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Dirk Maes, Tim Adriaens, Frank Van de Meutter, Kevin Maebe, Steven De Saeger, Geert De Knijf, Jasmijn Hillaert, Toon Spanhove, Pieter Vanormelingen, Carine Wils

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DELINEATING IMPORTANT POLLINATOR AREAS IN FLANDERS (NORTHERN BELGIUM)

Dirk Maes, Tim Adriaens, Frank Van de Meutter, Kevin Maebe, Steven De Saeger, Geert De Knijf, Jasmijn Hillaert, Toon Spanhove, Pieter Vanormelingen & Carine Wils

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Abstract

The strong and rapid decline of pollinators and other insects has recently drawn attention from both scientists and the media. The main threats to insects are habitat loss and fragmentation, pesticides, climate change and invasive species (such as the Yellow-legged hornet). To halt this decline, it is crucial to conserve and manage areas that are important for insects in general and for pollinators in particular. Using a recently published report on important European habitat types for pollinators (Kudrnovsky et al. 2020), we delineate potentially important areas for pollinators in Flanders. In total, we identified 226,140 hectares of such areas, of which 79,044 hectares (35%) are located in Natura2000 sites. Grasslands (92,857 ha) occupy the largest amount of important pollinator areas in Flanders, followed by non-Habitats Directive biotopes (51,892 ha) and forests (44,863 ha). The best protected pollinator habitats by Natura2000 are coastal habitats and halophytic vegetations and coastal dunes (both 94%), followed by heathland and shrub vegetation (67%). Important grassland habitats (24%) and non-European habitat types (17%), however, are very poorly represented in Natura2000 sites. The maps produced here can be useful in protecting important areas for pollinators, as well as in setting priorities for eradicating the Yellow-legged hornet. We also provide a non-exhaustive list of scientific articles supporting suitable management for various habitats. Finally, we call for better baseline data and for the establishment of a scientifically supported monitoring network for pollinators in Flanders so that trends in their abundance can be closely monitored.

Picture 1 Patchwork Leaf-Cutter Bee (*Megachile centuncularis*, left) and Comma butterfly (*Polygonia c-album*, right) (picture: Dirk Maes).

Samenvatting

De sterke en snelle achteruitgang van bestuivers en andere insecten kreeg recent veel aandacht van zowel wetenschappers als de media. De voornaamste bedreigingen voor deze dieren zijn biotoopverlies en -versnippering, pesticiden, klimaatverandering en invasieve exoten (waaronder de Aziatische hoornaar). Om deze achteruitgang een halt toe te roepen, is het cruciaal dat gebieden die belangrijk zijn voor insecten in het algemeen en voor bestuivers in het bijzonder beschermd en gepast beheerd worden. Met behulp van een recent gepubliceerd rapport over belangrijke Europese habitattypes voor bestuivers (Kudrnovsky et al. 2020), bakenen we dergelijke potentieel belangrijke gebieden voor deze bestuivers af in Vlaanderen. In totaal duidden we 226.140 hectare potentieel belangrijk gebied voor bestuivers aan, waarvan 79.044 hectare (35%) in Natura2000-gebied ligt. Graslanden (92.857 ha) beslaan het grootste deel van belangrijke bestuiversgebieden in Vlaanderen, gevolgd door niet-Habitatrichtlijn biotopen (51.892 ha) en bossen (44.863 ha). Een groot deel van de kusthabitats, halofytenvegetaties en zeekustduinen (beide 94%) ligt in Natura2000-gebied. De belangrijkste heide- en struweelvegetaties voor bestuivers liggen voor 67% in Natura2000-gebied. Belangrijke graslandbiotopen (24%) en niet-Europese habitattypes (17%) zijn, daarentegen, slecht vertegenwoordigd in Natura200-gebied. De kaarten die hier gemaakt werden, kunnen nuttig zijn bij het afbakenen van bijkomend belangrijk gebied voor bestuivers, maar bijvoorbeeld ook bij het stellen van prioriteiten voor de bestrijding van de Aziatische hoornaar. We geven ook een niet-exhaustieve lijst van wetenschappelijke artikels die een geschikt beheer voor verschillende biotopen onderbouwen. Tenslotte roepen we op om betere basisgegevens over bestuivers te verzamelen en een wetenschappelijk gefundeerd monitoringmeetnet op te starten in Vlaanderen zodat trends in de abundantie van bestuivers op de voet gevolgd kunnen worden.

Picture 2 Common quaker (*Orthosia cerasi*) carrying willow pollen (picture: Lieven Decrick & Timon Boumon).

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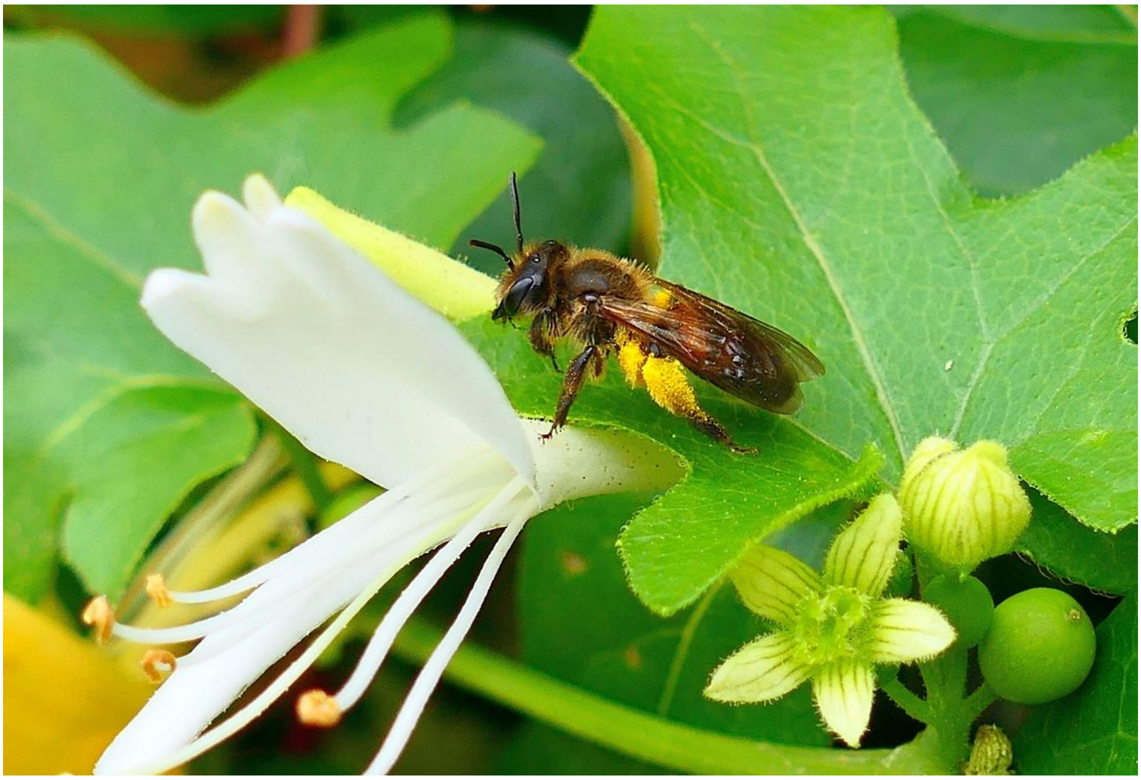
Picture 3 Ashy Furrow Bee (*Lasioglossum sexnotatum*, picture: Dirk Maes).

1 INTRODUCTION

Insects are in strong decline, both globally (Wagner et al. 2021) and regionally (Hallmann et al. 2017). Among insects, the decline of pollinators is particularly worrying because of the possible impacts on the pollination ecosystem service they deliver (Potts et al. 2010; Wratten et al. 2012; Vanbergen et al. 2013; Dicks et al. 2021; Perennes et al. 2021). All authors agree that this decline is a combination of habitat loss (leading to a decline in nectar and/or pollen sources), habitat fragmentation (Xiao et al. 2016), pesticides (Goulson et al. 2015), climate change (Vasiliev & Greenwood 2021) and invasive alien species (Rodríguez et al. 2023).

One way to conserve pollinators and other threatened insects is to delineate and/or manage protected areas (Chowdhury et al. 2023). The European Birds and Habitats Directives, for example, can be used to assign protected areas on the basis of the presence of species of European conservation concern (Louette et al. 2015). For some taxonomic groups, such as birds (Van Vreeswijk et al. 2019), plants (Sparrius et al. 2019) and butterflies (van Swaay & Warren 2006), important areas for conservation have been suggested on a European or even global scale, based on quantitative criteria (e.g., plants – Darbyshire et al. 2017). With the recently published list of habitats important for pollinators (Kudrnovsky et al. 2020), we can delineate sites that contain these habitats in Flanders (northern Belgium) using the Biological Valuation Map, a regional mapping project of biotopes (De Saeger et al. 2017).



Picture 4 Bryony mining bee (*Andrena florea*, picture: Dirk Maes).

2 METHODS

2.1 STUDY AREA

In Belgium, all conventions (apart from marine conservation) regarding nature conservation are delegated to the regions. As a result, the three different administrative regions (Flanders, Wallonia and the Brussels Capital Region) are responsible for their nature conservation policy. Flanders is the northern administrative region of Belgium and covers an area of 13,522 km² (Figure 1). It is one of the most densely populated regions in Europe (481 inhabitants/km²; www.vlaanderen.be). More than half of the territory of Flanders is agricultural land and 26% is urbanised (Poelmans & Van Rompaey 2009). The average percentage of land take (all land used by man and thus not for agriculture, semi-natural areas, forestry or water) is 32% (Pisman & Vanacker 2021), compared to 4% in Europe. The region is also taking the cake in terms of urban sprawl (urban fragmentation of the landscape) in Europe (EEA 2016).

Due to habitat loss and fragmentation, anthropogenic pollution and habitat degradation (e.g., eutrophication due to nitrogen deposition), many species across all taxonomic groups have suffered severe losses in recent times in Flanders (e.g., vascular plants – Van Landuyt et al. (2008), butterflies – Maes et al. (2022), freshwater fishes – Verreycken et al. (2014), ladybirds – Adriaens et al. (2015), breeding birds – Devos et al. (2016), hoverflies – Van de Meutter et al. 2021) and macro-moths – Veraghtert et al. 2023)).

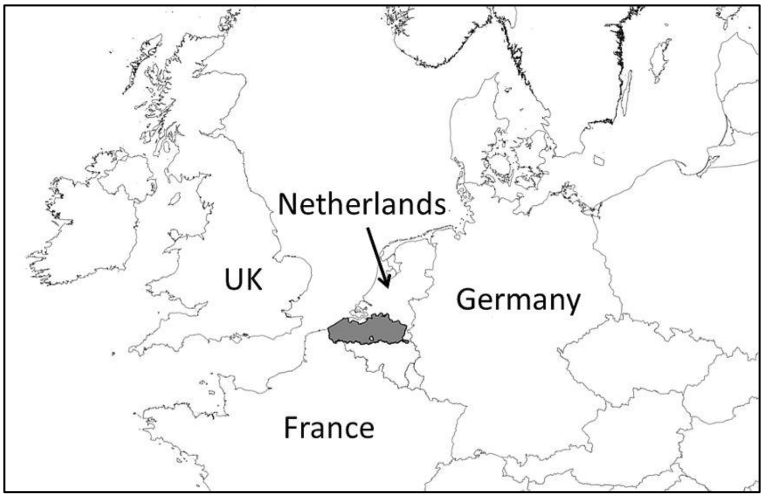


Figure 1 Location of Flanders (in grey) in NW Europe.

