	Trends in 1991 (Rasmont et al. 1993)	IUCN Red List Category (Belgium)	IUCN Red List Criteria (Belgium)	IUCN Red List Category (Europe)	IUCN Red List Criteria (Europe)
Nomada melathoracica	No	DD	RE		LC	
Nomada mutabilis	No	DD	RE		LC	
Nomada mutica	No	DD	CR	B1ab(i,ii,iii,iv) + 2ab(i,ii,iii,iv)	NT	
Nomada obscura	Yes	=	LC		LC	
Nomada obtusifrons	No	DD	CR	B1ab(i,ii,iii,iv) + 2ab(i,ii,iii,iv)	NT	
Nomada opaca	No	DD	EN	B1ab(ii,iii) + 2ab(ii,iii)	NT	
Nomada panzeri	No	=	LC		LC	
Nomada piccioliana	No	DD	CR	B1ab(i,ii,iii,iv) + 2ab(i,ii,iii,iv)	LC	
Nomada pleurosticta	No	DD	RE		NT	
Nomada rhenana	No	DD	RE		NT	
Nomada roberjeotiana	No	-	RE		NT	
Nomada ruficornis	No	-	LC		LC	
Nomada rufipes	No	=	NT	A2c	LC	
Nomada sexfasciata	No	-	CR	A2bc	LC	
Nomada sheppardana	No	-	LC		LC	
Nomada signata	No	-	LC		LC	
Nomada similis	No	=	EN	A2bc; B1ab(i,ii,iii,iv) + 2ab(i,ii,iii,iv)	LC	
Nomada stigma	No	DD	LC		LC	
Nomada striata	No	=	VU	A2c	LC	
Nomada succincta	No	Not mentioned	LC		LC	
Nomada villosa	No	DD	EN	B1ab(i,ii,iii,iv) + 2ab(i,ii,iii,iv)	NT	
Nomada zonata	No	DD	LC		LC	
Thyreus orbatus	Yes	-	EN	A2bc	LC	
Xylocopa violaceae	No	DD	LC		LC	
Xylocopa virginica	No	Not mentioned	NA		-	
COLLETIDAE						
Colletes cunicularius	Yes	-	LC		LC	
Colletes daviesanus	No	+	LC		LC	
Colletes fodiens	No	=	LC		VU	B2ab(ii,iii)
Colletes halophilus	No	+	LC		NT	
Colletes hederae	No	Not mentioned	LC		LC	
Colletes hylaeiformis	No	Not mentioned	NA		LC	
Colletes marginatus	No	DD	LC		LC	
Colletes similis	No	DD	LC		LC	
Colletes succinctus	No	=	LC		NT	

Taxonomy	Protected in Wallonia	Trends in 1991 (Rasmont et al. 1993)	IUCN Red List Category (Belgium)	IUCN Red List Criteria (Belgium)	IUCN Red List Category (Europe)	IUCN Red List Criteria (Europe)
Hylaeus angustatus	No	DD	EN	B1ab(iii) + 2ab(iii)	LC	
Hylaeus annularis	No	+	DD		DD	
Hylaeus annulatus	No	Not mentioned	NA		DD	
Hylaeus bifasciatus	No	DD	NA		DD	
Hylaeus brevicornis	No	=	DD		LC	
Hylaeus clypearis	No	DD	DD		LC	
Hylaeus communis	No	+	LC		LC	
Hylaeus confusus	No	=	LC		LC	
Hylaeus cornutus	No	=	LC		LC	
Hylaeus difformis	No	DD	LC		LC	
Hylaeus dilatatus	No	Not mentioned	DD		LC	
Hylaeus gibbus	No	=	DD		LC	
Hylaeus gracilicornis	No	DD	DD		LC	
Hylaeus gredleri	No	Not mentioned	DD		LC	
Hylaeus hyalinatus	No	+	LC		LC	
Hylaeus incongruus	No	Not mentioned	DD		DD	
Hylaeus leptocephalus	No	-	CR	B1ab(i,ii,iii,iv) + 2ab(i,ii,iii,iv)	LC	
Hylaeus nigritus	No	DD	EN	B1ab(i,ii,iii,iv) + 2ab(i,ii,iii,iv)	LC	
Hylaeus paulus	No	Not mentioned	DD		LC	
Hylaeus pectoralis	No	=	LC		DD	
Hylaeus pictipes	No	=	LC		LC	
Hylaeus pilosulus	No	=	RE		DD	
Hylaeus punctulatissimus	No	=	LC		DD	
Hylaeus punctatus	No	Not mentioned	LC		LC	
Hylaeus rinki	No	=	VU	A2bc; B1ab(i,ii,iii,iv) + 2ab(i,ii,iii,iv)	LC	
Hylaeus signatus	No	=	LC		LC	
Hylaeus sinuatus	No	DD	DD		LC	
Hylaeus styriacus	No	DD	LC		DD	
Hylaeus variegatus	No	-	NT	A2bc	LC	
HALICTIDAE						
Dufourea dentiventris	No	=	EN	A2bc	NT	
Dufourea halictula	No	DD	CR	A2bc; B1ab(ii,iv) +2ab(ii,iv)	NT	
Dufourea inermis	No	=	CR	A2bc; B1ab(ii,iv) +2ab(ii,iv)	NT	

Taxonomy	Protected in Wallonia	Trends in 1991 (Rasmont et al. 1993)	IUCN Red List Category (Belgium)	IUCN Red List Criteria (Belgium)	IUCN Red List Category (Europe)	IUCN Red List Criteria (Europe)
Dufourea minuta	No	-	RE		NT	
Halictus eurygnathus	No	DD	CR	A2bc; B1ab(i,ii,iv) +2ab(i,ii,iv)	LC (*H. compressus*)	
Halictus maculatus	No	-	VU	A2bc	LC	
Halictus quadricinctus	No	-	CR	A2bc	NT	
Halictus rubicundus	No	=	LC		LC	
Halictus scabiosae	No	=	LC		LC	
Halictus sexcinctus	No	-	VU	A2bc	LC	
Halictus simplex	No	-	EN	A2bc; B2ab(ii,iv)	LC	
Lasioglossum albipes	No	=	NT	A2bc	LC	
Lasioglossum brevicorne	No	=	EN	A2bc; B2ab(ii,iv)	NT	
Lasioglossum breviventre	No	DD	RE		EN	B2ab(i,ii,v)
Lasioglossum calceatum	No	+	LC		LC	
Lasioglossum costulatum	No	DD	CR	B1ab(i,ii,iii,iv) +2ab(i,ii,iii,iv)	NT	
Lasioglossum fratellum	No	=	DD		LC	
Lasioglossum fulvicorne	No	=	LC		LC	
Lasioglossum glabriusculum	No	Not mentioned	NA		LC	
Lasioglossum interruptum	No	DD	RE		LC	
Lasioglossum laevigatum	No	=	VU	A2bc; B1ab(i,ii,iv)	NT	
Lasioglossum laticeps	No	=	LC		LC	
Lasioglossum lativentre	No	-	LC		LC	
Lasioglossum laeve	No	DD	RE		EN	B2ab(i,ii,iv)
Lasioglossum leucopus	No	=	NT	A2bc	LC	
Lasioglossum leucozonium	No	=	LC		LC	
Lasioglossum lineare	No	=	RE		DD	
Lasioglossum lucidulum	No	=	LC		LC	
Lasioglossum majus	No	Not mentioned	LC		NT	
Lasioglossum malachurum	No	=	LC		LC	
Lasioglossum minutissimum	No	=	LC		LC	
Lasioglossum minutulum	No	=	VU	A2bc; B1ab(i,ii,iii,iv) + 2ab(i,ii,iii,iv)	NT	
Lasioglossum monstrificum	No	Not mentioned	VU	A2c	NT (*L. sabulosum*)	
Lasioglossum morio	No	=	LC		LC	
Lasioglossum nigripes	No	Not mentioned	RE		LC	
Lasioglossum nitidiusculum	No	=	LC		LC	
Lasioglossum nitidulum	No	+	LC		LC	
Lasioglossum pallens	No	Not mentioned	LC		LC	

Taxonomy	Protected in Wallonia	Trends in 1991 (Rasmont et al. 1993)	IUCN Red List Category (Belgium)	IUCN Red List Criteria (Belgium)	IUCN Red List Category (Europe)	IUCN Red List Criteria (Europe)
Lasioglossum parvulum	No	=	LC		LC	
Lasioglossum pauxillum	No	=	LC		LC	
Lasioglossum politum	No	DD	RE		LC	
Lasioglossum prasinum	No	=	EN	B1ab(i,ii,iii,iv)	NT	
Lasioglossum punctatissimum	No	+	LC		LC	
Lasioglossum puncticolle	No	Not mentioned	NA		LC	
Lasioglossum pygmaeum	No	-	VU	B1ab(i,ii,iii,iv) + 2ab(i,ii,iii,iv)	NT	
Lasioglossum quadrinotatulum	No	=	VU	A2c	NT	
Lasioglossum quadrinotatum	No	=	CR	A2bc	NT	
Lasioglossum rufitarse	No	=	NT	A2bc	LC	
Lasioglossum semilucens	No	=	LC		LC	
Lasioglossum sexnotatum	No	-	LC		NT	
Lasioglossum sexstrigatum	No	=	LC		LC	
Lasioglossum subfasciatum	No	Not mentioned	RE		EN	B2ab(i,ii,v)
Lasioglossum subfulvicorne	No	Not mentioned	DD		LC	
Lasioglossum subhirtum	No	Not mentioned	RE		LC	
Lasioglossum tarsatum	No	DD	CR	B2ab(i,ii,iii,iv)	NT	
Lasioglossum villosulum	No	=	LC		LC	
Lasioglossum xanthopus	No	-	EN	A2bc	NT	
Lasioglossum zonulum	No	=	LC		LC	
Rhophitoides canus	No	Not mentioned	RE		LC	
Rophites quinquespinosus	Yes	DD	CR	A2bc B1ab(i)	NT	
Seladonia confusa	No	=	VU	A2c	LC (*H. confusus*)	
Seladonia leucahenea	No	-	CR	A2bc; B1ab(i,ii,iv) +2ab(i,ii,iv)	VU (*H. leucaheneus*)	B2ab(iii,v)
Seladonia subaurata	No	Not mentioned	NA		LC (*H. subauratus*)	
Seladonia tumulorum	No	+	LC		LC (*H. tumulorum*)	
Sphecodes albilabris	No	-	LC		LC	
Sphecodes alternatus	No	Not mentioned	DD		LC	
Sphecodes crassus	No	+	LC		LC	
Sphecodes ephippius	No	+	LC		LC	
Sphecodes ferruginatus	No	=	LC		LC	
Sphecodes geoffrellus	No	+	LC		LC	
Sphecodes gibbus	No	=	LC		LC	
Sphecodes hyalinatus	No	=	LC		NT	

