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Invasive alien plant species, habitat types important for pollinators, and the possible risks in the European Union

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1 Introduction

There is strong evidence that species richness and abundance of flowering plants are positively correlated with species richness of pollinating insect species (Hatfield & LeBuhn 2007; Carvell 2002; Ebeling et al. 2008). These positive correlations were found across different pollinator guilds (honey bees, bumble bees, solitary bees, hover flies, butterflies, beetles and flies) with only few exceptions: visitation rate of solitary bees and hoverflies are mainly influenced by increasing blossom cover. In general, higher floral diversity creates a wider array of foraging niches for different functional groups of visitors (Fenster et al. 2004).

Availability of nesting sites is another important determinant of pollinator community composition. Gathering information on habitat type's ability to provide nesting sites for pollinators is much more difficult, because there is no "simple" indicator to detect this feature. Occurrence of nesting sites in a specific habitat type depends on the micro-structures locally available (e.g. areas of bare ground, deadwood, dead stems of plants) and cannot be evaluated at the level of the overall habitat type. However, it can be assumed that nesting sites should be relatively close to foraging resources in order to prevent energy demanding long flight distances of pollinating insects. For example, Knight et al. (2009) showed that bumblebee nest density is linked to the quantity of floral resources within 1000 metres of their sample site. Thus, flowering plants and plant species richness will also be major indicators to consider the occurrence of nesting sites.

Invasive alien species (IAS) are animals and plants that are introduced accidentally or deliberately into a natural environment where they are not normally found, with negative consequences for their new environment. These negative impacts are diverse and context-dependent, and include for example direct competition for resources, direct and indirect predation and herbivory, hybridisation, transmission of pathogens, and the chemical, physical or structural change of habitat characteristics (e.g. Blackburn et al. 2014, Pyšek et al. 2017). IAS can also negatively impact the services biodiversity provides for human well-being, for example as weeds or pests in agriculture and forestry and as parasites in livestock (provisioning services), reductions of natural biocontrol and pollination (regulating services) and the spread of human diseases and eco-tourism (cultural services) (Vilá & Hulme 2017).

Pollination, that is the transfer of pollen from a male to a female plant, happens by wind or water, or with the help from animals (e.g. insects, birds, bats). Animal pollination is considered a key ecosystem service maintaining the integrity of many terrestrial ecosystems and also supporting others, such as provisioning services, e.g. crop production (Morales et al. 2017). IAS can disrupt or interfere with pollination via different mechanisms, e.g. directly (animal-animal-interaction) and indirectly (plant-plant-interaction with subsequent knock-on effects on pollinators). Selected case studies presented in chapter 3.4 illustrate the complexity of impact mechanisms, which may include:

- i) direct impact (animal-animal interactions)
 - a. invasive species preys on native pollinators,
 - b. invasive pollinator competes with native pollinators (e.g. for food, nesting sites),
 - c. invasive pollinator hybridizes with native pollinators,
 - d. invasive pollinator transmits pathogens on native pollinators.
- ii) indirect impact (plant-plant-animal interactions)
 - a. attractive or abundant invasive alien plant species outcompeting native plants via shared pollinators ("floral market") and so affecting native plants and pollinators;
 - b. invasive alien plant species changing native plant communities (i.e. chemical, physical or structural change of habitat characteristics and structures) and affecting native pollinators.

Plant-pollinator networks are complex and when alien species are added to co-evolved communities, they may have strong impacts on species interactions. Data from experiments and field observations have rarely been able to consider all relevant factors. Thus, it is not surprising that invasive alien plants have been found to have positive, negative or neutral impacts on native pollinators (e.g. Chittka & Schürkens 2001, Brown et al. 2002, Bartomeus et al. 2008, 2010, Morales & Traveset 2009, Nielsen et al. 2008, Moron et al. 2009, Nienhuis et al. 2009, Drossart et al. 2017, Fenesi et al. 2015, Goodell & Parker 2017, Stout & Tiedeken 2017, Davis et al. 2018, Vanbergen et al. 2018, Szigeti et al. 2020).