2.2 ANNEX I HABITATS IMPORTANT FOR POLLINATORS

Recently, Kudrnovsky et al. (2020) published a list of Annex I habitats important for pollinators. This selection is largely based on the presence of pollinator-dependent plants (Appendix 1). Per biotope group, they made a selection of the five best European Habitats directive Annex I habitats with a high proportion of plant species providing foraging resources for pollinators. To calculate their value to pollinators, the authors also took into account the length of the flowering season of the flowering plants in these habitats. Apart from the top five habitats, they also selected additional other habitats that can be important for pollinators. In Kudrnovsky et al. (2020), however, some of the Annex I habitats are not present in Flanders and they are, hereafter, not mentioned or used for further analysis. Based on Decleer (2007), Vriens et al. (2011) and De Saeger et al. (2017), we translated the selected Annex I habitats into codes of the Biological Valuation Map (BVM), a high-resolution region-wide mapping project of land cover based on vegetation.

It is important to highlight that this report capitalizes on the critical role of nectar and pollen provision for pollinators, whereas for their survival additional resources and habitats are needed. As such, the presented habitats and maps may not represent the complete focal area to sustain pollinator populations, but they do address an important aspect of their life cycle. The resulting maps have to be considered as potentially important areas for pollinators and do not necessarily reflect actual pollinator-rich areas.

2.3 ADDITIONAL IMPORTANT BIOTOPES FOR POLLINATORS IN FLANDERS

Apart from the biotopes important for pollinators mentioned in Kudrnovsky et al. (2020), we additionally selected regional biotopes that are important for pollinators in Flanders. This selection of additional biotopes is based on Adriaens & Laget (2008), Vriens et al. (2011) and De Bie et al. (2018). Because they represent important assets for pollinators besides floral richness (e.g., nesting sites), we also included linear and small landscape elements in this selection.

2.4 METHOD

To delineate important areas for pollinators in Flanders, we used the GeoDynamiX (gdx) toolbox (https://geodynamix.eu/), developed by the Flemish Institute for Technological Research (VITO). This tool makes it possible to select sites at a very high resolution (20 x 20 m²) that fulfil specific ecological requirements (e.g., a certain biotope type needs to be present in a minimum area at a certain distance of another biotope type). The basis for the gdx toolbox is the Biological Valuation Map (BVM). The BVM project maps all habitats present at the scale of the parcel (De Saeger et al. 2017). A coding system is applied to map all biotope types (Appendix 2), the European Union Habitats Directive Annex I habitats (Council Directive 92/43/EEC; Decleer 2007) and the regionally important biotopes (De Bie et al. 2018) at the same resolution. The field surveys to assign BVM codes to parcels is largely based on the presence of vegetations and their structure, indicator plant species and the presence of ecological features such as small landscape elements. The BVM is subsequently rasterised at a 20 x 20 m² resolution to fit the resolution of the gdx toolbox.

We used both the list of Annex I habitats selected by Kudrnovsky et al. (2020) in combination with the corresponding codes in the regional Biological Valuation Map and in the regionally important biotopes to delineate potentially important areas for pollinators in Flanders. Per habitat type group (e.g., grasslands, heathlands, forests), we selected all grid cells that contain either the European habitat type and/or the corresponding BVM code. A '+' added to the BVM code refers to a high-quality habitat (Vriens et al. 2011). To assure a minimum area of potentially suitable sites, we grouped these grid cells into clusters of ≥ 0.5 ha (cf. Maes et al. 2019). We regrouped habitats according to the biotope classification in Paelinckx et al. (2019). We distinguish between priority habitat types (top five habitats in Kudrnovsky et al. 2020) and additional habitat types (as defined by Kudrnovsky et al. 2020).

Per biotope type, we determine the proportion of Important Pollinator Areas that is actually covered by Natura2000 sites. Natura2000 sites are the combination of the European Birds Directive and Habitats Directive sites. In Flanders, the total area of Natura2000 sites is 166,322 ha (12% of the Flemish territory).

2.5 BIOTOPES

2.5.1 Coastal and halophytic habitats

2.5.1.1 EU Annex I Habitats Directive habitat types

Two top five Annex I coastal and halophytic habitats important for pollinators are present in Flanders (Table 1).

Table 1 Annex I coastal and halophytic habitats important for pollinators present in Flanders together with the translation into Biological Valuation Map biotope codes (see Appendix 2).

Habitat	Top five habitats present in Flanders	BVM code
1130	Estuaries	mz
1330	Atlantic salt meadows (*Glauco-Puccinellietalia maritima*)	da,mz

2.5.1.2 Additional regional coastal and halophytic habitats important for pollinators

Based on Adriaens & Laget (2008) and regionally important habitats (De Bie et al. 2018), no additional important coastal and halophytic habitats for pollinators in Flanders were selected.

Picture 5 Salt meadows in Klemskerke, an example of Annex I habitat type 1330 in Flanders (picture: Yves Adams).

2.5.2 Coastal sand dunes

2.5.2.1 EU Annex I Habitats Directive habitat types

Three top five Annex I and one additional coastal sand dune habitats important for pollinators are present in Flanders (Table 2).

Table 2 Annex I coastal sand dune habitats important for pollinators present in Flanders together with the translation into Biological Valuation Map biotope codes (see Appendix 2).

Habitat	Top five habitats present in Flanders	BVM code
2190	Humid dune slacks	hc,mp,ae+
2130	Fixed coastal dunes with herbaceous vegetation ('grey dunes')	had,hd
2180	Wooded dunes of the Atlantic, Continental and Boreal region	ru,rud,vn
	Additional important habitats	
2170	Dunes with Salix repens ssp. argentea (*Salicion arenariae*)	sd

2.5.2.2 Additional regional coastal sand dunes important for pollinators

Based on Adriaens & Laget (2008) and regionally important habitats (De Bie et al. 2018), no additional coastal sand dune habitats important for pollinators in Flanders were selected.

Picture 6 Humid dune slack with Marsh helleborine (*Epipactis palustris*) in the Westhoek nature reserve in De Panne, an example of Annex I habitat type 2190 in Flanders (picture: Yves Adams).

2.5.3 Freshwater habitats

2.5.3.1 EU Annex I Habitats Directive habitat types

Two top five Annex I freshwater habitats important for pollinators are present in Flanders (Table 3).

Table 3 Annex I freshwater habitats important for pollinators present in Flanders together with the translation into Biological Valuation Map biotope codes (see Appendix 2).

Habitat	Top five habitats present in Flanders	BVM code
3130	Oligotrophic to mesotrophic standing waters with vegetation of the *Littorelletea uniflorae* and/or of the *Isoëto-Nanojuncetea*	aom
3270	Rivers with muddy banks with *Chenopodion rubri* p.p. and *Bidention* p.p. vegetation	-

2.5.3.2 Additional regional freshwater habitats important for pollinators

Based on Adriaens & Laget (2008) and regionally important habitats (De Bie et al. 2018), we selected two additional regional freshwater habitats important for pollinators in Flanders (Table 4).

Table 4 Additional freshwater habitats important for pollinators in Flanders.

Description	BVM code
Eutrophic water (several plant communities) with *Nymphaea alba* and *Nuphar lutea*	ae+,aev,aev+
Eutrophic water (several plant communities) with *Hydrocharis morsus-ranae* and *Stratiotes aloides*	

Picture 7 Oligotrophic water with *Potamogeton polygonifolius* in Dessel, an example of Annex I habitat type 3130 in Flanders (picture: Rollin Verlinde).

Picture 8 Wet heathland in Buitengoor, an example of Annex I habitat type 4010 in Flanders (picture: Yves Adams).

2.5.4 Sclerophyllous scrubs, temperate heaths and scrubs and inland dune habitats

2.5.4.1 EU Annex I Habitats Directive habitat types

Three top five and two additional Annex I sclerophyllous scrub, temperate heath and scrub, and inland dune grasslands important for pollinators according to Kudrnovsky et al. (2020) are present in Flanders (Table 5).

Table 5 Annex I sclerophyllous scrubs, temperate heaths and scrub, and inland dune grasslands important for pollinators present in Flanders together with the translation into Biological Valuation Map biotope codes (see Appendix 2).

Habitat	Top five habitats present in Flanders	BVM code
5130	*Juniperus communis* formations on heaths or calcareous grasslands	cg+jun
4030	European dry heaths	cg,cv,sg
2330	Inland dunes with open *Corynephorus* and *Agrostis* grasslands	ha,hat,hac
	Additional important habitats	
4010	Northern Atlantic wet heaths with *Erica tetralix*	ce,ces
2310	Dry sand heaths with *Calluna* and *Genista*	cg

2.5.4.2 Additional regional sclerophyllous scrubs, temperate heaths and scrubs and inland dune habitats important for pollinators

Based on Adriaens & Laget (2008) and regionally important habitats (De Bie et al. 2018), we selected one additional regional sclerophyllous scrubs, temperate heaths and scrubs, and inland dunes habitat type important for pollinators in Flanders.

Table 6 Additional sclerophyllous scrubs, temperate heaths and scrubs and inland dunes important for pollinators in Flanders.

Description	BVM or RIB code
Myrica gale scrubs	sm,rbbsm

2.5.5 Natural and semi-natural grasslands

2.5.5.1 EU Annex I Habitats Directive habitat types

Four top five and two additional Annex I natural and semi-natural grassland habitats important for pollinators according to Kudrnovsky et al. (2020) are present in Flanders (Table 7). The habitats given by Westrich (2018) for wild bees do not add other natural and semi-natural grassland habitats to the list of grasslands important for pollinators in Flanders.

Table 7 Annex I natural and semi-natural grassland habitats important for pollinators present in Flanders together with the translation into Biological Valuation Map biotope codes (see Appendix 2).

Habitat	Top five habitats present in Flanders	BVM code
6210	Semi-natural dry grasslands and scrubland facies on calcareous substrates (*Festuco-Brometalia*) (important orchid sites)	hk,sk
6430	Hydrophilous tall herb fringe communities of plains and of the montane to alpine levels	hf,hfc,hft, hfe,rbbhf,ku+
6510	Lowland hay meadows (*Alopecurus pratensis*, *Sanguisorba officinalis*)	hu
6230	Species-rich Nardus grasslands, on silicious substrates in mountain areas (and submountain areas in Continental Europe)	hmo,hn
	Additional important habitats	
6410	Molinia meadows on calcareous, peaty or clayey-silt-laden soils (*Molinion caeruleae*)	hm,hme hmm
6120	Xeric sand calcareous grasslands (in the Meuse ecodistrict)	hu

2.5.5.2 Additional regional natural and semi-natural grasslands important for pollinators

Based on Adriaens & Laget (2008) and regionally important habitats (De Bie et al. 2018), we selected seven additional regional natural and semi-natural grassland habitats important for pollinators in Flanders (Table 8).

Table 8 Additional natural and semi-natural grassland habitats important for pollinators in Flanders.

Description	BVM or RIB code
Species-rich cultivated grasslands	hp+
Species-rich cultivated grasslands with ditches and microrelief	hpr+
Abandoned grasslands	hr/hp+
Species-rich *Agrostis* grasslands	rbbha
Cynosurion grasslands	rbbkam
Species-rich *Alopecurion* grasslands	rbbvos
Potentilla anserina grasslands	rbbzil

Picture 9 Verge of the Canal Kortrijk-Bossuit in Moen, an example of Annex I habitat type 6210 in Flanders (picture: Yves Adams).

Picture 10 Marsh with Swamp sawgrass (*Cladium mariscus*) in Mol, an example of Annex I habitat type 7210 in Flanders (picture: Yves Adams).

2.5.6 Raised bogs, mires and fens

2.5.6.1 EU Annex I Habitats Directive habitat types

According to Kudrnovsky et al. (2020), four top five Annex I raised bog, mire and fen habitats important for pollinators are present in Flanders (Table 9).