Taxonomy	Protected in Wallonia	Trends in 1991 (Rasmont et al. 1993)	IUCN Red List Category (Belgium)	IUCN Red List Criteria (Belgium)	IUCN Red List Category (Europe)	IUCN Red List Criteria (Europe)
Sphecodes longulus	No	=	LC		LC	
Sphecodes majalis	No	Not mentioned	DD		NT	
Sphecodes marginatus	No	=	VU	B1ab(i,ii,iv) +2ab(i,ii,iv)	LC	
Sphecodes miniatus	No	=	LC		LC	
Sphecodes monilicornis	No	=	LC		LC	
Sphecodes niger	No	DD	VU	B1ab(i,ii,iv) +2ab(i,ii,iv)	LC	
Sphecodes pellucidus	No	+	LC		LC	
Sphecodes puncticeps	No	=	LC		LC	
Sphecodes reticulatus	No	-	LC		LC	
Sphecodes rubicundus	No	-	CR	A2bc; B1ab(i,ii,,iii,iv) +2ab(i,ii,iii,iv)	NT	
Sphecodes rufiventris	No	DD	CR	A2bc; B1ab(i,ii,iv) +2ab(i,ii,iv)	LC	
Sphecodes scabricollis	No	-	EN	A2bc	DD	
Sphecodes spinulosus	No	-	CR	A2bc; B1ab(i,ii,iv) +2ab(i,ii,iv)	NT	
MEGACHILIDAE						
Aglaoapis tridentata	No	DD	RE		LC	
Anthidiellum strigatum	No	=	LC		LC	
Anthidium manicatum	No	=	LC		LC	
Anthidium oblongatum	No	=	LC		LC	
Anthidium punctatum	Yes	-	LC		LC	
Chelostoma campanularum	No	=	LC		LC	
Chelostoma distinctum	No	=	VU	A2c; B1ab(ii,iii)	LC	
Chelostoma florisomne	No	=	LC		LC	
Chelostoma rapunculi	No	+	LC		LC	
Coelioxys afer	Yes	DD	CR	A2bc; B1ab(i,ii,iv) +2ab(i,ii,iv)	LC (*C. afra*)	
Coelioxys alatus	Yes	DD	VU	B1ab(iii) + 2ab(iii)	LC (*C. alata*)	
Coelioxys aurolimbatus	Yes	-	LC		LC (*C. aurolimbata*)	
Coelioxys conoideus	Yes	-	CR	A2bc; B1(i,ii,iii,iv,v)	LC (*C. conoidea*)	
Coelioxys echinatus	Yes	Not mentioned	DD		LC (*C. echinata*)	
Coelioxys elongatus	Yes	=	VU	A2bc; B1ab(iii) + 2ab(iii)	LC (*C. elongata*)	
Coelioxys emarginatus	Yes	DD	RE		LC (*C. emarginata*)	
Coelioxys inermis	Yes	=	LC		LC	

Taxonomy	Protected in Wallonia	Trends in 1991 (Rasmont et al. 1993)	IUCN Red List Category (Belgium)	IUCN Red List Criteria (Belgium)	IUCN Red List Category (Europe)	IUCN Red List Criteria (Europe)
Coelioxys mandibularis	Yes	=	VU	A2c; B1ab(i,ii,iii,iv) +2ab(i,ii,iii,iv)	LC	
Coelioxys quadridendatus	Yes	=	CR	A2bc; B1ab (i,ii,iv) +2ab (i,ii,iv)	LC (*C. quadridentata*)	
Coelioxys rufescens	Yes	-	NT	A2bc; B1ab(i,ii)	LC	
Heriades truncorum	No	+	LC		LC	
Hoplitis adunca	No	-	LC		LC	
Hoplitis anthocopoides	No	-	CR	A2bc; B1ab(i,ii,iii,iv) +2ab(i,ii,iii,iv)	LC	
Hoplitis claviventris	No	=	VU	A2bc	LC	
Hoplitis leucomelana	No	=	LC		LC	
Hoplitis mitis	No	DD	NA		LC	
Hoplitis papaveris	No	-	RE		LC	
Hoplitis ravouxi	No	=	CR	A2c; B1ab(i,ii,iv)	LC	
Hoplitis tridentata	No	Not mentioned	LC		LC	
Hoplitis villosa	No	-	RE		LC	
Megachile alpicola	No	=	VU	A2c; B1ab(i,ii,iv) +2ab(i,ii,iv)	DD	
Megachile analis	No	DD	CR	A2bc; B1ab(iii) +2ab(iii)	DD	
Megachile centuncularis	No	=	LC		LC	
Megachile circumcincta	No	-	EN	A2bc	LC	
Megachile ericetorum	No	=	LC		LC	
Megachile genalis	No	DD	CR	A2bc; B1ab(iii) +2ab(iii)	DD	
Megachile lagopoda	No	-	CR	A2bc; B1ab(i,ii,iii,iv)	LC	
Megachile lapponica	No	+	LC		DD	
Megachile leachella	No	=	VU	A2bc; B1ab(iii) +2ab(iii)	LC	
Megachile ligniseca	No	-	LC		DD	
Megachile maritima	No	=	CR	A2bc; B1ab(i,ii,iii,iv) +2ab(i,ii,iii,iv)	DD	
Megachile octosignata	No	Not mentioned	NA		DD	
Megachile pilidens	No	DD	CR	B2ab(iii)	LC	
Megachile pyrenaea	No	-	LC		DD	
Megachile rotundata	No	DD	LC		DD	
Megachile versicolor	No	=	LC		DD	
Megachile willughbiella	No	=	LC		LC	
Osmia andrenoides	No	DD	CR	B1ab(iii) +2ab(iii)	LC	
Osmia aurulenta	No	-	NT	A2c	LC	

Taxonomy	Protected in Wallonia	Trends in 1991 (Rasmont et al. 1993)	IUCN Red List Category (Belgium)	IUCN Red List Criteria (Belgium)	IUCN Red List Category (Europe)	IUCN Red List Criteria (Europe)
Osmia bicolor	Yes	=	LC		LC	
Osmia bicornis	No	+	LC		LC	
Osmia brevicornis	No	DD	NA		LC	
Osmia caerulescens	No	=	LC		LC	
Osmia cornuta	No	+	LC		LC	
Osmia inermis	No	DD	NA		LC	
Osmia leaiana	No	=	LC		LC	
Osmia mustelina	No	DD	NA		LC	
Osmia niveata	No	=	LC		LC	
Osmia parietina	No	=	EN	A2c; B1ab(i,ii,iv) +2ab(i,ii,iv)	LC	
Osmia pilicornis	No	-	RE		LC	
Osmia rufohirta	No	=	EN	A2bc; B1ab(i,ii,iii,iv) +2ab(i,ii,iii,iv)	LC	
Osmia spinulosa	No	-	NT	A2bc; B1ab(iii) +2ab(iii)	LC	
Osmia uncinata	No	=	EN	A2bc; B1ab(i,ii,iv) +2ab(i,ii,iv)	LC	
Osmia xanthomelana	No	-	RE		LC	
Pseudanthidium scapulare	No	Not mentioned	NA		DD	
Stelis breviuscula	No	=	LC		LC	
Stelis minima	No	DD	RE		LC	
Stelis minuta	No	=	RE		LC	
Stelis odontopyga	No	DD	NA		LC	
Stelis ornatula	No	=	VU	A2bc; B2ab(i,ii,iv)	LC	
Stelis phaeoptera	No	-	NT	A2bc; B1ab(i,ii) +2ab(i,ii)	DD	
Stelis punctulatissima	No	-	LC		LC	
Stelis signata	No	-	VU	A2bc	LC	
Trachusa byssina	Yes	-	LC		LC	
MELITTIDAE						
Dasypoda argentata	No	Not mentioned	RE		NT	
Dasypoda hirtipes	Yes	=	LC		LC	
Macropis europaea	Yes	=	LC		LC	
Macropis fulvipes	Yes	=	LC		LC	
Melitta dimidiata	No	Not mentioned	NA		NT	
Melitta haemorrhoidalis	No	=	LC		LC	
Melitta leporina	No	-	LC		LC	
Melitta nigricans	No	=	LC		LC	
Melitta tricincta	No	=	VU	B2ab(i,ii,iii)	NT	

Appendix 2: IUCN Red List status of Belgian bees by major ecological traits.

Taxonomy	IUCN Red List Category (Belgium)	IUCN Red List Criteria (Belgium)	Host range	Sociality	Nesting
ANDRENIDAE					
Andrena agilissima	EN	A2bc; B2ab(iv)	Specialised	Solitary	Excavator - Ground
Andrena alfkenella	DD		Opportunist	Solitary	Excavator - Ground
Andrena angustior	NT	A2bc	Opportunist	Solitary	Excavator - Ground
Andrena anthrisci	DD		Unknown	Solitary	Excavator - Ground
Andrena apicata	DD		Specialised	Solitary	Excavator - Ground
Andrena argentata	NT	A2bc; B1ab(iii)	Opportunist	Solitary	Excavator - Ground
Andrena assimilis	NA		Opportunist	Solitary	Excavator - Ground
Andrena barbareae	NA		Opportunist	Solitary	Excavator - Ground
Andrena barbilabris	LC		Opportunist	Solitary	Excavator - Ground
Andrena batava	DD		Specialised	Solitary	Excavator - Ground
Andrena bicolor	LC		Opportunist	Solitary	Excavator - Ground
Andrena bimaculata	NT	A2c	Opportunist	Solitary	Excavator - Ground
Andrena carantonica	LC		Opportunist	Solitary	Excavator - Ground
Andrena chrysopus	DD		Specialised	Solitary	Excavator - Ground
Andrena chrysopyga	RE		Opportunist	Solitary	Excavator - Ground
Andrena chrysosceles	LC		Opportunist	Solitary	Excavator - Ground
Andrena cineraria	LC		Opportunist	Solitary	Excavator - Ground
Andrena cinerea	LC		Opportunist	Solitary	Excavator - Ground
Andrena clarkella	LC		Specialised	Solitary	Excavator - Ground
Andrena coitana	EN	B1ab(i,ii,iv) +2ab(i,ii,iv)	Opportunist	Solitary	Excavator - Ground
Andrena combinata	CR	A2bc	Opportunist	Solitary	Excavator - Ground
Andrena curvungula	CR	A2c; B1ab(i,ii,iv) +2ab(i,ii,iv)	Specialised	Solitary	Excavator - Ground
Andrena decipiens	NA		Opportunist	Solitary	Excavator - Ground
Andrena denticulata	NT	A2c	Specialised	Solitary	Excavator - Ground
Andrena distinguenda	RE		Specialised	Solitary	Excavator - Ground
Andrena dorsata	LC		Opportunist	Solitary	Excavator - Ground
Andrena falsifica	DD		Unknown	Solitary	Excavator - Ground
Andrena ferox	CR	B1ab(i,ii,iv) +2ab(i,ii,iv)	Opportunist	Solitary	Excavator - Ground
Andrena flavipes	LC		Opportunist	Solitary	Excavator - Ground
Andrena florea	LC		Specialised	Solitary	Excavator - Ground
Andrena floricola	RE		Unknown	Solitary	Excavator - Ground
Andrena fucata	VU	A2bc	Opportunist	Solitary	Excavator - Ground
Andrena fulva	LC		Opportunist	Solitary	Excavator - Ground
Andrena fulvago	NT	A2bc	Specialised	Solitary	Excavator - Ground
Andrena fulvata	NA		Opportunist	Solitary	Excavator - Ground
Andrena fulvida	EN	A2c; B1ab(i,ii,iii, iv) +2ab(i,ii,iii,iv)	Opportunist	Solitary	Excavator - Ground
Andrena fuscipes	LC		Specialised	Solitary	Excavator - Ground
Andrena gelriae	RE		Specialised	Solitary	Excavator - Ground
Andrena gravida	LC		Opportunist	Solitary	Excavator - Ground