Because of the lack of co-evolution between alien plants and native pollinators, it is expected that insect-pollinated alien plant species are mostly generalists with attractive flowers accessible for a wide group of generalist native pollinators, which are more likely to profit, whereas specialized native pollinators are not (Traveset & Richardson 2014). Albrecht et al. (2014) have shown that alien plants have higher generalization levels with respect to their pollinators than native plants. As a consequence, rather than displacing native pollinator species, invasive plants cause role shifts and modify the roles of species in the pollination network (Albrecht et al. 2014). In summary, however, biological invasions are highly context-dependent and impacts on pollinator networks difficult to generalize.

To reduce negative impacts from invasive alien species, Regulation (EU) 1143/2014 on the prevention and management of the introduction and spread of invasive alien species, entered into force on 1 January 2015, provides a list of so-called “IAS of Union concern” (the Union list) for which a set of measures applies. Such measures are e.g. ban from trade, action plan on the pathways of unintentional introduction and spread, management actions for widespread species. Within the first reporting period (2015-2018), 48 “IAS of Union concern” (23 plants, 25 animals) have been listed and their distribution reported by MS in 2019.

The following preliminary analysis is based on these distributional data and an assessment of Annex I habitat types of the Habitat Directive with great importance for pollinating insects (Kudrnovsky et al. 2020). In order to decide on the importance of habitat types for pollinators, Kudrnovsky et al. (2020) considered the habitats’ ability to provide food sources (pollen and nectar) and nesting sites, as these are the two essential parameters governing the life cycles of pollinator insects. It was concluded that plant species richness is the best variable to assess the ability of habitat types to provide food sources for pollinators. The use of pollen and nectar by insects can be expected for all insect-pollinated plants as well as for a high number of wind-pollinated plants. Therefore, Annex I habitat types important for pollinators were identified by detecting the number of pollinator-dependent plant species present in each habitat type or the number of wind-pollinated plants used as nectar or pollen sources (Kudrnovsky et al. 2020).

A comparison of these datasets reveals areas within the European Union, where invasive alien plant species and habitats important for pollinators coincide. Although generalizations are difficult, this preliminary analysis may provide some insight into possible risks for pollinators and the pollinating service at a coarse scale.

2 Method

2.1 Data

2.1.1 Habitat Directive spatial data

Article 17 requires Member States to report every six years about the progress made with the implementation of the Habitats Directive. As the main objective of the directive is on maintaining and restoring a favourable conservation status for habitat types and species of community interest, monitoring and reporting under Article 17 is focusing on capturing the status and trends of these habitat types and species.

An important component of the Article 17 report is the distribution of habitats in the Member States and its geographical representation in the EU 10 x 10 km reference grid (EEA 2021). Spatial data used for this report is derived from the Article 17 report for the period 2013-2018 (EU 2021).

2.1.2 IAS spatial data

Regulation (EU) 1143/2014 on invasive alien species (IAS) entered into force on 1 January 2015 and Member States were obliged to report the spatial distribution of “IAS of Union concern” in the EU 10 x 10 km reference grid.

For this report, the spatial distribution of 15 invasive plant species is used (Table 1). We excluded five predominantly aquatic species (*Cabomba caroliniana*, *Eichhornia crassipes*, *Elodea nuttallii*, *Lagarosiphon major*, *Myriophyllum heterophyllum*), but included *Hydrocotyle ranunculoides*, *Ludwigia grandiflora*, *Ludwigia peploides*, and *Myriophyllum aquaticum*, considering that these species are able to occupy also (semi)terrestrial habitats along the shoreline (e.g. BfN 2021; Nehring & Hussner 2013; LANUV NRW 2021).

The Macaronesian biogeographical region is excluded from the analysis, because no spatial IAS data are available for this region.