Table 9 Annex I raised bogs, mires and fen habitats important for pollinators present in Flanders together with the translation into Biological Valuation Map biotope codes (see Appendix 2).

Habitat	Top five habitats present in Flanders	BVM code
7230	Alkaline fens	mk
7140	Transition mires and quaking bogs	md,ms
7210	Calcareous fens with *Cladium mariscus* and species of the Caricion davalliana	mm
7220	Petrifying springs with tufa formation (*Cratoneurion*)	-

2.5.6.2 Additional regional raised bogs, mires and fens important for pollinators

Based on Adriaens & Laget (2008) and regionally important habitats (De Bie et al. 2018), we selected one additional regional raised bog, mire and fen habitat important for pollinators in Flanders (Table 10).

Table 10 Additional regional raised bogs, mires and fen habitat important for pollinators in Flanders.

Description	BVM/RIB code
Reed marshes	mr,rbbmr

2.5.7 Forests

2.5.7.1 EU Annex I Habitats Directive habitat types

Two top five and two additional Annex I forest habitats important for pollinators, following Kudrnovsky et al. (2020) are present in Flanders (Table 11).

Table 11 Annex I forest habitats important for pollinators present in Flanders together with the translation into Biological Valuation Map biotope codes (see Appendix 2).

Habitat	Top five habitats present in Flanders	BVM code
91E0	Alluvial forests with *Alnus glutinosa* and *Fraxinus excelsior* (Alno-Padion, Alnion incanae, Salicion albae)	vc,va,vf,vm vn,vo,sf
91F0	Riparian mixed forests of *Quercus robur*, *Ulmus laevis* and *Ulmus minor*, *Fraxinus excelsior* or *Fraxinus angustifolia*, along the great rivers (Ulmenion minoris)	qa,ru
	Additional important habitats	
9130	Asperulo-Fagetum beech forests	fa,fe,fm,qa,qe
9160	Sub-Atlantic and medio-European oak or oak-hornbeam forests of the *Carpinion betuli*	qa,fa,ru

2.5.7.2 Additional regional forests important for pollinators

Based on Adriaens & Laget (2008) and regionally important habitats (De Bie et al. 2018), we selected two additional regional forest habitats important for pollinators in Flanders (Table 12).

Table 12 Annex forest habitats important for pollinators in Flanders.

Description	BVM code
Acidophilous oak wood (often with ruderal undergrowth)	qs
Scrubs of forest clearings	se

Picture 11 Bluebells in the Haller forest in Halle, an example of Annex I habitat type 9130 in Flanders (picture: Dirk Maes).

Picture 12 A Red-shanked bumblebee (*Bombus ruderarius*) on a road verge (picture: Pieter Vanormelingen).

2.5.8 Other non-Annex I habitats important for pollinators in Flanders

In Table 13, we give additional non-Annex I natural and semi-natural grassland habitats important for pollinators present in Flanders, that are not mentioned in Kudrnovsky et al. (2020) based on Adriaens & Laget (2008), Biological Valuation Map codes (De Bie et al. 2018) and/or Regionally Important Biotopes (RIBs ; De Bie et al. 2018).

2.5.8.1 Small and linear landscape elements

We selected four additional regional non-Annex I small and linear landscape elements as important for pollinators (Table 13).

Table 13 Additional regional non-Annex I small and linear landscape elements important for pollinators in Flanders based on Biological Valuation Map codes (BVM) and regionally important biotopes (RIB).

Description	BVM code
Hedgerows	kh
Wooded banks	khw
Orchards	kj
Talud	kt

2.5.8.2 Scrubs

We selected four additional regional non-Annex I shrub habitats as important for pollinators (Table 14).

Table 14 Additional regional non-Annex I shrub habitats important for pollinators in Flanders based on Biological Valuation Map codes (BVM) and regionally important biotopes (RIB).

Description	BVM/RIB code
Blackberry scrub	spr
Thorn scrub	sz/rbbsp
Wet *Salix* scrubs on acid peaty soil	rbbso,rbbsf

2.5.8.3 Man-made habitats

We selected three additional regional non-Annex man-made habitats as important for pollinators (Table 15).

Table 15 Additional regional non-Annex I man-made habitats important for pollinators in Flanders based on Biological Valuation Map codes (BVM) and regionally important biotopes (RIB).

Description	BVM code
Flower-rich arable land	bs+,bc+,bu+
Quarries	kc
Slag heaps	kg

Picture 13 Deserted quarry in the Kikbeekbron in Maasmechelen, an example of a non-Annex I habitat type important for pollinators in Flanders (picture: Yves Adams).

3 RESULTS

In this report, we show maps with the distribution of the most important areas for pollinators in Flanders. These maps can also be consulted in more detail on the following webservice: geo.inbo.be/importantpollinatorareas.

3.1 COASTAL AND HALOPHYTIC HABITATS

The total area of coastal and halophytic habitats important for pollinators in Flanders is 5,551 ha of which 5,244 ha (94%) is within Natura2000 sites (Table 16). The distribution of coastal and halophytic habitats important for pollinators in Flanders is shown in Figure 2.

Table 16 Area (in hectares) of coastal and halophytic habitats important for pollinators in Flanders.

Type	Total area	AreaN2000	%N2000
Top five habitats	5,551	5,244	94

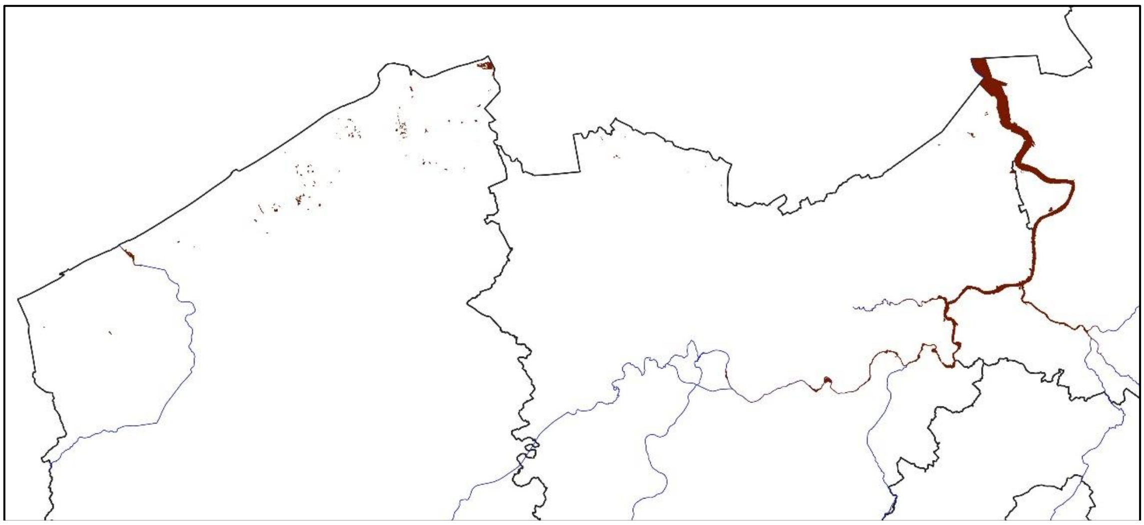


Figure 2 Distribution of coastal and halophytic habitats important for pollinators in Flanders. See geo.inbo.be/importantpollinatorareas for more details.

3.2 COASTAL SAND DUNE HABITATS

The total area of coastal sand dune habitats important for pollinators in Flanders is 2,283 ha of which 2,143 ha (94%) is within Natura2000 sites (Table 17). The distribution of coastal sand dunes important for pollinators in Flanders is shown in Figure 3.

Table 17 Area of coastal sand dune habitats important for pollinators in Flanders.

Type	Total area	AreaN2000	%N2000
Top five habitats	2,027	1,908	94
Additional habitats	256	235	92
Total	2,283	2,143	94

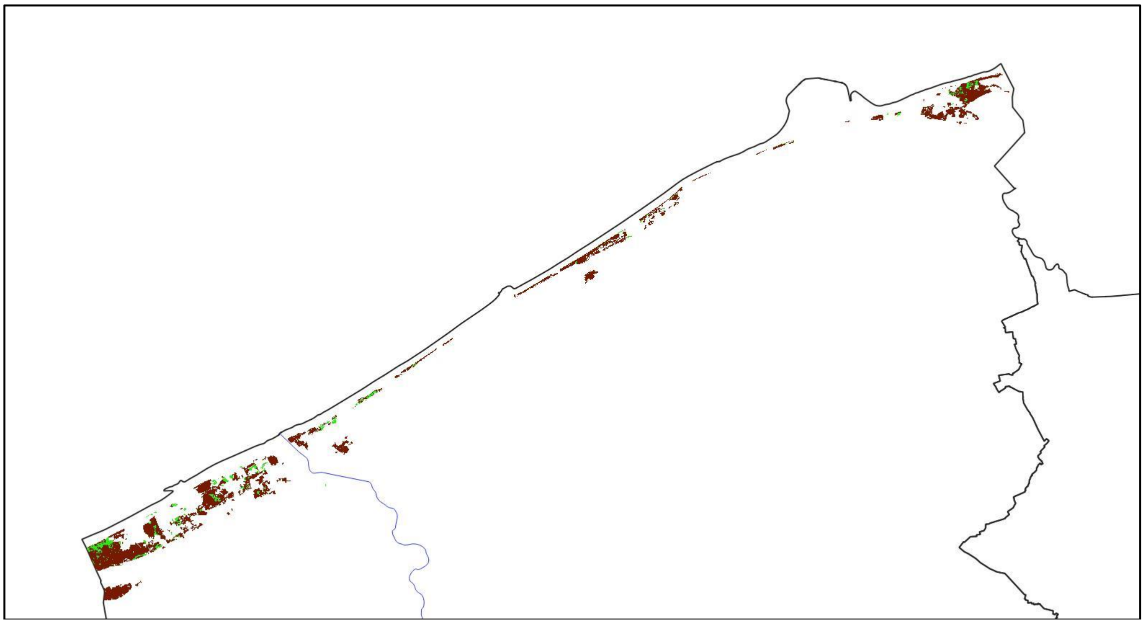


Figure 3 Distribution of top five habitats (dark red) and other (light green) coastal sand dune habitats important for pollinators in Flanders. See geo.inbo.be/importantpollinatorareas for more details.

3.3 FRESHWATER HABITATS

The total area of freshwater habitats important for pollinators in Flanders is 2,665 ha of which 1,517 ha (57%) is within Natura2000 sites (Table 18). The distribution of freshwater habitats important for pollinators in Flanders is shown in Figure 4.

Table 18 Area (in hectares) of freshwater habitats important for pollinators in Flanders.