Taxonomy	IUCN Red List Category (Belgium)	IUCN Red List Criteria (Belgium)	Host range	Sociality	Nesting
Andrena haemorrhoa	LC		Opportunist	Solitary	Excavator - Ground
Andrena hattorfiana	NT	A2bc; B1ab(i,iii) +2ab(i,iii)	Specialised	Solitary	Excavator - Ground
Andrena helvola	VU	A2c	Opportunist	Solitary	Excavator - Ground
Andrena humilis	LC		Specialised	Solitary	Excavator - Ground
Andrena intermedia	EN	B1ab(iii) +2ab(iii)	Specialised	Solitary	Excavator - Ground
Andrena labialis	NT	A2bc	Specialised	Solitary	Excavator - Ground
Andrena labiata	LC		Opportunist	Solitary	Excavator - Ground
Andrena lapponica	VU	B1ab(ii,iii,iv) +2ab(ii,iii,iv)	Specialised	Solitary	Excavator - Ground
Andrena lathyri	NT	A2b	Specialised	Solitary	Excavator - Ground
Andrena limata	RE		Opportunist	Solitary	Excavator - Ground
Andrena marginata	RE		Specialised	Solitary	Excavator - Ground
Andrena minutula	LC		Opportunist	Solitary	Excavator - Ground
Andrena minutuloides	DD		Opportunist	Solitary	Excavator - Ground
Andrena mitis	LC		Specialised	Solitary	Excavator - Ground
Andrena nana	DD		Opportunist	Solitary	Excavator - Ground
Andrena nanula	NA		Unknown	Solitary	Excavator - Ground
Andrena nigriceps	CR	B1ab(ii,iii,iv) +2ab(ii,iii,iv)	Opportunist	Solitary	Excavator - Ground
Andrena nigroaenea	LC		Opportunist	Solitary	Excavator - Ground
Andrena nigrospina	DD		Opportunist	Solitary	Excavator - Ground
Andrena nitida	LC		Opportunist	Solitary	Excavator - Ground
Andrena nitidiuscula	VU	B1ab(iii) +2ab(iii)	Specialised	Solitary	Excavator - Ground
Andrena nitidula	NA		Unknown	Solitary	Excavator - Ground
Andrena niveata	DD		Specialised	Solitary	Excavator - Ground
Andrena nycthemera	LC		Specialised	Solitary	Excavator - Ground
Andrena ovatula	NT	A2c	Opportunist	Solitary	Excavator - Ground
Andrena pandellei	VU	B2ab(iii)	Specialised	Solitary	Excavator - Ground
Andrena pilipes	DD		Opportunist	Solitary	Excavator - Ground
Andrena polita	CR	A2bc; B1ab(i,ii,iii,iv) +2ab(i,ii,iii,iv)	Specialised	Solitary	Excavator - Ground
Andrena potentillae	CR	B1ab(iii) +2ab(iii)	Specialised	Solitary	Excavator - Ground
Andrena praecox	LC		Specialised	Solitary	Excavator - Ground
Andrena propinqua	DD		Opportunist	Solitary	Excavator - Ground
Andrena proxima	LC		Specialised	Solitary	Excavator - Ground
Andrena pusilla	DD		Unknown	Solitary	Excavator - Ground
Andrena rosae	LC		Opportunist	Solitary	Excavator - Ground
Andrena ruficrus	NT	A2b	Specialised	Solitary	Excavator - Ground
Andrena schencki	EN	A2bc; B1ab(i,ii,iii,iv) +2ab(i,ii,iii,iv)	Opportunist	Solitary	Excavator - Ground
Andrena semilaevis	DD		Opportunist	Solitary	Excavator - Ground
Andrena similis	CR	A2bc; B1ab(i,ii,iv) +2ab(i,ii,iv)	Specialised	Solitary	Excavator - Ground
Andrena spreta	DD		Unknown	Solitary	Excavator - Ground
Andrena strohmella	DD		Opportunist	Solitary	Excavator - Ground

Taxonomy	IUCN Red List Category (Belgium)	IUCN Red List Criteria (Belgium)	Host range	Sociality	Nesting
Andrena subopaca	LC		Opportunist	Solitary	Excavator - Ground
Andrena synadelpha	CR	A2bc; B1ab(i,ii,iii,iv) +2ab(i,ii,iii,iv)	Opportunist	Solitary	Excavator - Ground
Andrena tarsata	EN	A2bc	Specialised	Solitary	Excavator - Ground
Andrena thoracica	RE		Opportunist	Solitary	Excavator - Ground
Andrena tibialis	LC		Opportunist	Solitary	Excavator - Ground
Andrena trimmerana	DD		Opportunist	Solitary	Excavator - Ground
Andrena vaga	LC		Specialised	Solitary	Excavator - Ground
Andrena varians	CR	A2bc	Opportunist	Solitary	Excavator - Ground
Andrena ventralis	LC		Specialised	Solitary	Excavator - Ground
Andrena viridescens	LC		Specialised	Solitary	Excavator - Ground
Andrena wilkella	NT	A2c	Specialised	Solitary	Excavator - Ground
Panurgus banksianus	LC		Specialised	Solitary	Excavator - Ground
Panurgus calcaratus	LC		Specialised	Solitary	Excavator - Ground
Panurgus dentipes	LC		Specialised	Solitary	Excavator - Ground
APIDAE					
Ammobates punctatus	CR	A2bc; B1ab(i,ii,iii,iv) +2ab(i,ii,iii,iv)	-	Kleptoparasite	-
Anthophora aestivalis	RE		Opportunist	Solitary	Excavator - Ground
Anthophora bimaculata	CR	A2bc; B1ab(i,ii,iii,iv) +2ab(i,ii,iii,iv)	Opportunist	Solitary	Excavator - Ground
Anthophora borealis	RE		Opportunist	Solitary	Excavator - Ground
Anthophora furcata	LC		Specialised	Solitary	Excavator - Ground
Anthophora plagiata	RE		Opportunist	Solitary	Excavator - Ground
Anthophora plumipes	LC		Opportunist	Solitary	Excavator - Ground
Anthophora quadrimaculata	LC		Opportunist	Solitary	Excavator - Ground
Anthophora retusa	EN	A2c	Opportunist	Solitary	Excavator - Ground
Apis mellifera	DD		Opportunist	Eusocial	Renter - Existing cavities above ground
Biastes truncatus	RE		-	Kleptoparasite	-
Bombus barbutellus	CR	A2bc; B1ab(i,ii,iii,iv)	-	Social parasite	-
Bombus bohemicus	NT	A2bc	-	Social parasite	-
Bombus campestris	VU	A2bc	-	Social parasite	-
Bombus confusus	RE		Opportunist with strong pref	Primitively eusocial	Renter - Existing cavities above ground
Bombus cryptarum	EN	A2bc	Opportunist	Primitively eusocial	Renter - Existing cavities above ground
Bombus cullumanus	RE		Opportunist	Primitively eusocial	Unknown
Bombus distinguendus	RE		Opportunist with strong pref	Primitively eusocial	Renter - Existing cavities above ground
Bombus hortorum	NT	A2bc	Opportunist	Primitively eusocial	Renter - Existing cavities below ground
Bombus humilis	CR	A2bc; B1ab(i,ii,iii,iv)	Opportunist	Primitively eusocial	Carder

Taxonomy	IUCN Red List Category (Belgium)	IUCN Red List Criteria (Belgium)	Host range	Sociality	Nesting
Bombus hypnorum	LC		Opportunist	Primitively eusocial	Renter - Existing cavities above ground
Bombus jonellus	VU	A2bc	Opportunist	Primitively eusocial	Renter - Existing cavities below ground
Bombus lapidarius	LC		Opportunist	Primitively eusocial	Renter - Existing cavities below ground
Bombus lucorum	NT	A2bc	Opportunist	Primitively eusocial	Renter - Existing cavities above ground
Bombus magnus	EN	A2bc	Opportunist	Primitively eusocial	Renter - Existing cavities above ground
Bombus muscorum	CR	A2bc	Opportunist	Primitively eusocial	Carder
Bombus norvegicus	VU	B1ab(i,ii) +2ab(i,ii)	-	Social parasite	-
Bombus pascuorum	LC		Opportunist	Primitively eusocial	Carder
Bombus pomorum	RE		Opportunist	Primitively eusocial	Renter - Existing cavities above ground
Bombus pratorum	LC		Opportunist	Primitively eusocial	Renter - Existing cavities below ground
Bombus ruderarius	EN	A2bc	Opportunist	Primitively eusocial	Carder
Bombus ruderatus	CR	A2bc; B1ab(i,ii,iii,iv)	Opportunist	Primitively eusocial	Renter - Existing cavities below ground
Bombus rupestris	EN	A2bc	-	Social parasite	-
Bombus soroeensis	VU	A2bc	Opportunist	Primitively eusocial	Renter - Existing cavities above ground
Bombus subterraneus	RE		Opportunist	Primitively eusocial	Renter - Existing cavities below ground
Bombus sylvarum	CR	A2bc; B1ab(i,ii,iii,iv)	Opportunist	Primitively eusocial	Carder
Bombus sylvestris	LC		-	Social parasite	-
Bombus terrestris	LC		Opportunist	Primitively eusocial	Renter - Existing cavities above ground
Bombus vestalis	NT	A2bc	-	Social parasite	-
Bombus veteranus	CR	A2bc	Opportunist	Primitively eusocial	Carder
Bombus wurflenii	RE		Opportunist	Primitively eusocial	Renter - Existing cavities below ground
Ceratina cyanea	LC		Opportunist	Solitary	Excavator - Deadstems
Epeoloides coecutiens	LC		-	Kleptoparasite	-
Epeolus cruciger	NT	A2c	-	Kleptoparasite	-
Epeolus tarsalis	CR	B1ab(i,ii,iii) +2ab(i,ii,iii)	-	Kleptoparasite	-
Epeolus variegatus	LC		-	Kleptoparasite	-
Eucera longicornis	VU	A2bc; B1ab(i,iii) +2ab(i,iii)	Specialised	Solitary	Excavator - Ground
Eucera nigrescens	EN	A2bc; B1ab(i,iii)	Specialised	Solitary	Excavator - Ground
Melecta albifrons	NT	A2c	-	Kleptoparasite	-
Melecta luctuosa	CR	A2bc; B1ab(i,ii,iii,iv)	-	Kleptoparasite	-
Nomada alboguttata	LC		-	Kleptoparasite	-
Nomada argentata	RE		-	Kleptoparasite	-