Table 1 Invasive alien plant species used in this report to analyse their possible influence on habitats important for pollinators

species name	english name	terrestrial	freshwater
<i>Alternanthera philoxeroides</i> (Mart.) Griseb.	Alligator weed	*	*
<i>Asclepias syriaca</i> L.	Common milkweed	*	
<i>Baccharis halimifolia</i> L.	Eastern baccharis	*	
<i>Gunnera tinctoria</i> (Molina) Mirbel	Chilean rhubarb	*	
<i>Heracleum mantegazzianum</i> Sommier & Levier	Giant hogweed	*	
<i>Heracleum persicum</i> Fischer	Persian hogweed	*	
<i>Heracleum sosnowskyi</i> Mande- nova	Sosnowsky's hogweed	*	
<i>Hydrocotyle ranunculoides</i> L. f.	Floating pennywort		*

species name	english name	terrestrial	freshwater
<i>Impatiens glandulifera</i> Royle	Himalayan balsam	*	
<i>Ludwigia grandiflora</i> (Michx.) Greuter & Burdet	Water-primrose	*	*
<i>Ludwigia peploides</i> (Kunth) P.H. Raven	Floating primrose-willow		*
<i>Lysichiton americanus</i> Hultén and St. John	American skunk cabbage	*	
<i>Myriophyllum aquaticum</i> (Vell.) Verdc.	Parrot's feather	*	*
<i>Pennisetum setaceum</i> (Forsk.) Chiov.	Crimson fountaingrass	*	
<i>Pueraria montana</i> (Lour.) Merr. var. <i>lobata</i> (Willd.)	Kudzu vine	*	

2.1.3 EU-Habitat types with relevance for pollinators

Plant species richness is a suitable variable to assess the ability of a habitat type to provide food source to pollinators. Identifying Annex I habitat types of the Habitat Directive with a high proportion of plant species providing foraging resources to pollinators can be done by detecting pollinator-dependent plant species present in each habitat type. Kudrnovsky et al. (2020) compiled a list of species classified by pollinator importance. Furthermore Annex I habitat groups and habitat types are ranked according to the absolute number of typical plant species and the proportion of plant species classified as important food sources for pollinating insect compared to the total number of typical plant species.

The ranking of habitat types according to their importance for pollinators within their respective habitat group is based on the absolute number of plant species classified as important for pollinating insects for all habitat types with more than 50% of their relevant plant species classified as so.

For all habitat groups, “Top 5 habitat types” are selected according to:

- The total number of relevant plant species,
- The total number of plant species classified as important for pollinators and,
- A high percentage of plant species that could be classified.

2.2 GIS analysis

The 10 x 10 km distribution grid data includes habitat and IAS information per grid cell (see Table 2).

Table 2 Example of GIS attribute data of invasive alien plant species and habitat per reference grid cell

cellcode	country	region	EASIN code	Species name	legal name	english name	habitatcode	Habitat name
10kmE378N251	FR	CON	R07719	<i>Impatiens glandulifera</i>	<i>Impatiens glandulifera</i> Royle	Himalayan balsam	6210	Semi-natural dry grasslands and scrubland facies on calcareous substrates (Festuco-Brometalia) (* important orchid sites)

Based upon this attribute information about invasive alien plant species and habitats per reference grid cell, the following GIS analysis are conducted:

- Distribution and overall total count of terrestrial habitat types per grid cell,
- Distribution and total count heat map of habitat types per habitat group and grid cell,
- Distribution of Top 5 pollinator relevant habitat types per habitat group and grid cell,
- Distribution heat map of relevant (semi-)terrestrial invasive alien plant species,
- Bivariate count heat maps of invasive alien plant species and all terrestrial habitat types,
- A simple calculation of the number of grid cells of these bivariate heat maps across the EU (+UK) and the biogeographical regions.

The total count heat map symbols of habitat types per grid cell are scaled in the same way for all habitat groups for easier readability. The heat map symbol scale is grouped in the following classes 1–5, 6–10, 11–15 and 16–18 habitat types, with 18 habitat types as the highest overall count per grid cell.

3 Results

3.1 Terrestrial habitat types important for pollinators

3.1.1 Overall habitat types distribution

Figure 1 shows the overall distribution of the selected terrestrial habitat types, which are considered important for pollinators, per 10 x 10 km² for the Article 17 reporting period 2013–18. For some areas (e.g. western France, central Spain, eastern Romania), no terrestrial habitats are reported based on the reference grid. Mountain regions (e.g. Alps, Apennines, and Pyrenees) show a higher total number of habitat types per grid cell due to their horizontal and vertical geomorphological landscape heterogeneity.