Type	Total area	AreaN2000	%N2000
Top five habitats	1,579	1,042	66
Additional habitats	1,086	475	44
Total	2,665	1,517	57

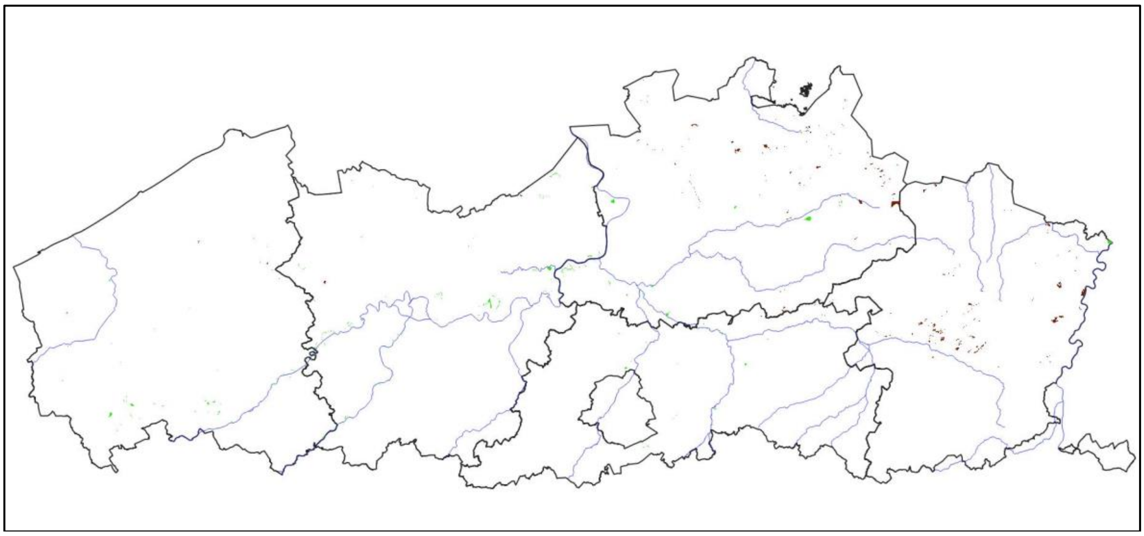


Figure 4 Distribution of top five (dark red) and other (light green) freshwater habitats important for pollinators in Flanders. See geo.inbo.be/importantpollinatorareas for more details.

3.4 SCLEROPHYLLOUS SCRUBS, TEMPERATE HEATHS AND SCRUBS, AND INLAND DUNE HABITATS

The total area of sclerophyllous scrubs, temperate heaths and scrubs, and inland dune habitats in Flanders is 19,285 ha of which 12,983 ha (67%) is within Natura2000 sites (Table 19). The distribution of sclerophyllous scrubs, temperate heaths and scrubs, and inland dune habitats important for pollinators in Flanders is shown in Figure 5.

Table 19 Area of sclerophyllous scrubs, temperate heaths and scrubs, and inland dune habitats important for pollinators in Flanders.

Type	**Total area**	**AreaN2000**	**%N2000**
Top five habitats	17,026	10,928	64
Additional habitats	2,259	2,055	91
Total	19,285	12,983	67

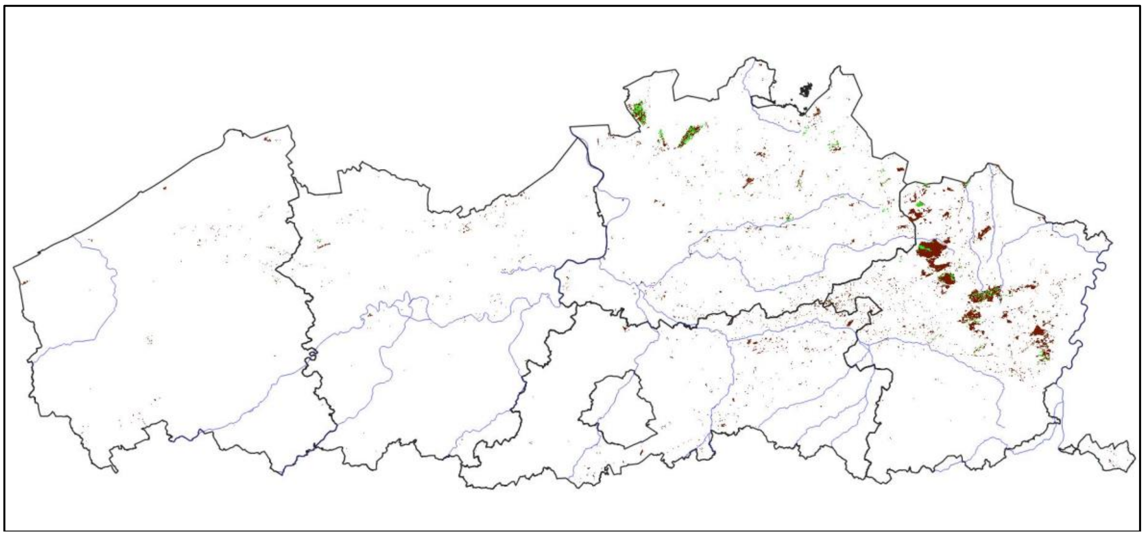


Figure 5 Distribution of top five (dark red) and other (light green) sclerophyllous scrub, temperate heath and scrub, and inland dune habitats important for pollinators in Flanders. See geo.inbo.be/importantpollinatorareas for more details.

3.5 NATURAL AND SEMI-NATURAL GRASSLAND HABITATS

The total area of top five natural and semi-natural grasslands important for pollinators in Flanders is 92,857 ha of which 22,715 ha (24%) is within Natura2000 sites (Table 20). The distribution of natural and semi-natural grassland habitats important for pollinators in Flanders is shown in Figure 6.

Table 20 Area of natural and semi-natural grassland habitats important for pollinators in Flanders.

Type	Total area	AreaN2000	%N2000
Top five habitats	18,091	6,877	38
Additional habitats	74,766	15,838	21
Total	92,857	22,715	24

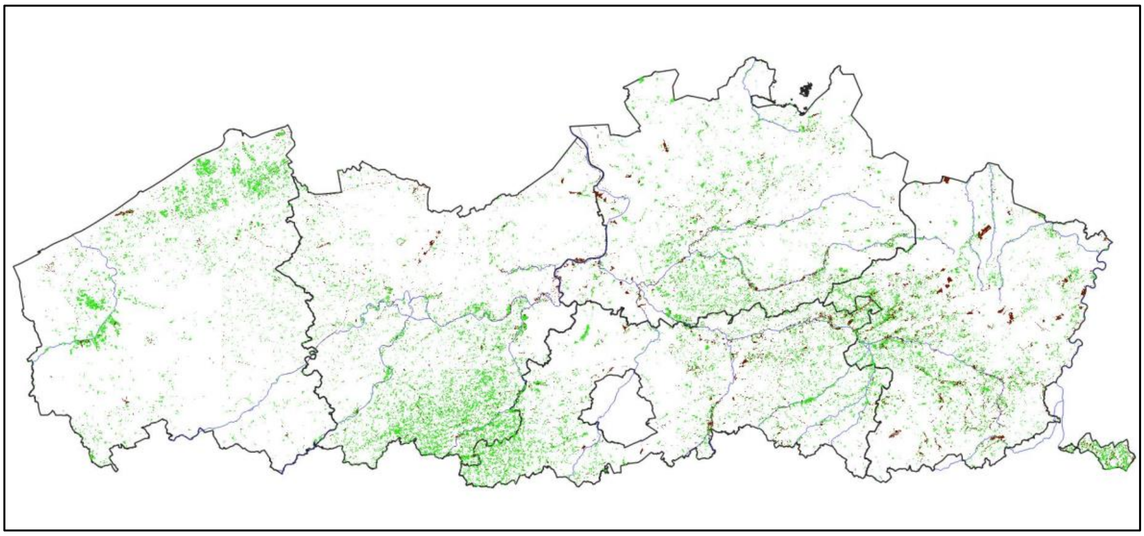


Figure 6 Distribution of top five sites (dark red) and other (light green) natural and semi-natural grassland habitats important for pollinators in Flanders. See geo.inbo.be/importantpollinatorareas for more details.

3.6 RAISED BOGS, MIRES AND FEN HABITATS

The total area of raised bogs, mires and fen habitats important for pollinators in Flanders is 6,744 ha of which 3,756 ha (56%) is within Natura2000 sites (Table 21). The distribution of other raised bogs, mire and fen habitats important for pollinators in Flanders is shown in Figure 7.

Table 21 Area of raised bogs, mires and fen habitats important for pollinators in Flanders.

Type	Total area	AreaN2000	%N2000
Top five habitats	1,608	1,123	70
Additional habitats	5,136	2,633	51
Total	6,744	3,756	56

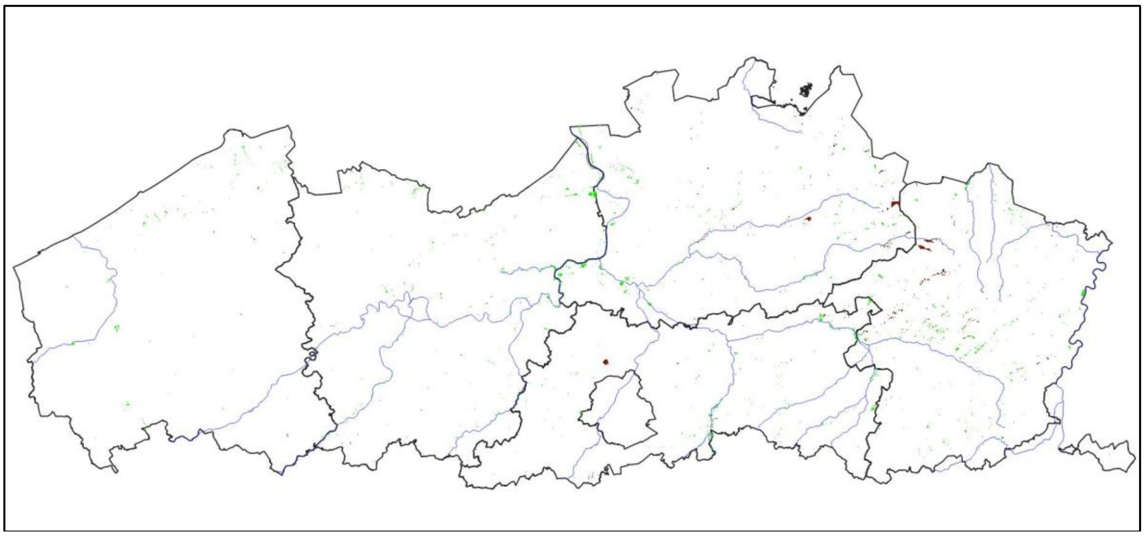


Figure 7 Distribution of top five (dark red) and other (light green) raised bog, mire and fen habitats important for pollinators in Flanders. See geo.inbo.be/importantpollinatorareas for more details.

3.7 FOREST HABITATS

The total area of forest habitats important for pollinators in Flanders is 44,863 ha of which 21,862 ha (49%) is within Natura2000 sites (Table 22). The distribution of forest habitats important for pollinators in Flanders is shown in Figure 8.

Table 22 Area of forest habitats important for pollinators in Flanders.

Type	Total area	AreaN2000	%N2000
Top five habitats	23,607	11,905	50
Additional habitats	21,256	9,957	47
Total	44,863	21,862	49

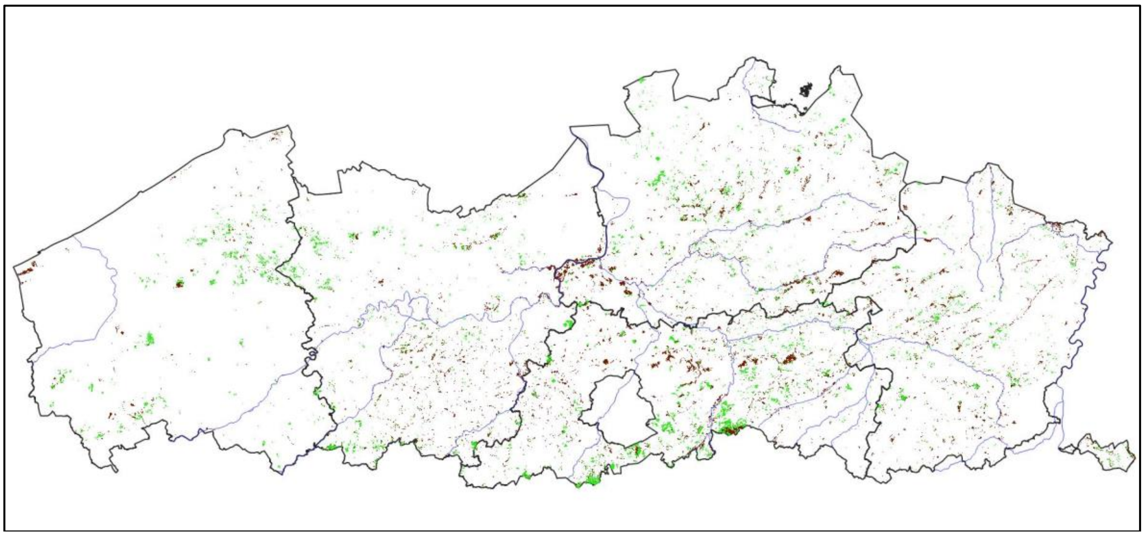


Figure 8 Distribution of top five (dark red) and other (light green) forest habitats important for pollinators in Flanders. See geo.inbo.be/importantpollinatorareas for more details.