Taxonomy	IUCN Red List Category (Belgium)	IUCN Red List Criteria (Belgium)	Host range	Sociality	Nesting
Nomada armata	EN	B1ab(i,ii,iii) +2ab(i,ii,iii)	-	Kleptoparasite	-
Nomada baccata	DD		-	Kleptoparasite	-
Nomada bifasciata	LC		-	Kleptoparasite	-
Nomada castellana	RE		-	Kleptoparasite	-
Nomada conjungens	LC		-	Kleptoparasite	-
Nomada distinguenda	EN	A2bc; B1ab(i,ii,iii) +2ab(i,ii,iii)	-	Kleptoparasite	-
Nomada emarginata	RE		-	Kleptoparasite	-
Nomada fabriciana	LC		-	Kleptoparasite	-
Nomada facilis	LC		-	Kleptoparasite	-
Nomada femoralis	VU	A2bc	-	Kleptoparasite	-
Nomada ferruginata	LC		-	Kleptoparasite	-
Nomada flava	LC		-	Kleptoparasite	-
Nomada flavoguttata	LC		-	Kleptoparasite	-
Nomada flavopicta	LC		-	Kleptoparasite	-
Nomada fucata	LC		-	Kleptoparasite	-
Nomada fulvicornis	LC		-	Kleptoparasite	-
Nomada furva	EN	A2bc; B1ab(i,ii,iii,iv) + 2ab(i,ii,iii,iv)	-	Kleptoparasite	-
Nomada fuscicornis	EN	A2bc; B1ab(i,ii,iii,iv) + 2ab(i,ii,iii,iv)	-	Kleptoparasite	-
Nomada goodeniana	LC		-	Kleptoparasite	-
Nomada guttulata	LC		-	Kleptoparasite	-
Nomada integra	VU	A2bc	-	Kleptoparasite	-
Nomada lathburiana	LC		-	Kleptoparasite	-
Nomada leucophthalma	LC		-	Kleptoparasite	-
Nomada marshamella	LC		-	Kleptoparasite	-
Nomada melathoracica	RE		-	Kleptoparasite	-
Nomada mutabilis	RE		-	Kleptoparasite	-
Nomada mutica	CR	B1ab(i,ii,iii,iv) + 2ab(i,ii,iii,iv)	-	Kleptoparasite	-
Nomada obscura	LC		-	Kleptoparasite	-
Nomada obtusifrons	CR	B1ab(i,ii,iii,iv) + 2ab(i,ii,iii,iv)	-	Kleptoparasite	-
Nomada opaca	EN	B1ab(ii,iii) + 2ab(ii,iii)	-	Kleptoparasite	-
Nomada panzeri	LC		-	Kleptoparasite	-
Nomada piccioliana	CR	B1ab(i,ii,iii,iv) + 2ab(i,ii,iii,iv)	-	Kleptoparasite	-
Nomada pleurosticta	RE		-	Kleptoparasite	-
Nomada rhenana	RE		-	Kleptoparasite	-
Nomada roberjeotiana	RE		-	Kleptoparasite	-
Nomada ruficornis	LC		-	Kleptoparasite	-
Nomada rufipes	NT	A2c	-	Kleptoparasite	-
Nomada sexfasciata	CR	A2bc	-	Kleptoparasite	-
Nomada sheppardana	LC		-	Kleptoparasite	-

Taxonomy	IUCN Red List Category (Belgium)	IUCN Red List Criteria (Belgium)	Host range	Sociality	Nesting
Nomada signata	LC		-	Kleptoparasite	-
Nomada similis	EN	A2bc; B1ab(i,ii,iii,iv) + 2ab(i,ii,iii,iv)	-	Kleptoparasite	-
Nomada stigma	LC		-	Kleptoparasite	-
Nomada striata	VU	A2c	-	Kleptoparasite	-
Nomada succincta	LC		-	Kleptoparasite	-
Nomada villosa	EN	B1ab(i,ii,iii,iv) + 2ab(i,ii,iii,iv)	-	Kleptoparasite	-
Nomada zonata	LC		-	Kleptoparasite	-
Thyreus orbatus	EN	A2bc	-	Kleptoparasite	-
Xylocopa violaceae	LC		Opportunist	Solitary	Excavator - Deadstems
Xylocopa virginica	NA		Opportunist	Solitary + Primitively eusocial	Excavator - Deadstems
COLLETIDAE					
Colletes cunicularius	LC		Opportunist	Solitary	Excavator - Ground
Colletes daviesanus	LC		Specialised	Solitary	Excavator - Ground
Colletes fodiens	LC		Specialised	Solitary	Excavator - Ground
Colletes halophilus	LC		Specialised	Solitary	Excavator - Ground
Colletes hederae	LC		Opportunist with strong pref	Solitary	Excavator - Ground
Colletes hylaeiformis	NA		Specialised	Solitary	Excavator - Ground
Colletes marginatus	LC		Opportunist	Solitary	Excavator - Ground
Colletes similis	LC		Specialised	Solitary	Excavator - Ground
Colletes succinctus	LC		Specialised	Solitary	Excavator - Ground
Hylaeus angustatus	EN	B1ab(iii) + 2ab(iii)	Opportunist	Solitary	Renter - Existing cavities above ground
Hylaeus annularis	DD		Opportunist	Solitary	Renter - Existing cavities above ground
Hylaeus annulatus	NA		Opportunist	Solitary	Renter - Existing cavities above ground
Hylaeus bifasciatus	NA		Unknown	Solitary	Renter - Existing cavities above ground
Hylaeus brevicornis	DD		Opportunist	Solitary	Renter - Existing cavities above ground
Hylaeus clypearis	DD		Opportunist	Solitary	Renter - Existing cavities above ground
Hylaeus communis	LC		Opportunist	Solitary	Renter - Existing cavities above ground
Hylaeus confusus	LC		Opportunist	Solitary	Renter - Existing cavities above ground
Hylaeus cornutus	LC		Opportunist	Solitary	Renter - Existing cavities above ground
Hylaeus difformis	LC		Opportunist	Solitary	Renter - Existing cavities above ground
Hylaeus dilatatus	DD		Opportunist	Solitary	Renter - Existing cavities above ground
Hylaeus gibbus	DD		Opportunist	Solitary	Renter - Existing cavities above ground

Taxonomy	IUCN Red List Category (Belgium)	IUCN Red List Criteria (Belgium)	Host range	Sociality	Nesting
Hylaeus gracilicornis	DD		Opportunist	Solitary	Renter - Existing cavities above ground
Hylaeus gredleri	DD		Opportunist	Solitary	Renter - Existing cavities above ground
Hylaeus hyalinatus	LC		Opportunist	Solitary	Renter - Existing cavities above ground
Hylaeus incongruus	DD		Unknown	Solitary	Renter - Existing cavities above ground
Hylaeus leptocephalus	CR	B1ab(i,ii,iii,iv) + 2ab(i,ii,iii,iv)	Opportunist	Solitary	Renter - Existing cavities above ground
Hylaeus nigritus	EN	B1ab(i,ii,iii,iv) + 2ab(i,ii,iii,iv)	Specialised	Solitary	Renter - Existing cavities above ground
Hylaeus paulus	DD		Opportunist	Solitary	Renter - Existing cavities above ground
Hylaeus pectoralis	LC		Opportunist	Solitary	Renter - Existing cavities above ground
Hylaeus pictipes	LC		Opportunist	Solitary	Renter - Existing cavities above ground
Hylaeus pilosulus	RE		Unknown	Solitary	Renter - Existing cavities above ground
Hylaeus punctatus	LC		Opportunist	Solitary	Renter - Existing cavities above ground
Hylaeus punctulatissimus	LC		Specialised	Solitary	Renter - Existing cavities above ground
Hylaeus rinki	VU	A2bc; B1ab(i,ii,iii,iv) + 2ab(i,ii,iii,iv)	Opportunist	Solitary	Renter - Existing cavities above ground
Hylaeus signatus	LC		Specialised	Solitary	Renter - Existing cavities above ground
Hylaeus sinuatus	DD		Unknown	Solitary	Renter - Existing cavities above ground
Hylaeus styriacus	LC		Opportunist	Solitary	Renter - Existing cavities above ground
Hylaeus variegatus	NT	A2bc	Opportunist	Solitary	Renter - Existing cavities above ground
HALICTIDAE					
Dufourea dentiventris	EN	A2bc	Specialised	Solitary	Excavator - Ground
Dufourea halictula	CR	A2bc; B1ab(ii,iv) +2ab(ii,iv)	Specialised	Solitary	Excavator - Ground
Dufourea inermis	CR	A2bc; B1ab(ii,iv) +2ab(ii,iv)	Specialised	Solitary	Excavator - Ground
Dufourea minuta	RE		Specialised	Solitary	Excavator - Ground
Halictus eurygnathus	CR	A2bc; B1ab(i,ii,iv) +2ab(i,ii,iv)	Opportunist	Unknown	Excavator - Ground
Halictus maculatus	VU	A2bc	Opportunist	Primitively eusocial	Excavator - Ground
Halictus quadricinctus	CR	A2bc	Opportunist	Solitary	Excavator - Ground
Halictus rubicundus	LC		Opportunist	Solitary + Primitively eusocial	Excavator - Ground
Halictus scabiosae	LC		Opportunist	Primitively eusocial	Excavator - Ground