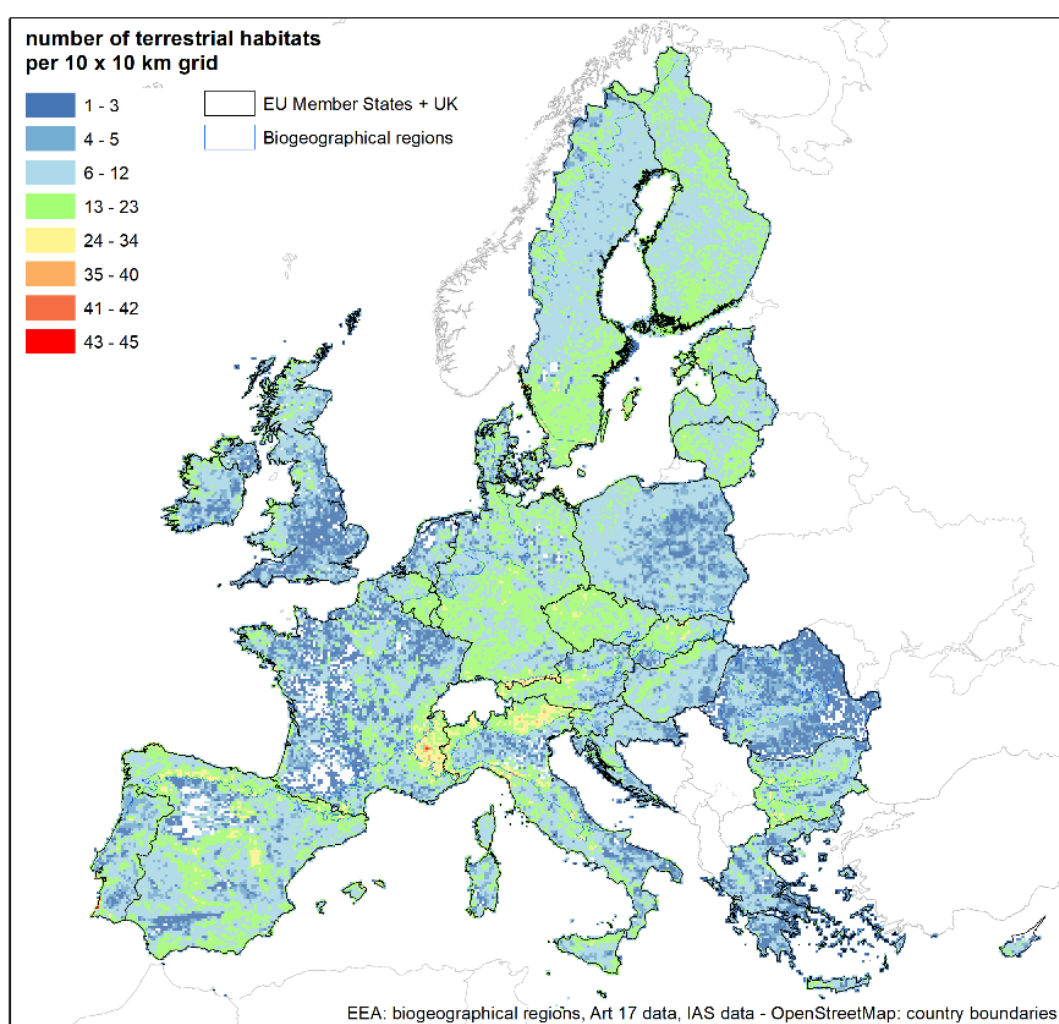


Figure 1 Overall distribution of terrestrial habitat types per 10 x 10 km² for the Article 17 reporting period 2013–18

3.1.2 Habitat groups

According to Kudrnovsky et al. (2020) the habitat group “Natural and semi-natural grassland” is the most important for pollinators, followed by “Sclerophyllous scrub” and “Temperate heath and scrub”.

- Natural and semi-natural grassland (32 habitat types),
- Sclerophyllous scrub (matorral) (13 habitat types),
- Temperate heath and scrub (12 habitat types),
- Raised bogs and mires and fens (12 habitat types),
- Forests (81 habitat types),
- Coastal sand dunes and inland dunes (21 habitat types),
- Coastal and halophytic habitats (28 habitat types),
- Freshwater habitats (20 habitat types),
- Rocky habitats and caves (14 habitat types).