3.8 OTHER NON-ANNEX I HABITATS IMPORTANT FOR POLLINATORS IN FLANDERS

The total area of non-Annex I habitats important for pollinators in Flanders is 51,892 ha of which 8,844 ha (17%) is within Natura2000 sites. The distribution of non-Annex I habitats important for pollinators in Flanders is shown in Figure 9.

Table 23 Area (in hectares) of other regionally important for pollinators in Flanders.

Type	Total area	AreaN2000	%N2000
Additional regional habitats	51,892	8,844	17

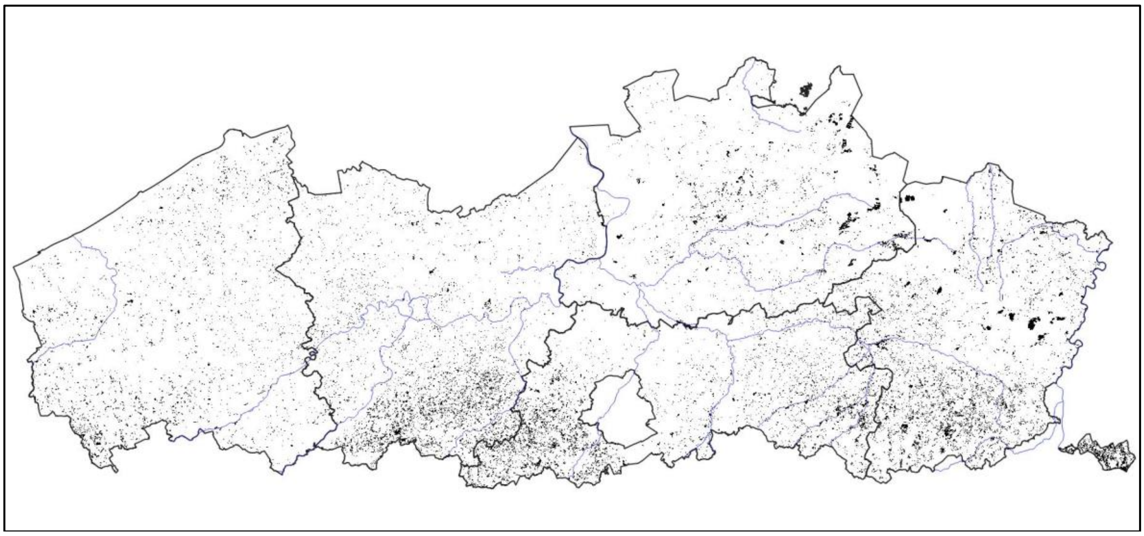


Figure 9 Distribution of additional regional non-Annex I habitats important for pollinators in Flanders. See geo.inbo.be/importantpollinatorareas for more details.

3.9 OVERVIEW

The total area of habitats important for pollinators in Flanders is 226,140 ha (17% of Flanders) of which 79,044 ha (35%) is within Natura2000 sites (Table 24).

Table 24 Overview of the area per habitat type important for pollinators in Flanders in descending order of area covered by Natura2000 sites. The total area is not necessarily the sum of all habitats since they can overlap.

Habitat type	**Area (ha)**	**N2000 (ha)**
Coastal and halophytic habitats	5,551	5,244 (94%)
Coastal sand dune habitats	2,283	2,143 (94%)
Sclerophyllous scrubs, temperate heaths and scrubs, and inland dune habitats	19,285	12,983 (67%)
Freshwater habitats	2,665	1,517 (57%)
Raised bogs, mires and fen habitats	6,744	3,756 (56%)
Forest habitats	44,863	21,862 (49%)
Natural and semi-natural grassland habitats	92,857	22,715 (24%)
Other non-Annex I habitats	51,892	8,844 (17%)
Total	226,140	79,044 (35%)

The distribution of habitats important for pollinators in Flanders is shown in Figure 10.

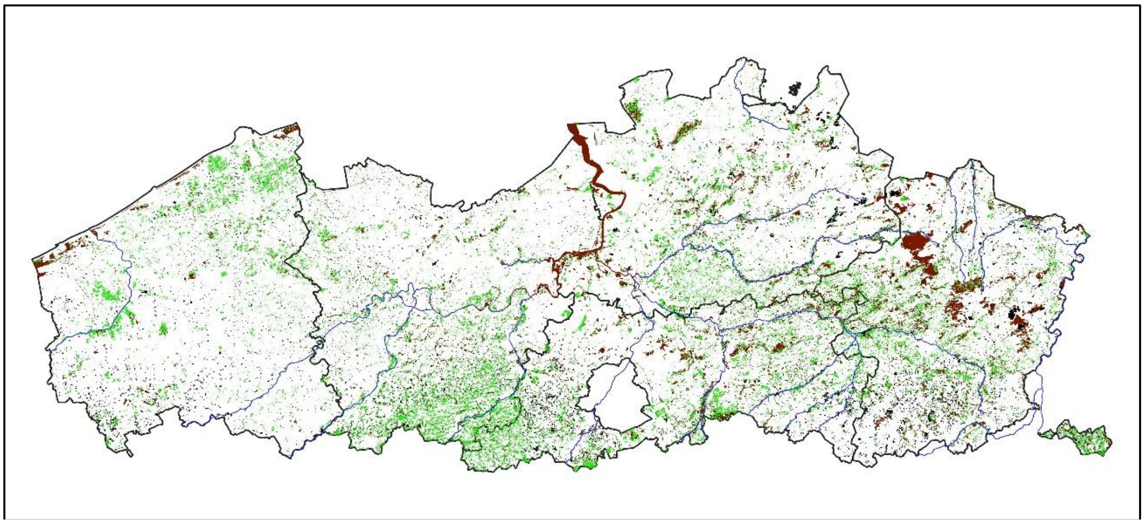


Figure 10 Distribution of top five (dark red) and other (light green) Annex I habitats and additional regional habitats (black) important for pollinators in Flanders. See geo.inbo.be/importantpollinatorareas for more details.

4 IMPLICATIONS FOR CONSERVATION

4.1 DISCLAIMER

The delineation of Important Pollinator Areas in Flanders used the Biological Valuation Map (BVM) version 2018 and some changes may have occurred since then (e.g., tree plantations on former arable fields, felling of trees to create heathland). Therefore, the maps need to be looked at as important sites with a potential for pollinators. Updated versions of the Biological Valuation Map might result in slightly different delineations, but the maps should not be used to the square meter, but as indicative locations. Furthermore, the BVM classification does not always differentiate between high and low quality habitats which means that this delineation needs to be interpreted with additional local knowledge of habitat suitability for pollinators. Historical differences in the level of mapping details might, however, still result in biased results. This is especially true for hedgerows in agricultural landscapes, which were not consequently mapped in the past. With the ongoing actualisation of the BVM and the use of a stricter methodology, these historical biases will fade when using upcoming versions of the BVM.

The list of important habitat types determined in the report of Kudrnovsky et al. (2020) is based on the number of plant species important for pollinators per habitat type on a European scale. This number of plant species can, however, differ considering the habitats at a regional (Flemish) scale.

Alternative and complementary methods for the delineation of Important Pollinator Areas are possible as well. These include a focus on nesting (wild bees) or larval habitats (e.g., hoverflies), using hotspots of threatened species that are sometimes already compiled in Red Lists (e.g., Veraghtert et al. 2023), or using habitat associations of the pollinators themselves.

Notwithstanding these obvious pitfalls, it would be interesting to perform a validation study on the currently proposed site selection based on habitat variables. This could be done by using existing databases with recent distribution data of pollinators. This type of data often suffers from unbalances in sampling protocol, sampling intensity or synchrony which may compromise statistical testing. Balanced and coordinated sampling, possibly as part of a larger monitoring scheme (see further) could provide the required type of data over time.

4.2 COVERAGE OF IMPORTANT POLLINATOR SITES BY NATURA2000 SITES

In total, 226,140 ha is delineated as being important for pollinators in Flanders of which 79,044 (35%) is situated within Natura2000 sites (Table 24). Coastal and halophytic habitats (94%) and coastal sand dune habitats (94%) are the habitat types that are most covered by Natura2000 sites, followed by sclerophyllous scrub, temperate heaths and scrubs, and inland dune habitats (67%), freshwater habitats (57%) and raised bogs, mires and fen habitats (56%). Forest habitats (49%) and especially natural and semi-natural grassland habitats (24%) important for pollinators are the Annex I habitat types that are the least covered by Natura2000 sites. In addition, 51,892 ha of additional non-Annex I habitats are considered important for pollinators, of which only 17% is covered by Natura2000 areas (Figure 11).

All biotope types important for pollinators are in an unfavourable conservation status in Flanders: 24 have an unfavourable-bad conservation status and four have an unfavourable-inadequate conservation status (Paelinckx et al. 2019).

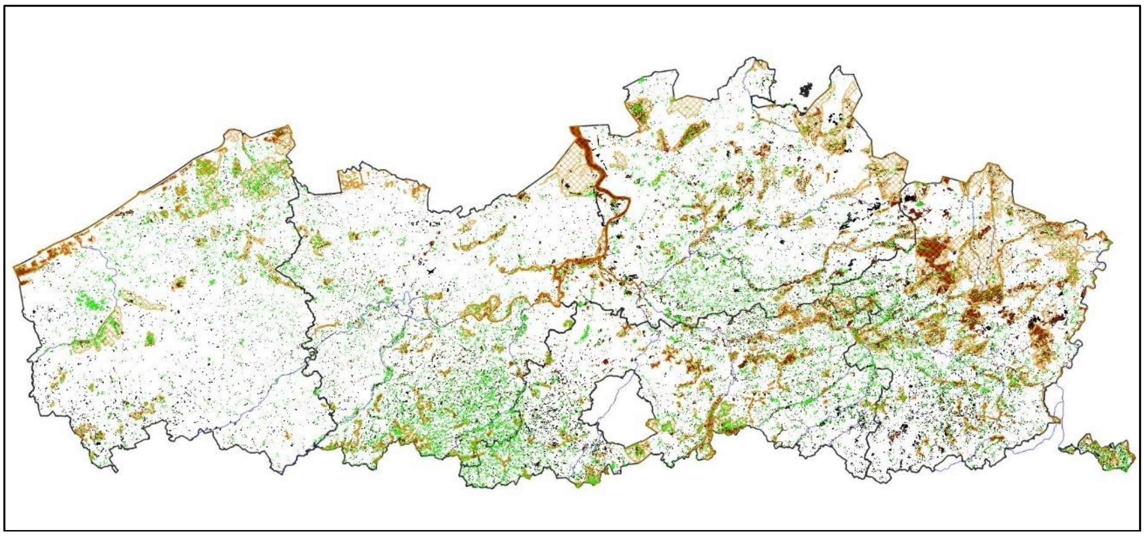


Figure 11 Distribution of top five (dark red) and other (light green) Annex I habitats and additional regional habitats (black) important for pollinators in Flanders and the location of Natura 2000 areas (orange). See geo.inbo.be/importantpollinatorareas for more details.