Taxonomy	IUCN Red List Category (Belgium)	IUCN Red List Criteria (Belgium)	Host range	Sociality	Nesting
Halictus sexcinctus	VU	A2bc	Opportunist	Solitary + Primitively eusocial	Excavator - Ground
Halictus simplex	EN	A2bc; B2ab(ii,iv)	Opportunist	Primitively eusocial	Excavator - Ground
Lasioglossum albipes	NT	A2bc	Opportunist	Primitively eusocial	Excavator - Ground
Lasioglossum brevicorne	EN	A2bc; B2ab(ii,iv)	Specialised	Primitively eusocial	Excavator - Ground
Lasioglossum breviventre	RE		Unknown	Solitary	Excavator - Ground
Lasioglossum calceatum	LC		Opportunist	Primitively eusocial	Excavator - Ground
Lasioglossum costulatum	CR	B1ab(i,ii,iii,iv) +2ab(i,ii,iii,iv)	Specialised	Solitary	Excavator - Ground
Lasioglossum fratellum	DD		Unknown	Primitively eusocial	Excavator - Ground
Lasioglossum fulvicorne	LC		Opportunist	Solitary	Excavator - Ground
Lasioglossum glabriusculum	NA		Opportunist	Primitively eusocial	Excavator - Ground
Lasioglossum interruptum	RE		Opportunist	Primitively eusocial	Excavator - Ground
Lasioglossum laeve	RE		Opportunist	Solitary	Excavator - Ground
Lasioglossum laevigatum	VU	A2bc; B1ab(i,ii,iv)	Opportunist	Solitary	Excavator - Ground
Lasioglossum laticeps	LC		Opportunist	Primitively eusocial	Excavator - Ground
Lasioglossum lativentre	LC		Opportunist	Solitary	Excavator - Ground
Lasioglossum leucopus	NT	A2bc	Opportunist	Primitively eusocial	Excavator - Ground
Lasioglossum leucozonium	LC		Opportunist	Solitary	Excavator - Ground
Lasioglossum lineare	RE		Opportunist	Primitively eusocial	Excavator - Ground
Lasioglossum lucidulum	LC		Opportunist	Solitary	Excavator - Ground
Lasioglossum majus	LC		Opportunist	Solitary	Excavator - Ground
Lasioglossum malachurum	LC		Opportunist	Primitively eusocial	Excavator - Ground
Lasioglossum minutissimum	LC		Opportunist	Solitary	Excavator - Ground
Lasioglossum minutulum	VU	A2bc; B1ab(i,ii,iii,iv) + 2ab(i,ii,iii,iv)	Opportunist	Solitary	Excavator - Ground
Lasioglossum monstrificum	VU	A2c	Opportunist	Solitary	Excavator - Ground
Lasioglossum morio	LC		Opportunist	Primitively eusocial	Excavator - Ground
Lasioglossum nigripes	RE		Opportunist	Primitively eusocial	Excavator - Ground
Lasioglossum nitidiusculum	LC		Opportunist	Solitary	Excavator - Ground
Lasioglossum nitidulum	LC		Opportunist	Primitively eusocial	Excavator - Ground
Lasioglossum pallens	LC		Opportunist	Solitary	Excavator - Ground
Lasioglossum parvulum	LC		Opportunist	Solitary	Excavator - Ground
Lasioglossum pauxillum	LC		Opportunist	Primitively eusocial	Excavator - Ground

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Lasioglossum politum	RE		Opportunist	Primitively eusocial	Excavator - Ground
Lasioglossum prasinum	EN	B1ab(i,ii,iii,iv)	Opportunist	Solitary	Excavator - Ground
Lasioglossum punctatissimum	LC		Opportunist	Solitary	Excavator - Ground
Lasioglossum puncticolle	NA		Opportunist	Primitively eusocial	Excavator - Ground
Lasioglossum pygmaeum	VU	B1ab(i,ii,iii,iv) + 2ab(i,ii,iii,iv)	Opportunist	Solitary	Excavator - Ground
Lasioglossum quadrinotatulum	VU	A2c	Opportunist	Solitary	Excavator - Ground
Lasioglossum quadrinotatum	CR	A2bc	Opportunist	Solitary	Excavator - Ground
Lasioglossum rufitarse	NT	A2bc	Opportunist	Solitary	Excavator - Ground
Lasioglossum semilucens	LC		Opportunist	Solitary	Excavator - Ground
Lasioglossum sexnotatum	LC		Opportunist	Solitary	Excavator - Ground
Lasioglossum sexstrigatum	LC		Opportunist	Primitively eusocial	Excavator - Ground
Lasioglossum subfasciatum	RE		Opportunist	Solitary	Excavator - Ground
Lasioglossum subfulvicorne	DD		Unknown	Solitary	Excavator - Ground
Lasioglossum subhirtum	RE		Opportunist	Solitary	Excavator - Ground
Lasioglossum tarsatum	CR	B2ab(i,ii,iii,iv)	Opportunist	Solitary	Excavator - Ground
Lasioglossum villosulum	LC		Opportunist	Primitively eusocial	Excavator - Ground
Lasioglossum xanthopus	EN	A2bc	Opportunist	Solitary	Excavator - Ground
Lasioglossum zonulum	LC		Opportunist	Solitary	Excavator - Ground
Rhophitoides canus	RE		Specialised	Solitary	Excavator - Ground
Rophites quinquespinosus	CR	A2bc B1ab(i)	Specialised	Solitary	Excavator - Ground
Seladonia confusa	VU	A2c	Opportunist	Solitary + Primitively eusocial	Excavator - Ground
Seladonia leucahenea	CR	A2bc; B1ab(i,ii,iv) +2ab(i,ii,iv)	Opportunist	Solitary	Excavator - Ground
Seladonia submediterranea	DD		Unknown	Unknown	Unknown
Seladonia subaurata	NA		Opportunist	Primitively eusocial	Excavator - Ground
Seladonia tumulorum	LC		Opportunist	Solitary + Primitively eusocial	Excavator - Ground
Sphecodes albilabris	LC		-	Kleptoparasite	-
Sphecodes alternatus	DD		-	Kleptoparasite	-
Sphecodes crassus	LC		-	Kleptoparasite	-
Sphecodes ephippius	LC		-	Kleptoparasite	-
Sphecodes ferruginatus	LC		-	Kleptoparasite	-
Sphecodes geoffrellus	LC		-	Kleptoparasite	-
Sphecodes gibbus	LC		-	Kleptoparasite	-
Sphecodes hyalinatus	LC		-	Kleptoparasite	-
Sphecodes longulus	LC		-	Kleptoparasite	-

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Sphecodes majalis	DD		-	Kleptoparasite	-
Sphecodes marginatus	VU	B1ab(i,ii,iv) +2ab(i,ii,iv)	-	Kleptoparasite	-
Sphecodes miniatus	LC		-	Kleptoparasite	-
Sphecodes monilicornis	LC		-	Kleptoparasite	-
Sphecodes niger	VU	B1ab(i,ii,iv) +2ab(i,ii,iv)	-	Kleptoparasite	-
Sphecodes pellucidus	LC		-	Kleptoparasite	-
Sphecodes puncticeps	LC		-	Kleptoparasite	-
Sphecodes reticulatus	LC		-	Kleptoparasite	-
Sphecodes rubicundus	CR	A2bc; B1ab(i,ii,,iii,iv) +2ab(i,ii,iii,iv)	-	Kleptoparasite	-
Sphecodes rufiventris	CR	A2bc; B1ab(i,ii,iv) +2ab(i,ii,iv)	-	Kleptoparasite	-
Sphecodes scabricollis	EN	A2bc	-	Kleptoparasite	-
Sphecodes spinulosus	CR	A2bc; B1ab(i,ii,iv) +2ab(i,ii,iv)	-	Kleptoparasite	-
MEGACHILIDAE					
Aglaoapis tridentata	RE		-	Kleptoparasite	-
Anthidiellum strigatum	LC		Opportunist	Solitary	Mason
Anthidium manicatum	LC		Opportunist	Solitary	Renter - Existing cavities above ground
Anthidium oblongatum	LC		Opportunist	Solitary	Renter - Existing cavities above ground
Anthidium punctatum	LC		Opportunist	Solitary	Renter - Existing cavities above ground
Chelostoma campanularum	LC		Specialised	Solitary	Renter - Existing cavities above ground
Chelostoma distinctum	VU	A2c; B1ab(ii,iii)	Specialised	Solitary	Renter - Existing cavities above ground
Chelostoma florisomne	LC		Specialised	Solitary	Renter - Existing cavities above ground
Chelostoma rapunculi	LC		Specialised	Solitary	Renter - Existing cavities above ground
Coelioxys afer	CR	A2bc; B1ab(i,ii,iv) +2ab(i,ii,iv)	-	Kleptoparasite	-
Coelioxys alatus	VU	B1ab(iii) + 2ab(iii)	-	Kleptoparasite	-
Coelioxys aurolimbatus	LC		-	Kleptoparasite	-
Coelioxys conoideus	CR	A2bc; B1(i,ii,iii,iv,v)	-	Kleptoparasite	-
Coelioxys echinatus	DD		-	Kleptoparasite	-
Coelioxys elongatus	VU	A2bc; B1ab(iii) + 2ab(iii)	-	Kleptoparasite	-
Coelioxys emarginatus	RE		-	Kleptoparasite	-
Coelioxys inermis	LC		-	Kleptoparasite	-
Coelioxys mandibularis	VU	A2c; B1ab(i,ii,iii,iv) +2ab(i,ii,iii,iv)	-	Kleptoparasite	-
Coelioxys quadridendatus	CR	A2bc; B1ab (i,ii,iv) +2ab (i,ii,iv)	-	Kleptoparasite	-
Coelioxys rufescens	NT	A2bc; B1ab(i,ii)	-	Kleptoparasite	-

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Heriades truncorum	LC		Specialised	Solitary	Renter - Existing cavities above ground
Hoplitis adunca	LC		Specialised	Solitary	Renter - Existing cavities above ground
Hoplitis anthocopoides	CR	A2bc; B1ab(i,ii,iii,iv) +2ab(i,ii,iii,iv)	Specialised	Solitary	Renter - Existing cavities below ground
Hoplitis claviventris	VU	A2bc	Opportunist	Solitary	Excavator - Ground
Hoplitis leucomelana	LC		Opportunist	Solitary	Renter - Existing cavities above ground
Hoplitis mitis	NA		Specialised	Solitary	Excavator - Ground
Hoplitis papaveris	RE		Opportunist	Solitary	Excavator - Ground
Hoplitis ravouxi	CR	A2c; B1ab(i,ii,iv)	Opportunist	Solitary	Renter - Existing cavities above ground
Hoplitis tridentata	LC		Opportunist with strong pref	Solitary	Renter - Existing cavities above ground
Hoplitis villosa	RE		Specialised	Solitary	Renter - Existing cavities below ground
Megachile alpicola	VU	A2c; B1ab(i,ii,iv) +2ab(i,ii,iv)	Opportunist	Solitary	Renter - Existing cavities above ground
Megachile analis	CR	A2bc; B1ab(iii) +2ab(iii)	Opportunist	Solitary	Excavator - Ground
Megachile apicalis	NA		Opportunist	Solitary	Renter - Existing cavities above ground
Megachile centuncularis	LC		Opportunist	Solitary	Renter - Existing cavities above ground
Megachile circumcincta	EN	A2bc	Opportunist	Solitary	Excavator - Ground
Megachile ericetorum	LC		Specialised	Solitary	Renter - Existing cavities above ground
Megachile genalis	CR	A2bc; B1ab(iii) +2ab(iii)	Specialised	Solitary	Renter - Existing cavities above ground
Megachile lagopoda	CR	A2bc; B1ab(i,ii,iii,iv)	Opportunist	Solitary	Excavator - Ground
Megachile lapponica	LC		Opportunist with strong pref	Solitary	Renter - Existing cavities above ground
Megachile leachella	VU	A2bc; B1ab(iii) +2ab(iii)	Opportunist with strong pref	Solitary	Excavator - Ground
Megachile ligniseca	LC		Opportunist	Solitary	Renter - Existing cavities above ground
Megachile maritima	CR	A2bc; B1ab(i,ii,iii,iv) +2ab(i,ii,iii,iv)	Opportunist	Solitary	Excavator - Ground
Megachile octosignata	NA		Unknown	Solitary	Renter - Existing cavities above ground
Megachile pilidens	CR	B2ab(iii)	Opportunist with strong pref	Solitary	Excavator - Ground
Megachile pyrenaea	LC		Opportunist	Solitary	Excavator - Ground
Megachile rotundata	LC		Opportunist	Solitary	Renter - Existing cavities above ground
Megachile versicolor	LC		Opportunist	Solitary	Renter - Existing cavities above ground