Natural and semi-natural grassland habitats (6***)

The natural and semi-natural grassland habitats are distributed all over Europe (Fig. 2). According to Kudrnovsky et al. (2020), the Top Five habitat types having the highest importance for pollinators are 6210 Semi-natural dry grasslands and scrubland facies on calcareous substrates (*Festuco-Brometalia*), 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 siliceous substrates in mountain areas (and submountain areas in Continental Europe). These Top Five habitat types include lowland as well as mountain habitats and cover large areas in Europe with some reductions in the Boreal and Mediterranean biogeographic regions (Fig. 3). Spatial distribution of grassland habitat types is not available in the Article 17 report of Latvia for the period 2013-18.

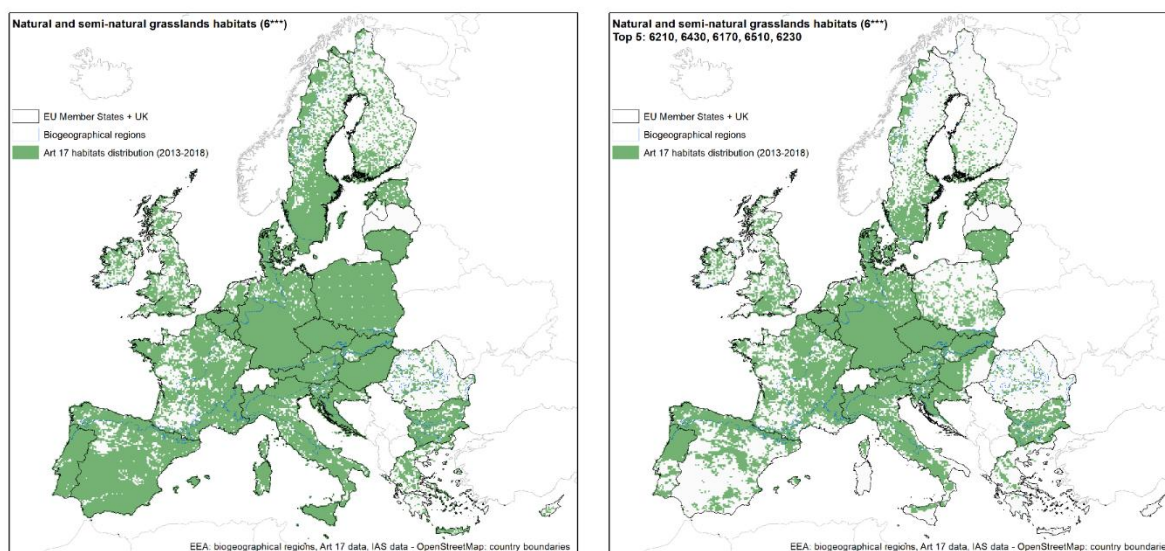


Figure 2 and 3 Overall (left) and Top Five (right) distribution of “Natural and semi-natural grasslands habitats” per 10 x 10 km² reference grid

A heat map of the number of habitat types per grid cell within the “Natural and semi-natural grasslands habitats” group indicates that mountain areas such as the Alps, the Apennines and the Pyrenees include a higher total number of grassland habitats per 10 x 10 km² grid cell than most other

regions. The map however also shows some scattered (and sometimes) isolated patches of higher habitat diversity in lowland areas of the Mediterranean, Continental, Boreal and Steppic biogeographical regions (Fig. 4).