4.3 USING IMPORTANT POLLINATOR AREAS TO PRIORITISE YELLOW-LEGGED HORNET CONTROL

The Yellow-legged hornet is an invasive alien species that is rapidly spreading in NW Europe since its introduction in 2004 in France (Arca et al. 2015; Keeling et al. 2017; Villemant et al. 2011). In Belgium, the first observation was in 2011 in Vloesberg (Hainaut). Based on risk assessments, it was identified as a potential threat to wild pollinators and other native insects and was therefore added to the list of species of European Union concern according to the invasive alien species Regulation (EU 1143/2014). The species impacts different pollinator groups, primarily bees and wasps (Hymenoptera, Apoidea and Vespoidae) and flies (Diptera, Muscidae, Calliphoridae, Syrphidae) (IUCN 2019). Since the find of the first nest in 2017 (Poperinge, Western Flanders), the Yellow-legged hornet has firmly established in Flanders and spread to the east. The citizen science programme Vespa-Watch (www.vespawatch.be) monitors its expansion and gathers data in support of control. The number of nests in Flanders increased from 40 to 1,400 (2018-2022) showing a fivefold increase in the last two years. With nests reported in 1,062 km^2 squares the species has invaded at least 7.5% of the region (2022). Nest densities are still fairly modest with 1.4 nests per km^2. The species seems to occur mostly in urban areas and has not yet invaded more natural areas at large.

The impact of Yellow-legged hornets on native (non-cultivated) pollinators is through direct predation (Stainton et al. 2023) and through the creation of landscapes of fear which keep native pollinators away from their food plants. The presence of Yellow-legged hornets in flowering plant patches reduces flower visitation rates of small hymenopterans, bumblebees and hoverflies which in turn decreases the quantity of conspecific pollen on stigmas of the studied native plants and ultimately reduced seed set (Rojas-Nossa & Calviño-Cancela 2020; Rojas-Nossa et al. 2023). Also, O'Shea-Wheller et al. (2023) showed a negative association of Yellow-legged hornet densities on the fitness of *Bombus terrestris* colonies indicating potential indirect effects upon colony growth of native eusocial insects.

The feasibility of eradication and spread limitation scenarios for the Yellow-legged hornet in Belgium was assessed as low, mostly because of the high costs and high likelihood of reintroductions or recolonisation from neighbouring countries and regions (Adriaens et al. 2019). Nonetheless, during the first six years after the colonisation, Flanders applied an intensive, area-wide eradication management with 82% (67%-91%) of all reported nests successfully destroyed. Nest destruction is done by using the pyrethroid insecticide permas-D which is currently one of the few compounds allowed for this purpose (Hillaert et al. 2021). Since 2023, however, funding is no longer proportionate to the number of nests. A coordinator was appointed to oversee interventions and provide communication, yet the control campaign has become a patchwork of managed and unmanaged areas. Nest destruction is performed with public funds or on a paid basis and by a variety of operators.

In light of the limited budget available for nest destruction, there is a need for a more targeted approach to mitigate Yellow-legged hornet impacts on biodiversity and native pollinators. The map of important pollinator areas can be used to decide in which regions the eradication of Yellow-legged hornet nests could be prioritised. When combined with the location of detected hornet nests (Picture 14), it can be a flexible tool to assess the priority for nest destruction at any given location. Upon doing so the foraging range of hornets should be taken into account (on average 1,000m around the nest; Poidatz et al. 2018; Van Ransbeeck et al. 2024) and also site ownership, conservation status and management responsibilities can or have to be weighted in the prioritisation. Additionally, the presence of rare wild pollinators and other insects (e.g., oligolectic bees, potential prey insects subject to a species protection plan) should be taken into consideration.

Picture 14 Secondary nest of a Yellow-legged hornet.

4.4 NATURE MANAGEMENT IN IMPORTANT POLLINATOR AREAS

Apart from delineating important areas for pollinators in Flanders, nature management is at least equally important to make these suggest areas suitable for pollinators and other insects. A detailed description of favourable management measures is out of the scope of this publication, but in Appendix 4 we refer to some non-exhaustive international references about nature management in different biotope types.

4.5 THE NEED FOR BASELINE DATA ON POLLINATORS

The exercise presented in the current report represents a first step in systematic conservation planning for the protection of pollinators using an established framework at a European level. We have applied this method at a regional scale, and also supplemented and refined it using habitat-specific maps and information on regionally important biotopes for pollinators.

Although in theory protecting pollinator habitats should represent the most robust measure to ensure sustainable pollinator populations, the life-histories of pollinators play at different scales (Martins 2021). Habitats can be available, but in a bad state, or – even if they appear in a good conservation status based on structural and vegetational criteria – they can lack the specific conditions that pollinators need to fulfil their ecological requirements. For example, various pollinators need specific microclimatic conditions for thermoregulation, shelter from adverse weather conditions, nesting sites (within a short enough distance of the food resources), predator avoidance etc. Some, such as bees and wasps, have hydration needs and need access to water sources or suitable humidity levels. On top of the occurrence of sufficient resource plants, they might also need a specific phenology (floral timing) of their floral resources, a specific phenotype of their host plant etc. Nocturnal pollinators such as moths can have requirements in terms of preservation of darkness or exposure to artificial light (Dekeukeleire et al. 2023). Additionally, for species with a restricted mobility, suitable habitat patches may not be large enough or within the colonisation distance of empty patches, leading to local extinctions (Griffin & Haddad 2021). Although the value of habitats for pollinators is based on available specific information (i.e., the occurrence of pollinator-dependent plants in habitats), it clearly does not take into account all of these factors. Therefore, there is a need for baseline data on pollinators and their ecological requirements to make informed conservation decisions.

First, there is a need to **identify important pollinators**. A very diverse set of organisms/insects provide pollination services to wild plants. Thanks to the Database of Pollinator Interactions (Balfour et al. 2022) and data on plant-pollinator assemblages (Reverté et al. 2023; Klaus et al. 2024), a lot of information is already available on pollinator-plant interactions. Four orders of insects are thought to be most important (Diptera, Hymenoptera, Lepidoptera and Coleoptera) but within these orders many different families are involved, many more than we currently study in the region. The relative importance of different groups to pollination is poorly known and probably strongly depends on plant species, region, time of year, weather etc. Additionally, it is generally hard to discriminate between 'flower-visiting' versus 'pollinating' insects but it is safe to say that a wide range of insects depend on flowers as a resource. Collecting direct observations of pollen transport is labour-intensive and much of the research is skewed towards agricultural crops. For the latter, abundant, relatively specialised insects with long active periods are likely to provide more pollination services (Villa-Galaviz et al. 2023). One established method to determine plant-pollinator interactions to provide such data are **Flower-Insect Timed (FIT) counts** (UK Pollinator Monitoring Scheme 2023). This simple survey method, for which a specific app is available, consists of watching flowers for ten minutes and the insects that land or sit on it (Figure 12). FIT Counts can be done anywhere in 50 x 50 cm² plots, including gardens and parks, in warm, dry weather during daylight hours from 1 April to 30 September. Participants are not asked to identify their observations to species level but to simply record the number of species groups: bumblebees, honeybees, solitary bees, wasps, hoverflies, butterflies and moths, beetles (larger than 3mm), small insects (such as pollen beetles) less than 3mm long or other insects and to provide a picture of what they did observe. In Flanders, a similar initiative, 'Flowerpower', was undertaken in 2023 but focused primarily on flower visitation by pollinators (ID'd with the ObsIdentify app) in gardens. The scope of FIT could be generalized to include more landscape types including semi-natural areas. Recording the number and identity of insects visiting flowers within a specific time frame also allows to understand foraging patterns.

Figure 12 People performing a Flower-Insect Timed (FIT) count (picture: Martin Harvey; source: UK Pollinator Monitoring Scheme).

Secondary data from citizen science projects (i.e., additional information intentionally or unintentionally captured in species records, especially in multimedia-based citizen science reports; e.g., GLOBI database) also provide a valuable source of information on flower visitation (Pernat et al. 2024). In waarnemingen.be, pollinator-flower visit (and other species) interactions can be explicitly entered. This is, for instance, actively promoted among bee experts of the regional wild bees and wasps working group Aculea, resulting at present (March 2021) in 81,000, 48,000 and 9,000 reliable records of wild bee, butterfly and hoverfly - flower interactions, respectively. In addition, the image databases of waarnemingen.be and iNaturalist could be further mined for pictures of insects on flowers potentially using available image classification algorithms to efficiently produce a regionally relevant database of flower visitation by pollinators. Of course, these databases probably also already hold relevant primary interaction data (sensu Groom et al. 2021) for pollinators, their resource plants, predators etc. that could be harvested. Drafting such a database at a regional level actually represents baseline data for a better inclusion of pollinators in nature management schemes and conservation planning. For instance, it could help to calculate the pollinator value of biotopes at various spatial scales to make decisions on mowing regimes of roadside verges (e.g., KleurKeur) and grasslands or, to help choose appropriate flower seed mixes for public greenery and stewardship schemes (cf. Mergeay & Adriaens 2013).

Finally, geographical trends in pollinator diversity, rarity and trend (e.g., for Red List assessments) and the main drivers of pollinator loss represent specific research needs that should be addressed at the regional level (e.g., Mayer et al. 2011; Vanbergen et al. 2013).

4.6 TOWARDS A FLEMISH POLLINATOR MONITORING SCHEME

At the end of 2020, an expert panel of the *STING-project* (**S**cience and **T**echnology for Pollinat**ing** Insects), proposed a ***EU Pollinator Monitoring Scheme*** to the European Commission (EU-PoMS; Potts et al. 2020). EU-PoMS is a field-based monitoring scheme aimed to harmonise the systematic monitoring and to provide robust information on the status and trends of pollinator populations across the EU. To pilot and prepare all 27 EU countries for the implementation of EU-PoMS, the European Commission launched the SPRING-project (***S****trengthening* ***P****ollinator* ***R****ecovery through* ***IN****dicators and monitorin****G***) in June 2021, focussing on the monitoring of butterflies, wild bees and hoverflies. To enable the analysis of this pilot study, the project continuation and the further methodological development, the *STING2* project was launched in November 2022 (Figure 13). In the frame of the Nature Restoration Law Member States are required to set up robust monitoring schemes from 2025 to collect data on the abundance and diversity of pollinators and for assessing their population trends.