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Megachile willughbiella	LC		Opportunist	Solitary	Renter - Existing cavities above ground
Osmia andrenoides	CR	B1ab(iii) +2ab(iii)	Specialised	Solitary	Renter - Snail shells
Osmia aurulenta	NT	A2c	Opportunist	Solitary	Renter - Snail shells
Osmia bicolor	LC		Opportunist	Solitary	Renter - Snail shells
Osmia bicornis	LC		Opportunist	Solitary	Renter - Existing cavities above ground
Osmia brevicornis	NA		Specialised	Solitary	Renter - Existing cavities above ground
Osmia caerulescens	LC		Opportunist	Solitary	Renter - Existing cavities above ground
Osmia cornuta	LC		Opportunist	Solitary	Renter - Existing cavities above ground
Osmia inermis	NA		Opportunist with strong pref	Solitary	Renter - Existing cavities above ground
Osmia leaiana	LC		Specialised	Solitary	Renter - Existing cavities above ground
Osmia melanogaster	DD		Specialised	Solitary	Renter - Existing cavities above ground
Osmia mustelina	NA		Opportunist	Solitary	Renter - Existing cavities above ground
Osmia niveata	LC		Specialised	Solitary	Renter - Existing cavities above ground
Osmia parietina	EN	A2c; B1ab(i,ii,iv) +2ab(i,ii,iv)	Opportunist with strong pref	Solitary	Renter - Existing cavities above ground
Osmia pilicornis	RE		Opportunist with strong pref	Solitary	Excavator - Ground
Osmia rufohirta	EN	A2bc; B1ab(i,ii,iii,iv) +2ab(i,ii,iii,iv)	Opportunist with strong pref	Solitary	Renter - Snail shells
Osmia spinulosa	NT	A2bc; B1ab(iii) +2ab(iii)	Specialised	Solitary	Renter - Snail shells
Osmia uncinata	EN	A2bc; B1ab(i,ii,iv) +2ab(i,ii,iv)	Opportunist	Solitary	Renter - Existing cavities above ground
Osmia xanthomelana	RE		Specialised	Solitary	Renter - Existing cavities above ground
Pseudanthidium scapulare	NA		Specialised	Solitary	Renter - Existing cavities above ground
Stelis breviuscula	LC		-	Kleptoparasite	-
Stelis minima	RE		-	Kleptoparasite	-
Stelis minuta	RE		-	Kleptoparasite	-
Stelis odontopyga	NA		-	Kleptoparasite	-
Stelis ornatula	VU	A2bc; B2ab(i,ii,iv)	-	Kleptoparasite	-
Stelis phaeoptera	NT	A2bc; B1ab(i,ii) +2ab(i,ii)	-	Kleptoparasite	-
Stelis punctulatissima	LC		-	Kleptoparasite	-
Stelis signata	VU	A2bc	-	Kleptoparasite	-
Trachusa byssina	LC		Specialised	Solitary	Excavator - Ground

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MELITTIDAE					
Dasypoda argentata	RE		Specialised	Solitary	Excavator - Ground
Dasypoda hirtipes	LC		Specialised	Solitary	Excavator - Ground
Macropis europaea	LC		Specialised	Solitary	Excavator - Ground
Macropis fulvipes	LC		Specialised	Solitary	Excavator - Ground
Melitta dimidiata	NA		Specialised	Solitary	Excavator - Ground
Melitta haemorrhoidalis	LC		Specialised	Solitary	Excavator - Ground
Melitta leporina	LC		Specialised	Solitary	Excavator - Ground
Melitta nigricans	LC		Specialised	Solitary	Excavator - Ground
Melitta tricincta	VU	B2ab(i,ii,iii)	Specialised	Solitary	Excavator - Ground

Appendix 3: Inferred Red List status of wild bees based on Rasmont et al. (1993)

Taxonomy	Trends in 1993 (Rasmont et al. 1993)	Inferred IUCN Red List Category (1993)	IUCN Red List Category (Drossart al. 2019)	IUCN Red List Criteria (2019)
ANDRENIDAE				
Andrena agilissima	-	Threatened	EN	A2bc; B2ab(iv)
Andrena alfkenella	Not mentioned	Not mentioned	DD	
Andrena angustior	+	LC	NT	A2bc
Andrena anthrisci	DD	DD	DD	
Andrena apicata	=	LC	DD	
Andrena argentata	=	LC	NT	A2bc; B1ab(iii)
Andrena assimilis	Not mentioned	Not mentioned	NA	
Andrena barbareae	Not mentioned	Not mentioned	NA	
Andrena barbilabris	+	LC	LC	
Andrena batava	Not mentioned	Not mentioned	DD	
Andrena bicolor	+	LC	LC	
Andrena bimaculata	DD	DD	NT	A2c
Andrena carantonica	+	LC	LC	
Andrena chrysopus	Not mentioned	Not mentioned	DD	
Andrena chrysopyga	-	Threatened	RE	
Andrena chrysosceles	+	LC	LC	
Andrena cineraria	=	LC	LC	
Andrena cinerea	Not mentioned	Not mentioned	LC	
Andrena clarkella	=	LC	LC	
Andrena coitana	=	LC	EN	B1ab(i,ii,iv) +2ab(i,ii,iv)
Andrena combinata	-	Threatened	CR	A2bc
Andrena curvungula	=	LC	CR	A2c; B1ab(i,ii,iv) +2ab(i,ii,iv)
Andrena decipiens	Not mentioned	Not mentioned	NA	
Andrena denticulata	-	Threatened	NT	A2c
Andrena distinguenda	Not mentioned	Not mentioned	RE	
Andrena dorsata	=	LC	LC	
Andrena falsifica	=	LC	DD	
Andrena ferox	DD	DD	CR	B1ab(i,ii,iv) +2ab(i,ii,iv)
Andrena flavipes	+	LC	LC	
Andrena florea	=	LC	LC	
Andrena floricola	Not mentioned	Not mentioned	RE	
Andrena fucata	+	LC	VU	A2bc
Andrena fulva	+	LC	LC	
Andrena fulvago	=	LC	NT	A2bc
Andrena fulvata	Not mentioned	Not mentioned	NA	
Andrena fulvida	-	Threatened	EN	A2c; B1ab(i,ii,iii, iv) +2ab(i,ii,iii,iv)
Andrena fuscipes	=	LC	LC	
Andrena gelriae	DD	DD	RE	
Andrena gravida	=	LC	LC	

Taxonomy	Trends in 1993 (Rasmont et al. 1993)	Inferred IUCN Red List Category (1993)	IUCN Red List Category (Drossart al. 2019)	IUCN Red List Criteria (2019)
Andrena haemorrhoa	+	LC	LC	
Andrena hattorfiana	=	LC	NT	A2bc; B1ab(i,iii) +2ab(i,iii)
Andrena helvola	+	LC	VU	A2c
Andrena humilis	=	LC	LC	
Andrena intermedia	DD	DD	EN	B1ab(iii) +2ab(iii)
Andrena labialis	=	LC	NT	A2bc
Andrena labiata	=	LC	LC	
Andrena lapponica	=	LC	VU	B1ab(ii,iii,iv) +2ab(ii,iii,iv)
Andrena lathyri	=	LC	NT	A2b
Andrena limata	DD	DD	RE	
Andrena marginata	-	Threatened	RE	
Andrena minutula	+	LC	LC	
Andrena minutuloides	=	LC	DD	
Andrena mitis	=	LC	LC	
Andrena nana	DD	DD	DD	
Andrena nanula	Not mentioned	Not mentioned	NA	
Andrena nigriceps	DD	DD	CR	B1ab(ii,iii,iv) +2ab(ii,iii,iv)
Andrena nigroaenea	+	LC	LC	
Andrena nigrospina	Not mentioned	Not mentioned	DD	
Andrena nitida	+	LC	LC	
Andrena nitidiuscula	DD	DD	VU	B1ab(iii) +2ab(iii)
Andrena nitidula	Not mentioned	Not mentioned	NA	
Andrena niveata	DD	DD	DD	
Andrena nycthemera	DD	DD	LC	
Andrena ovatula	-	Threatened	NT	A2c
Andrena pandellei	=	LC	VU	B2ab(iii)
Andrena pilipes	-	Threatened	DD	
Andrena polita	=	LC	CR	A2bc; B1ab(i,ii,iii,iv) +2ab(i,ii,iii,iv)
Andrena potentillae	DD	DD	CR	B1ab(iii) +2ab(iii)
Andrena praecox	=	LC	LC	
Andrena propinqua	Not mentioned	Not mentioned	DD	
Andrena proxima	=	LC	LC	
Andrena pusilla	Not mentioned	Not mentioned	DD	
Andrena rosae	-	Threatened	LC	
Andrena ruficrus	=	LC	NT	A2b
Andrena schencki	-	Threatened	EN	A2bc; B1ab(i,ii,iii,iv) +2ab(i,ii,iii,iv)
Andrena semilaevis	=	LC	DD	
Andrena similis	=	LC	CR	A2bc; B1ab(i,ii,iv) +2ab(i,ii,iv)
Andrena spreta	=	LC	DD	
Andrena strohmella	=	LC	DD	

Taxonomy	Trends in 1993 (Rasmont et al. 1993)	Inferred IUCN Red List Category (1993)	IUCN Red List Category (Drossart al. 2019)	IUCN Red List Criteria (2019)
Andrena subopaca	+	LC	LC	
Andrena synadelpha	+	LC	CR	A2bc; B1ab(i,ii,iii,iv) +2ab(i,ii,iii,iv)
Andrena tarsata	-	Threatened	EN	A2bc
Andrena thoracica	DD	DD	RE	
Andrena tibialis	=	LC	LC	
Andrena trimmerana	Not mentioned	Not mentioned	DD	
Andrena vaga	=	LC	LC	
Andrena varians	=	LC	CR	A2bc
Andrena ventralis	=	LC	LC	
Andrena viridescens	Not mentioned	Not mentioned	LC	
Andrena wilkella	=	LC	NT	A2c
Panurgus banksianus	=	LC	LC	
Panurgus calcaratus	-	Threatened	LC	
Panurgus dentipes	DD	DD	LC	
APIDAE				
Ammobates punctatus	-	Threatened	CR	A2bc; B1ab(i,ii,iii,iv) +2ab(i,ii,iii,iv)
Anthophora aestivalis	-	Threatened	RE	
Anthophora bimaculata	-	Threatened	CR	A2bc; B1ab(i,ii,iii,iv) +2ab(i,ii,iii,iv)
Anthophora borealis	Not mentioned	Not mentioned	RE	
Anthophora furcata	-	Threatened	LC	
Anthophora plagiata	-	NT	RE	
Anthophora plumipes	+	LC	LC	
Anthophora quadrimaculata	-	Threatened	LC	
Anthophora retusa	-	Threatened	EN	A2c
Apis mellifera	Not mentioned	Not mentioned	DD	
Biastes truncatus	DD	DD	RE	
Bombus barbutellus	-	Threatened	CR	A2bc; B1ab(i,ii,iii,iv)
Bombus bohemicus	+	LC	NT	A2bc
Bombus campestris	-	Threatened	VU	A2bc
Bombus confusus	-	RE	RE	
Bombus cryptarum	Not mentioned	Not mentioned	EN	A2bc
Bombus cullumanus	-	RE	RE	
Bombus distinguendus	-	Threatened	RE	
Bombus hortorum	-	Threatened	NT	A2bc
Bombus humilis	-	Threatened	CR	A2bc; B1ab(i,ii,iii,iv)
Bombus hypnorum	+	LC	LC	
Bombus jonellus	-	Threatened	VU	A2bc
Bombus lapidarius	-	Threatened	LC	
Bombus lucorum	Not mentioned	Not mentioned	NT	A2bc
Bombus magnus	Not mentioned	Not mentioned	EN	A2bc
Bombus muscorum	-	Threatened	CR	A2bc
Bombus norvegicus	DD	DD	VU	B1ab(i,ii) +2ab(i,ii)