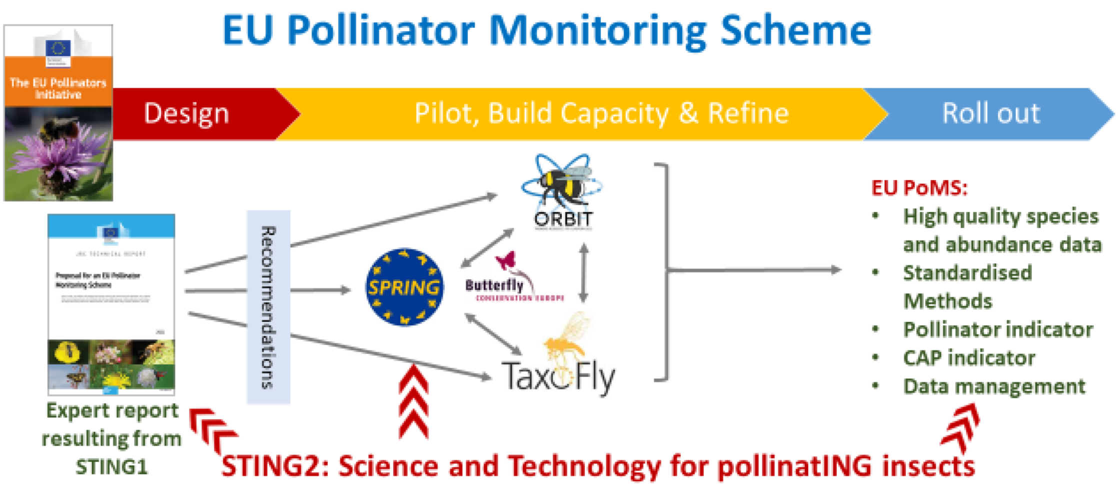
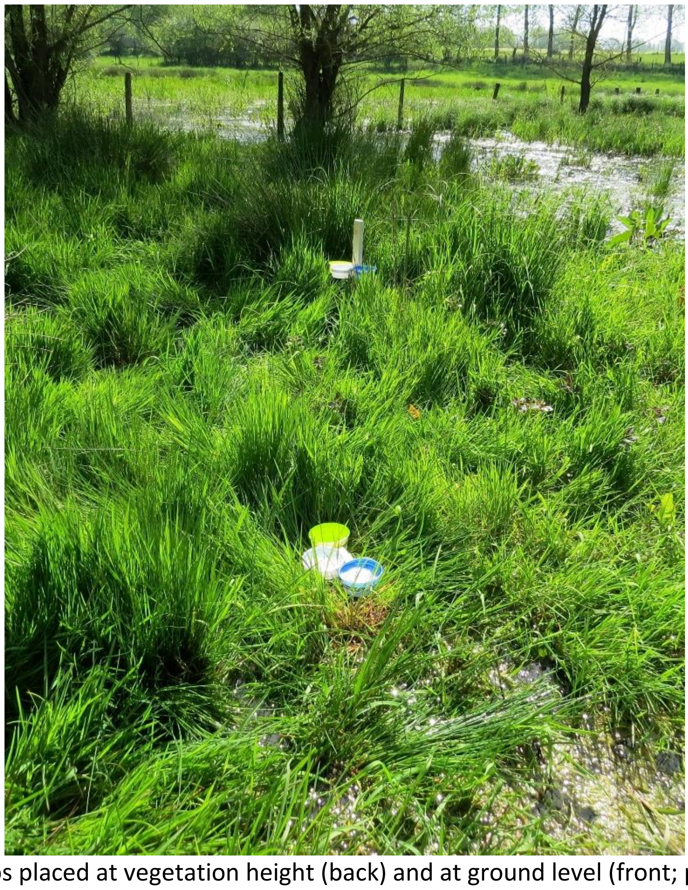


Figure 13 The road to establishing an European EU Pollinator Monitoring Scheme (EUPoMS).

INBO was responsible for the SPRING sampling in Flanders, testing the protocols at three sites:

- ILVO trial sites and Aelmoezeneibos, Gontrode (in collaboration with ILVO and the Forest and Nature Lab, ForNaLab, Ghent University)
- The Bourgoyen-Ossemeersen Nature Reserve (in collaboration with the City of Ghent)
- Den Dotter Nature Reserve in Haaltert (in collaboration with Natuurpunt)

Between May and September 2023, each site was surveyed one day per month. Wild pollinator monitoring (wild bees, butterflies and hoverflies) was done by walking standardised transects walks of 500m – 10 sub-transects of 50m each – and 10 pan traps (blue, yellow and white; Picture 15) per site placed at vegetation height that remained operational for six hours. Wild bees and hoverflies were identified to species level, all other invertebrates were counted and identified to order level. The obtained data was then uploaded into the SPRING Europe portal and will also be published by INBO as a GBIF dataset. In SPRING Flanders, we have also assessed and evaluated additional pollinator sampling methods than those requested within SPRING. This was done by slightly adjusting the pollinator collection methods. During the transect walks, we randomly swept the vegetation with sweeping nets and for the pan traps, we (i) adjusted the height at which they were placed to soil surface level, (ii) we also used non-UV pan traps, or (iii) we placed the traps operational during a maximum of nine days instead of a single day.



Picture 15 Pan traps placed at vegetation height (back) and at ground level (front; picture: INBO).

The assessment of the different methods used for sampling and identifying pollinators in SPRING Flanders will not only be used to inform SPRING Europe, but will also be used to develop a large monitoring program of wild pollinators in Flanders, namely MONIPOLLI (**Moni**toring **polli**nators and other insects). MONIPOLLI is a research component within the **M**onitoring **B**iodiversity in **Ag**ricultural Areas Network (MBAG; Dumortier et al. 2022) and aims to develop a pollinator monitoring network of wild pollinators (butterflies, wild bees, hoverflies and moths), at a large number of locations, both inside and outside agricultural areas. The outcomes should enable us to select the best or most suitable sampling method(s) that will be implemented within the future pollinator monitoring scheme for Flanders.

An important group that is missing in most current pollinator monitoring schemes is that of moths, although they are increasingly shown to be excellent pollinators (e.g., Vanzandt et al. 2020; Alison et al. 2022a; Buxton et al. 2022; Singh et al. 2022; Anderson et al. 2023; Ellis et al. 2023; García et al. 2024). In Flanders, there is a moth monitoring network coordinated by Natuurpunt Studie, but the sample locations are typically gardens and the network is at present only dense enough to monitor the abundance of fairly common species (Veraghtert et al. 2019). The traditional way of sampling moths is through Skinner traps with a UV-lamp, requiring electricity or a generator. The use of LED-buckets (White et al. 2016) together with identification tools such as ObsIdentify could be investigated as a complementary moth monitoring scheme with citizen scientists. LED-buckets can be used with a power bank, making it possible to trap moths in more distant areas and rarer habitats. This could allow to monitor threatened habitat-specialists more easily.

The maps generated during this exercise can serve as a basis for the design of a pollinator monitoring network in Flanders (cf. Westra et al. 2016). They allow to select suitable areas for pollinator monitoring using randomised stratified sampling (Onkelinx et al. 2019). Given the large extent of the future monitoring network a close collaboration with citizen scientists will be needed (Bane & Pocock 2023).

Finally, single rare species of conservation interest (Red List or habitat-specific species) are generally not picked up (in sufficient numbers) in general monitoring schemes. To include them into monitoring projects yearly counts of the existing populations with a fixed protocol could be implemented (e.g., Larsson & Franzén 2008). This is already achieved for several threatened butterflies in the meetnetten.be monitoring scheme, in which other main pollinator groups are entirely lacking (Maes et al. 2023).

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Picture 16 Flower-rich grassland in Hoegaarden (picture: Pieter Vanormelingen).

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APPENDIX

Appendix 1 List of Annex I habitats important for pollinators according to Kudrnovsky et al. (2020). The habitats in bold are present in Flanders (Decleer 2007).

Natural and semi-natural grasslands

Top five

6210 Semi-natural dry grasslands and scrubland facies on calcareous substrates (*Festuco-Brometalia*) (* important orchid sites)
6430 Hydrophilous tall herb fringe communities of plains and of the montane to alpine levels
6170 Alpine and subalpine calcareous grasslands
6510 Lowland hay meadows (*Alopecurus pratensis*, *Sanguisorba officinalis*)
6230 Species-rich Nardus grasslands, on silicious substrates in mountain areas (and submountain areas in Continental Europe)

Other natural and semi-natural grassland habitats important for pollinators

6520 Mountain hay meadows
6240 Sub-Pannonic steppic grasslands
6410 Molinia meadows on calcareous, peaty or clayey-silt-laden soils (*Molinion caeruleae*)
6110 Rupicolous calcareous or basophilic grasslands of the *Alysso-Sedion albi*
6220 Pseudo-steppe with grasses and annuals of the *Thero-Brachypodietea*
6150 Siliceous alpine and boreal grasslands
6190 Rupicolous pannonic grasslands (*Stipo-Festucetalia pallentis*)
6440 Alluvial meadows of river valleys of the *Cnidion dubii*
62A0 Eastern sub-Mediterranean dry grasslands (*Scorzoneratalia villosae*)
6120 Xeric sand calcareous grasslands
6420 Mediterranean tall humid grasslands of the *Molinio-Holoschoenion*
6250 Pannonic loess steppic grasslands
6130 Calaminarian grasslands of the *Violetalia calaminariae*
62C0 Ponto-Sarmatic steppes
6260 Pannonic sand steppes
6530 Fennoscandian wooded meadows

Heathlands, sclerophyllous scrubs and inland dunes (regrouped from Kudrnovsky et al. 2020)

Top five

2330 Inland dunes with open *Corynephorus* and *Agrostis* grasslands
4030 European dry heaths
40A0 Subcontinental peri-Pannonic scrub
4060 Alpine and Boreal heaths
4090 Endemic oro-Mediterranean heaths with gorse
4070 Bushes with Pinus mugo and Rhododendron hirsutum (Mugo-Rhododendretum hirsuti)

5130 ***Juniperus communis*** **formations on heaths or calcareous grasslands**
5330 Thermo-Mediterranean and pre-desert scrub
5110 Stable xerothermophilous formations with *Buxus sempervirens* on rock slopes (*Berberidion* p.p.)
5210 Arborescent matorral with *Juniperus* spp
5420 Sarcopoterium spinosum phryganas

Other heathlands, sclerophyllous scrubs and inland dune habitats important for pollinators

2310 Dry sandy heaths with *Calluna* and *Genista*
4080 Sub-Arctic Salix spp. scrub
4010 Northern Atlantic wet heaths with *Erica tetralix*
5430 Endemic phryganas of the *Euphorbio-Verbascion*

Raised bogs, mires and fens

Top five

7230 Alkaline fens
7140 Transition mires and quaking bogs
7210 Calcareous fens with *Cladium mariscus* and species of the *Caricion davallianae*
7220 Petrifying springs with tufa formation (*Cratoneurion*)
7120 Degraded raised bogs still capable of natural regeneration

Forests

Top five

91E0 Alluvial forests with Alnus glutinosa and Fraxinus excelsior (Alno-Padion, Alnion incanae, Salicion albae)
9180 *Tilio-Acerion* forests of slopes, screes and ravines
91F0 Riparian mixed forests of Quercus robur, Ulmus laevis and Ulmus minor, Fraxinus excelsior or Fraxinus angustifolia, along the great rivers (Ulmenion minoris)
9150 Medio-European limestone beech forests of the *Cephalanthero-Fagion*
9170 *Galio-Carpinetum* oak-hornbeam forests

Other forest habitats important for pollinators

91I0 Euro-Siberian steppic woods with *Quercus* spp.
9130 *Asperulo-Fagetum* beech forests
9160 Sub-Atlantic and medio-European oak or oak-hornbeam forests of the *Carpinion betuli*
91U0 Sarmatic steppe pine forest
91G0 Pannonic woods with Quercus petraea and Carpinus betulus
91H0 Pannonian woods with *Quercus pubescens*
9260 Castanea sativa woods
9530 (Sub-) Mediterranean pine forests with endemic black pines

Coastal sand dunes

Top five (adapted: heathland habitat types were moved to the heathlands section)

2190 Humid dune slacks
2130 Fixed coastal dunes with herbaceous vegetation (‘grey dunes’)

2180 Wooded dunes of the Atlantic, Continental and Boreal region

Other coastal sand dune habitats important for pollinators

2170 Dunes with Salix repens ssp. argentea (Salicion arenariae)

Coastal and halophytic habitats

Top five

1230 Vegetated sea cliffs of the Atlantic and Baltic Coasts
1240 Vegetated sea cliffs of the Mediterranean coasts with endemic *Limonium* spp.
1130 Estuaries
1330 Atlantic salt meadows (Glauco-Puccinellietalia maritimae)
1410 Mediterranean salt meadows (*Juncetalia maritimi*)

Other coastal and halophytic habitats important for pollinators

1160 Large shallow inlets and bays
1340 Inland salt meadows
1530 Pannonic salt steppes and salt marshes

Freshwater habitats

Top five

3130 Oligotrophic to mesotrophic standing waters with vegetation of the *Littorelletea uniflorae* and/or of the *Isoëto-Nanojuncetea*
3220 Alpine rivers and the herbaceous vegetation along their banks
3270 Rivers with muddy banks with *Chenopodion rubri* p.p. and *Bidention* p.p. vegetation
3240 Alpine rivers and their ligneous vegetation with *Salix elaeagnos*
3160 Natural dystrophic lakes and ponds

Appendix 2 List of Biological Valuation Map codes used in this report and their description.