Taxonomy	Trends in 1993 (Rasmont et al. 1993)	Inferred IUCN Red List Category (1993)	IUCN Red List Category (Drossart al. 2019)	IUCN Red List Criteria (2019)
Bombus pascuorum	+	LC	LC	
Bombus pomorum	-	RE	RE	
Bombus pratorum	+	LC	LC	
Bombus ruderarius	-	Threatened	EN	A2bc
Bombus ruderatus	-	Threatened	CR	A2bc; B1ab(i,ii,iii,iv)
Bombus rupestris	-	Threatened	EN	A2bc
Bombus soroeensis	-	Threatened	VU	A2bc
Bombus subterraneus	-	Threatened	RE	
Bombus sylvarum	-	Threatened	CR	A2bc; B1ab(i,ii,iii,iv)
Bombus sylvestris	+	LC	LC	
Bombus terrestris	Not mentioned	Not mentioned	LC	
Bombus vestalis	-	Threatened	NT	A2bc
Bombus veteranus	-	Threatened	CR	A2bc
Bombus wurflenii	-	RE	RE	
Ceratina cyanea	=	LC	LC	
Epeoloides coecutiens	DD	DD	LC	
Epeolus cruciger	=	LC	NT	A2c
Epeolus tarsalis	Not mentioned	Not mentioned	CR	B1ab(i,ii,iii) +2ab(i,ii,iii)
Epeolus variegatus	=	LC	LC	
Eucera longicornis	=	LC	VU	A2bc; B1ab(i,iii) +2ab(i,iii)
Eucera nigrescens	=	LC	EN	A2bc; B1ab(i,iii)
Melecta albifrons	+	LC	NT	A2c
Melecta luctuosa	-	Threatened	CR	A2bc; B1ab(i,ii,iii,iv)
Nomada alboguttata	=	LC	LC	
Nomada argentata	DD	DD	RE	
Nomada armata	=	LC	EN	B1ab(i,ii,iii) +2ab(i,ii,iii)
Nomada baccata	DD	DD	DD	
Nomada bifasciata	-	Threatened	LC	
Nomada castellana	DD	DD	RE	
Nomada conjungens	=	LC	LC	
Nomada distinguenda	-	Threatened	EN	A2bc; B1ab(i,ii,iii) +2ab(i,ii,iii)
Nomada emarginata	=	LC	RE	
Nomada fabriciana	=	LC	LC	
Nomada facilis	Not mentioned	Not mentioned	LC	
Nomada femoralis	-	Threatened	VU	A2bc
Nomada ferruginata	=	LC	LC	
Nomada flava	+	LC	LC	
Nomada flavoguttata	=	LC	LC	
Nomada flavopicta	-	Threatened	LC	
Nomada fucata	-	Threatened	LC	
Nomada fulvicornis	=	LC	LC	

Taxonomy	Trends in 1993 (Rasmont et al. 1993)	Inferred IUCN Red List Category (1993)	IUCN Red List Category (Drossart al. 2019)	IUCN Red List Criteria (2019)
Nomada furva	DD	DD	EN	A2bc; B1ab(i,ii,iii,iv) + 2ab(i,ii,iii,iv)
Nomada fuscicornis	-	Threatened	EN	A2bc; B1ab(i,ii,iii,iv) + 2ab(i,ii,iii,iv)
Nomada goodeniana	-	Threatened	LC	
Nomada guttulata	DD	DD	LC	
Nomada integra	-	Threatened	VU	A2bc
Nomada lathburiana	=	LC	LC	
Nomada leucophthalma	-	Threatened	LC	
Nomada marshamella	=	LC	LC	
Nomada melathoracica	DD	DD	RE	
Nomada mutabilis	DD	DD	RE	
Nomada mutica	DD	DD	CR	B1ab(i,ii,iii,iv) + 2ab(i,ii,iii,iv)
Nomada obscura	=	LC	LC	
Nomada obtusifrons	DD	DD	CR	B1ab(i,ii,iii,iv) + 2ab(i,ii,iii,iv)
Nomada opaca	DD	DD	EN	B1ab(ii,iii) + 2ab(ii,iii)
Nomada panzeri	=	LC	LC	
Nomada piccioliana	DD	DD	CR	B1ab(i,ii,iii,iv) + 2ab(i,ii,iii,iv)
Nomada pleurosticta	DD	DD	RE	
Nomada rhenana	DD	DD	RE	
Nomada roberjeotiana	-	Threatened	RE	
Nomada ruficornis	-	Threatened	LC	
Nomada rufipes	=	LC	NT	A2c
Nomada sexfasciata	-	Threatened	CR	A2bc
Nomada sheppardana	-	Threatened	LC	
Nomada signata	-	Threatened	LC	
Nomada similis	=	LC	EN	A2bc; B1ab(i,ii,iii,iv) + 2ab(i,ii,iii,iv)
Nomada stigma	DD	DD	LC	
Nomada striata	=	LC	VU	A2c
Nomada succincta	Not mentioned	Not mentioned	LC	
Nomada villosa	DD	DD	EN	B1ab(i,ii,iii,iv) + 2ab(i,ii,iii,iv)
Nomada zonata	DD	DD	LC	
Thyreus orbatus	-	Threatened	EN	A2bc
Xylocopa violaceae	DD	DD	LC	
Xylocopa virginica	Not mentioned	Not mentioned	NA	
COLLETIDAE				
Colletes cunicularius	-	NT	LC	
Colletes daviesanus	+	LC	LC	
Colletes fodiens	=	LC	LC	
Colletes halophilus	+	LC	LC	
Colletes hederae	Not mentioned	Not mentioned	LC	

Taxonomy	Trends in 1993 (Rasmont et al. 1993)	Inferred IUCN Red List Category (1993)	IUCN Red List Category (Drossart al. 2019)	IUCN Red List Criteria (2019)
Colletes hylaeiformis	Not mentioned	Not mentioned	NA	
Colletes marginatus	DD	DD	LC	
Colletes similis	DD	DD	LC	
Colletes succinctus	=	LC	LC	
Hylaeus angustatus	DD	DD	EN	B1ab(iii) + 2ab(iii)
Hylaeus annularis	+	LC	DD	
Hylaeus annulatus	Not mentioned	Not mentioned	NA	
Hylaeus bifasciatus	DD	DD	NA	
Hylaeus brevicornis	=	LC	DD	
Hylaeus clypearis	DD	DD	DD	
Hylaeus communis	+	LC	LC	
Hylaeus confusus	=	LC	LC	
Hylaeus cornutus	=	LC	LC	
Hylaeus difformis	DD	DD	LC	
Hylaeus dilatatus	Not mentioned	Not mentioned	DD	
Hylaeus gibbus	=	LC	DD	
Hylaeus gracilicornis	DD	DD	DD	
Hylaeus gredleri	Not mentioned	Not mentioned	DD	
Hylaeus hyalinatus	+	LC	LC	
Hylaeus incongruus	Not mentioned	Not mentioned	DD	
Hylaeus leptocephalus	-	Threatened	CR	B1ab(i,ii,iii,iv) + 2ab(i,ii,iii,iv)
Hylaeus nigritus	DD	DD	EN	B1ab(i,ii,iii,iv) + 2ab(i,ii,iii,iv)
Hylaeus paulus	Not mentioned	Not mentioned	DD	
Hylaeus pectoralis	=	LC	LC	
Hylaeus pictipes	=	LC	LC	
Hylaeus pilosulus	=	LC	RE	
Hylaeus punctatus	Not mentioned	Not mentioned	LC	
Hylaeus punctulatissimus	=	LC	LC	
Hylaeus rinki	=	LC	VU	A2bc; B1ab(i,ii,iii,iv) + 2ab(i,ii,iii,iv)
Hylaeus signatus	=	LC	LC	
Hylaeus sinuatus	DD	DD	DD	
Hylaeus styriacus	DD	DD	LC	
Hylaeus variegatus	-	Threatened	NT	A2bc
HALICTIDAE				
Dufourea dentiventris	=	LC	EN	A2bc
Dufourea halictula	DD	DD	CR	A2bc; B1ab(ii,iv) +2ab(ii,iv)
Dufourea inermis	=	LC	CR	A2bc; B1ab(ii,iv) +2ab(ii,iv)
Dufourea minuta	DD	DD	RE	
Halictus eurygnathus	DD	DD	CR	A2bc; B1ab(i,ii,iv) +2ab(i,ii,iv)
Halictus maculatus	-	NT	VU	A2bc

Taxonomy	Trends in 1993 (Rasmont et al. 1993)	Inferred IUCN Red List Category (1993)	IUCN Red List Category (Drossart al. 2019)	IUCN Red List Criteria (2019)
Halictus quadricinctus	-	Threatened	CR	A2bc
Halictus rubicundus	=	LC	LC	
Halictus scabiosae	=	LC	LC	
Halictus sexcinctus	-	Threatened	VU	A2bc
Halictus simplex	-	Threatened	EN	A2bc; B2ab(ii,iv)
Lasioglossum albipes	=	LC	NT	A2bc
Lasioglossum brevicorne	=	LC	EN	A2bc; B2ab(ii,iv)
Lasioglossum breviventre	DD	DD	RE	
Lasioglossum calceatum	+	LC	LC	
Lasioglossum costulatum	DD	DD	CR	B1ab(i,ii,iii,iv) +2ab(i,ii,iii,iv)
Lasioglossum fratellum	=	LC	DD	
Lasioglossum fulvicorne	=	LC	LC	
Lasioglossum glabriusculum	Not mentioned	Not mentioned	NA	
Lasioglossum interruptum	DD	DD	RE	
Lasioglossum laeve	DD	DD	RE	
Lasioglossum laevigatum	=	LC	VU	A2bc; B1ab(i,ii,iv)
Lasioglossum laticeps	=	LC	LC	
Lasioglossum lativentre	-	Threatened	LC	
Lasioglossum leucopus	=	LC	NT	A2bc
Lasioglossum leucozonium	=	LC	LC	
Lasioglossum lineare	=	LC	RE	
Lasioglossum lucidulum	=	LC	LC	
Lasioglossum majus	Not mentioned	Not mentioned	LC	
Lasioglossum malachurum	=	LC	LC	
Lasioglossum minutissimum	=	LC	LC	
Lasioglossum minutulum	=	LC	VU	A2bc; B1ab(i,ii,iii,iv) + 2ab(i,ii,iii,iv)
Lasioglossum monstrificum	Not mentioned	Not mentioned	VU	A2c
Lasioglossum morio	=	LC	LC	
Lasioglossum nigripes	Not mentioned	Not mentioned	RE	
Lasioglossum nitidiusculum	=	LC	LC	
Lasioglossum nitidulum	+	LC	LC	
Lasioglossum pallens	Not mentioned	Not mentioned	LC	
Lasioglossum parvulum	=	LC	LC	
Lasioglossum pauxillum	=	LC	LC	
Lasioglossum politum	DD	DD	RE	
Lasioglossum prasinum	=	LC	EN	B1ab(i,ii,iii,iv)
Lasioglossum punctatissimum	+	LC	LC	
Lasioglossum puncticolle	Not mentioned	Not mentioned	NA	
Lasioglossum pygmaeum	-	Threatened	VU	B1ab(i,ii,iii,iv) + 2ab(i,ii,iii,iv)