BVM code	Description
Natural and semi-natural grasslands	
ha	Unfertilized dry grassland on acid soil (*Thero-Airion, Corynephorion, Agrostion*)
hac	Unfertilized dry grassland on acid soil with Aira spp. (Thero-Airion)
had	Unfertilized dry grassland of decalcified coastal dunes
hat	Unfertilized dry grassland on acid soil with *Corynephorus canescens* (Spergulo-Corynephoretum*)*
hc	Moist, moderately eutrophic meadow (*Calthion*)
hd	Dry grassland on calcareous sand in coastal dunes (*Galio-Koelerion*)
hf	Moist tall herb vegetation with *Filipendula ulmaria*
hj	Moist, moderately fertilized meadow, dominated by *Juncus effusus* or *J. inflexus*
hk	Dry calcareous grassland (*Brometalia erecti*)
hm	Unfertilized wet meadow (*Molinion caeruleae*)
hn	Acid *Nardus* grassland (*Nardetea*)
hpr+	Complex of more diversified permanent pastures with ditches and/or microrelief
hu	Mesophilic hay meadow (*Arrhenatherion elatioris*)
rbbhf	*Filipendula* tall herb communities with grassland features
Sclerophyllous scrubs, temperate heathlands and scrubs, and inland dunes	
ce	Atlantic wet heath (*Ericetum tetralicis*)
cg	Dry heath (Calluno-Genistetum)
cg+jun	Dry heath (*Calluno-Genistetum*) with Juniperus communis
cv	Dry heath with Vaccinium (Calluno-Vaccinietum)
sg	Broom scrub (*Sarothamnion*)
Raised bogs, mires and fen biotopes	
ces	Atlantic wet heath with typical raised bog species
md	Quaking fen
mk	Alkaline fen (Caricion davallianae)
mm	Vegetation of *Cladium mariscus*
ms	Acid fen (Caricion curto-nigrae)
Coastal sand dune biotopes	
ae+	Eutrophic water
had	Unfertilized dry grassland of decalcified coastal dunes
hc	Moist, moderately eutrophic meadow (*Calthion*)
hd	Dry grassland on calcareous sand in coastal dunes (*Galio-Koelerion*)
mp	Dune slack calcareous fen
ru	Elm wood (Violo odoratae-Ulmetum)
rud	Elm wood in coastal dunes and polders
sd	Sea-buckthorn scrub (*Hippophaetum*)
vn	Nitrophilous alluvial alder wood (*Macrophorbio-Alnetum*)
Forests	
fa	Beech wood with spring flowers, no bluebell (*Milio-Fagetum*)

fe	Beech wood with bluebell Hyacinthoides non-scripta (Endymio-Fagetum)
fm	Beech wood with Melica and Galium odoratum (Melico-Fagetum)
qa	Oak-hornbeam wood (*Stellario-Carpinetum*)
ru	Elm wood (Violo odoratae-Ulmetum)
sf	Willow scrub on moist, mesotrophic to eutrophic soil
va	Alluvial ash-elm wood (*Ulmo-Fraxinetum*)
vc	Alder-ash wood of springs and spring rivulets (*Carici-Fraxinetum* and *Cardamino-Alnetum*)
vf	Moist to wet alder-oak wood (possibly with hornbeam)
vm	Mesotrophic alder wood with sedges (*Carici elongatae-Alnetum*)
vn	Nitrophilous alluvial alder wood (*Macrophorbio-Alnetum*)
vo	Oligotrophic alder wood with *Sphagnum* (*Sphagno-Alnetum*)

Coastal and halophytic habitats

da	Salt marsh
hj	Moist, moderately fertilized meadow, dominated by *Juncus effusus* or *J. inflexus*
mz	Vegetation of *Scirpus maritimus*

Freshwater habitats

ao+	Oligotrophic to mesotrophic water (well developed)
aom	Mesotrophic water, mesotrophic pool (*Littorellion!*)

Picture 17 *Cheilosia himantopus* foraging on Rough hawksbeard (*Crepis biennis*) (picture: Dirk Maes).

Appendix 3 Biotopes that can attract honeybees with the mass flowering aspect of certain forage plants (bron: Adriaens & Laget 2008).

Woodlands

Habitat description	BVM-code
Elm wood (Violo odoratae-Ulmetum) (Fraxino-Ulmetum alnetosum sensu van der Werff)	ru
Nitrophilous alluvial alder wood (Macrophorbio-Alnetum)	vn, vn+
Alluvial ash-elm wood (Ulmo-Fraxinetum)	va
Alder-ash wood of springs and spring rivulets (Carici-Fraxinetum and Cardamino-Alnetum)	vc
Alluvial forests with *Alnus glutinosa* and *Fraxinus excelsior* (Alno-Padion, Alnion incanae, Salicion albae)	-
Oak-hornbeam wood (Stellario-Carpinetum)	qa
Acidophilous oak wood (often with ruderal undergrowth)	qs
Willow scrub on moist, mesotrophic to eutrophic soil (Salicion albae p.p. especially Cardamino amarae-Salicetum albae)	sf

Dwarf shrubs

Habitat description	BVM-code
Dry grassland on calcareous sand in coastal dunes (Galio-Koelerion)	hd
Dry scrub	-
Broom scrub (Sarothamnion) (RG Cytisus scoparius-Calluno-Ulicetea/Nardetea)	sg
Wet or moist scrub	-
Sea-buckthorn scrub (Hippophaetum) with *Pyrola rotundifolia*	sd
Atlantic wet heath (Ericetum tetralicis)	ce
Dry heath (Calluno-Genistetum)	cg

Grasslands

Habitat description	BVM-code
Dry grassland on calcareous sand in coastal dunes (Galio-Koelerion) with *Thesium humifusum* and *Galium verum* (Polygalo-Koelerion)	hd
Acid *Nardus* grassland (Nardetea)	hn

Moist, moderately eutrophic meadow (Calthion)	hc
Dry calcareous grassland (Brometalia erecti)	hk
Mesophilic hay meadow (Arrhenatherion elatioris) (Sedo-cerastion)	hu
Potentilla anserina grasslands (Lolio-Potentillion)	rbbzil
Salt marsh	da

Pioneer vegetations

Habitat description	BVM-code
Scrub of forest clearings (Epilobietalia)	se
Well-developed arable land on sand, chalk or clay	bs+, bc+, bu+

Roughs

Habitat description	BVM-code
Moist tall herb vegetation with *Filipendula ulmaria* and *Epilobion hirsuti*	hf
Ruderal pioneer vegetation (on disturbed soil, former arable land, …)	ku
Abandoned pastures and meadows with *Alliaria petiolata* (Galio-Alliarion)	hr+
Ruderal pioneer vegetation on chalky soils (Trifolion medii)	(hu, ku)
Roughs on poor sandy soils with a low lime content: the association of *Holcus mollis* and *Hieraclum* spp. (Melampyrion pratensis)	-

Standing waters

Habitat description	BVM-code
Eutrophic water (several plant communities) with *Nymphaea alba* and *Nuphar lutea*	ae+, aev, aev+
(Relatively) ion-rich alkaline waters (both meso-, oligo- and eutrophic)	-
Eutrophic water (several plant communities) with *Hydrocharis morsus-ranae* and *Stratiotes aloides*	ae+, aev, aev+

Shrubs

Habitat description	BVM-code

Willow scrub on moist, mesotrophic to eutrophic soil (Salicion cinereae)	sf
Sea-buckthorn scrub (Hippophaetum) with *Hippophae rhamnoides* and *Ligustrum vulgare* (Berberidion)	sd
Thorn thicket (Rubion subatlanticum) with *Crataegus monogyna* and *Prunus spinosa* (Carpino-Prunion)	sp
Thorn thicket (Lonicero-Rubion sylvatici en Pruno-Rubion radulae)	spr
(Ruderal) scrub on (recently) disturbed soil	sz
Scrub on calcareous soil (Berberidion vulgaris)	sk
Willow scrub on moist, mesotrophic to eutrophic soil (Artemisio-Salicetum albae)	sf
Willow scrub on moist, mesotrophic to eutrophic soil with *Cardamine amara* (Salicion albae, Cardamino amarae-Salicetum albae)	sf

Appendix 4 Non-exhaustive list of references about nature management in different biotope types.

General

Martins (2021); Ministry of Agriculture & Nature and Food Quality (2018); Nowakowski & Pywell (2016); Pindar & Raine (2023)

Landscape-scale pollinator management

Brittain et al. (2010b); Meyer et al. (2009); Moquet et al. (2018); Schirmel et al. (2018); Steffan-Dewenter et al. (2002); Steffan-Dewenter & Westphal (2008); Winfree et al. (2011); Carvell et al. 2017

Urban biotopes and gardens

Comba et al. (1999); Derby Lewis et al. (2019); Dylewski et al. (2019); Eremeeva & Sushchev (2005); Geppert et al. (2022); Grossmann et al. (2023); Majewska et al. (2018); Muratet & Fontaine (2015); Rollings & Goulson (2019); Silva et al. (2023); Simao et al. (2018); Tew et al. (2022)

Dunes

Exeler et al. (2009)

Heathlands

de la Pena et al. (2012); Forup et al. (2008); Moquet et al. (2017)

Grasslands

Bruppacher et al. (2016); Carvell (2002); Gardein et al. (2022); Garrido et al. (2019); Jauker et al. (2013); Klein et al. (2007); Larkin & Stanley (2021); Öckinger et al. (2018); Potts et al. (2009); Sjödin (2007); Sjödin et al. (2008); Svara et al. (2021); Tanis et al. (2020)

Agricultural land

Alison et al. (2022b); Berg et al. (2019); Brittain et al. (2010a); Buhk et al. (2018); Carreck & Williams (2002); Carvalheiro et al. (2011); Cole et al. (2015); Garibaldi et al. (2011); Klatt et al. (2020); Lebeau et al. (2016a); Lebeau et al. (2016b); Maas et al. (2021); Maurer et al. (2022); Nichols et al. (2022); Ollerton et al. (2014); Phillips et al. (2019); Pywell et al. (2011); Schmidt et al. (2022); Timberlake et al. (2021); Van Geert et al. (2010); Walton et al. (2021a); Walton et al. (2021b); Windsor et al. (2021); Wood et al. (2016)

Woodland

Allen & Davies (2023); Steinert et al. (2018); Eeraerts et al. (2021); Steinert et al. (2020); Steinert et al. (2021); Van den Berge et al. (2018)

Man-made habitats

Novotny & Goodell (2020)

Competition between honeybees and wild pollinators

Ropars et al. (2019)

Picture 18 Common carder bee (*Bombus pascuorum*) foraging on Red Dead-nettle (*Lamium purpureum*) (picture: Dirk Maes).