Taxonomy	Trends in 1993 (Rasmont et al. 1993)	Inferred IUCN Red List Category (1993)	IUCN Red List Category (Drossart al. 2019)	IUCN Red List Criteria (2019)
Lasioglossum quadrinotatulum	=	LC	VU	A2c
Lasioglossum quadrinotatum	=	LC	CR	A2bc
Lasioglossum rufitarse	=	LC	NT	A2bc
Lasioglossum semilucens	=	LC	LC	
Lasioglossum sexnotatum	-	Threatened	LC	
Lasioglossum sexstrigatum	=	LC	LC	
Lasioglossum subfasciatum	Not mentioned	Not mentioned	RE	
Lasioglossum subfulvicorne	Not mentioned	Not mentioned	DD	
Lasioglossum subhirtum	Not mentioned	Not mentioned	RE	
Lasioglossum tarsatum	DD	DD	CR	B2ab(i,ii,iii,iv)
Lasioglossum villosulum	=	LC	LC	
Lasioglossum xanthopus	-	Threatened	EN	A2bc
Lasioglossum zonulum	=	LC	LC	
Rhophitoides canus	Not mentioned	Not mentioned	RE	
Rophites quinquespinosus	DD	DD	CR	A2bc B1ab(i)
Seladonia confusa	=	LC	VU	A2c
Seladonia leucahenea	-	Threatened	CR	A2bc; B1ab(i,ii,iv) +2ab(i,ii,iv)
Seladonia submediterranea	Not mentioned	Not mentioned	DD	
Seladonia subaurata	Not mentioned	Not mentioned	NA	
Seladonia tumulorum	+	LC	LC	
Sphecodes albilabris	-	NT	LC	
Sphecodes alternatus	Not mentioned	Not mentioned	DD	
Sphecodes crassus	+	LC	LC	
Sphecodes ephippius	+	LC	LC	
Sphecodes ferruginatus	=	LC	LC	
Sphecodes geoffrellus	+	LC	LC	
Sphecodes gibbus	=	LC	LC	
Sphecodes hyalinatus	=	LC	LC	
Sphecodes longulus	=	LC	LC	
Sphecodes majalis	Not mentioned	Not mentioned	DD	
Sphecodes marginatus	=	LC	VU	B1ab(i,ii,iv) +2ab(i,ii,iv)
Sphecodes miniatus	=	LC	LC	
Sphecodes monilicornis	=	LC	LC	
Sphecodes niger	DD	DD	VU	B1ab(i,ii,iv) +2ab(i,ii,iv)
Sphecodes pellucidus	+	LC	LC	
Sphecodes puncticeps	=	LC	LC	
Sphecodes reticulatus	-	NT	LC	
Sphecodes rubicundus	-	Threatened	CR	A2bc; B1ab(i,ii,,iii,iv) +2ab(i,ii,iii,iv)
Sphecodes rufiventris	DD	DD	CR	A2bc; B1ab(i,ii,iv) +2ab(i,ii,iv)

Taxonomy	Trends in 1993 (Rasmont et al. 1993)	Inferred IUCN Red List Category (1993)	IUCN Red List Category (Drossart al. 2019)	IUCN Red List Criteria (2019)
Sphecodes scabricollis	-	Threatened	EN	A2bc
Sphecodes spinulosus	-	Threatened	CR	A2bc; B1ab(i,ii,iv) +2ab(i,ii,iv)
MEGACHILIDAE				
Aglaoapis tridentata	DD	DD	RE	
Anthidiellum strigatum	=	LC	LC	
Anthidium manicatum	=	LC	LC	
Anthidium oblongatum	=	LC	LC	
Anthidium punctatum	-	Threatened	LC	
Chelostoma campanularum	=	LC	LC	
Chelostoma distinctum	=	LC	VU	A2c; B1ab(ii,iii)
Chelostoma florisomne	=	LC	LC	
Chelostoma rapunculi	+	LC	LC	
Coelioxys afer	DD	DD	CR	A2bc; B1ab(i,ii,iv) +2ab(i,ii,iv)
Coelioxys alatus	DD	DD	VU	B1ab(iii) + 2ab(iii)
Coelioxys aurolimbatus	-	Threatened	LC	
Coelioxys conoideus	-	Threatened	CR	A2bc; B1(i,ii,iii,iv,v)
Coelioxys echinatus	Not mentioned	Not mentioned	DD	
Coelioxys elongatus	=	LC	VU	A2bc; B1ab(iii) + 2ab(iii)
Coelioxys emarginatus	DD	DD	RE	
Coelioxys inermis	=	LC	LC	
Coelioxys mandibularis	=	LC	VU	A2c; B1ab(i,ii,iii,iv) +2ab(i,ii,iii,iv)
Coelioxys quadridendatus	=	LC	CR	A2bc; B1ab (i,ii,iv) +2ab (i,ii,iv)
Coelioxys rufescens	-	Threatened	NT	A2bc; B1ab(i,ii)
Heriades truncorum	+	LC	LC	
Hoplitis adunca	-	Threatened	LC	
Hoplitis anthocopoides	-	Threatened	CR	A2bc; B1ab(i,ii,iii,iv) +2ab(i,ii,iii,iv)
Hoplitis claviventris	=	LC	VU	A2bc
Hoplitis leucomelana	=	LC	LC	
Hoplitis mitis	DD	DD	NA	
Hoplitis papaveris	-	Threatened	RE	
Hoplitis ravouxi	=	LC	CR	A2c; B1ab(i,ii,iv)
Hoplitis tridentata	Not mentioned	Not mentioned	LC	
Hoplitis villosa	-	Threatened	RE	
Megachile alpicola	=	LC	VU	A2c; B1ab(i,ii,iv) +2ab(i,ii,iv)
Megachile analis	DD	DD	CR	A2bc; B1ab(iii) +2ab(iii)
Megachile apicalis	Not mentioned	Not mentioned	NA	
Megachile centuncularis	=	LC	LC	
Megachile circumcincta	-	Threatened	EN	A2bc

Taxonomy	Trends in 1993 (Rasmont et al. 1993)	Inferred IUCN Red List Category (1993)	IUCN Red List Category (Drossart al. 2019)	IUCN Red List Criteria (2019)
Megachile ericetorum	=	LC	LC	
Megachile genalis	DD	DD	CR	A2bc; B1ab(iii) +2ab(iii)
Megachile lagopoda	-	Threatened	CR	A2bc; B1ab(i,ii,iii,iv)
Megachile lapponica	+	LC	LC	
Megachile leachella	=	LC	VU	A2bc; B1ab(iii) +2ab(iii)
Megachile ligniseca	-	Threatened	LC	
Megachile maritima	=	LC	CR	A2bc; B1ab(i,ii,iii,iv) +2ab(i,ii,iii,iv)
Megachile octosignata	Not mentioned	Not mentioned	NA	
Megachile pilidens	DD	DD	CR	B2ab(iii)
Megachile pyrenaea	-	Threatened	LC	
Megachile rotundata	DD	DD	LC	
Megachile versicolor	=	LC	LC	
Megachile willughbiella	=	LC	LC	
Osmia andrenoides	DD	DD	CR	B1ab(iii) +2ab(iii)
Osmia aurulenta	-	Threatened	NT	A2c
Osmia bicolor	=	LC	LC	
Osmia bicornis	+	LC	LC	
Osmia brevicornis	DD	DD	NA	
Osmia caerulescens	=	LC	LC	
Osmia cornuta	+	LC	LC	
Osmia inermis	DD	DD	NA	
Osmia leaiana	=	LC	LC	
Osmia melanogaster	Not mentioned	Not mentioned	DD	
Osmia mustelina	DD	DD	NA	
Osmia niveata	=	LC	LC	
Osmia parietina	=	LC	EN	A2c; B1ab(i,ii,iv) +2ab(i,ii,iv)
Osmia pilicornis	-	Threatened	RE	
Osmia rufohirta	=	LC	EN	A2bc; B1ab(i,ii,iii,iv) +2ab(i,ii,iii,iv)
Osmia spinulosa	-	Threatened	NT	A2bc; B1ab(iii) +2ab(iii)
Osmia uncinata	=	LC	EN	A2bc; B1ab(i,ii,iv) +2ab(i,ii,iv)
Osmia xanthomelana	-	Threatened	RE	
Pseudanthidium scapulare	Not mentioned	Not mentioned	NA	
Stelis breviuscula	=	LC	LC	
Stelis minima	DD	DD	RE	
Stelis minuta	=	LC	RE	
Stelis odontopyga	DD	DD	NA	
Stelis ornatula	=	LC	VU	A2bc; B2ab(i,ii,iv)
Stelis phaeoptera	-	Threatened	NT	A2bc; B1ab(i,ii) +2ab(i,ii)

Taxonomy	Trends in 1993 (Rasmont et al. 1993)	Inferred IUCN Red List Category (1993)	IUCN Red List Category (Drossart al. 2019)	IUCN Red List Criteria (2019)
Stelis punctulatissima	-	NT	LC	
Stelis signata	-	NT	VU	A2bc
Trachusa byssina	=	LC	LC	
MELITTIDAE				
Dasypoda argentata	Not mentioned	Not mentioned	RE	
Dasypoda hirtipes	=	LC	LC	
Macropis europaea	=	LC	LC	
Macropis fulvipes	=	LC	LC	
Melitta dimidiata	Not mentioned	Not mentioned	NA	
Melitta haemorrhoidalis	=	LC	LC	
Melitta leporina	-	Threatened	LC	
Melitta nigricans	=	LC	LC	
Melitta tricincta	=	LC	VU	B2ab(i,ii,iii)

Megachile maritima (Critically Endangered). Kurt Geeraerts

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