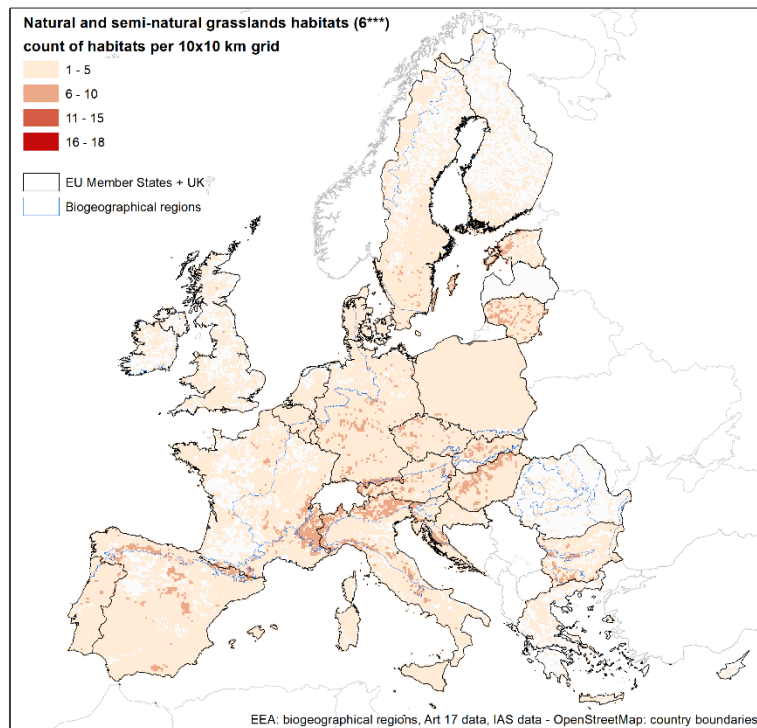


Figure 3 Heat map of Natural and semi-natural grasslands habitat types - 10 x 10 km² reference grid

Sclerophyllous scrub (matorral) habitats (5***)

The second ranked habitat group being of high importance for pollinators are sclerophyllous scrub habitats, which mostly occur in southern Europe and have scattered occurrences across Europe (Fig. 5).

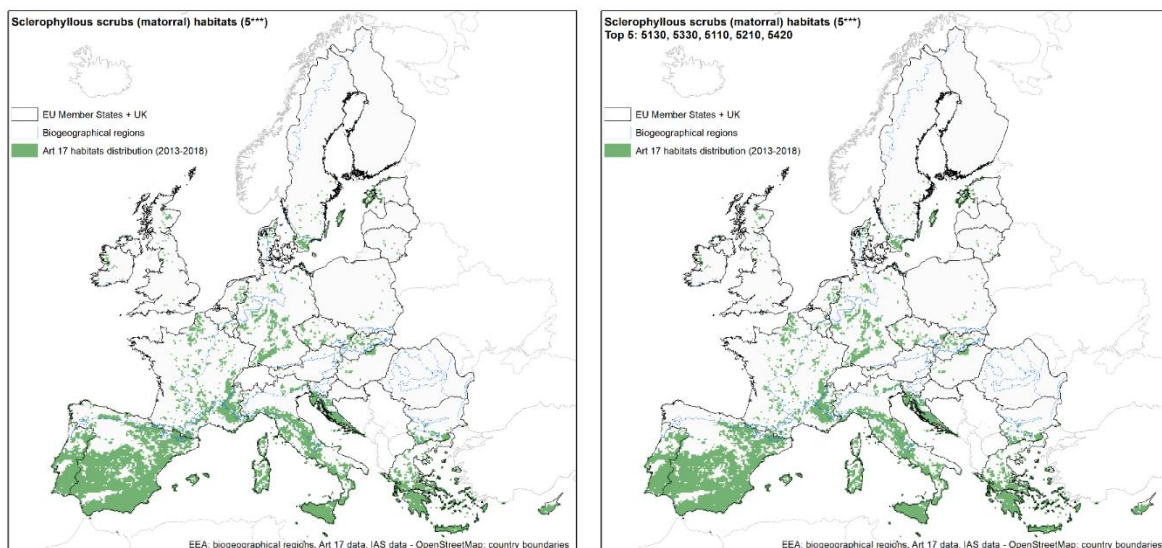


Figure 5 and 6 Overall (left) and Top Five (right) distribution of “Sclerophyllous scrubs (matorral) habitats” per 10 x 10 km² reference grid

The Top Five habitat types in this group are 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.*, and 5420 *Sarcopoterium spinosum* – Phrygas. There is no obvious difference in the distribution of the Top Five habitat types compared to the complete habitat group (Fig. 6).

A heat map of the number of habitat types per grid cell within the “Sclerophyllous scrubs” habitat group indicates highest numbers of habitat types in the mediterranean south (Fig. 7).

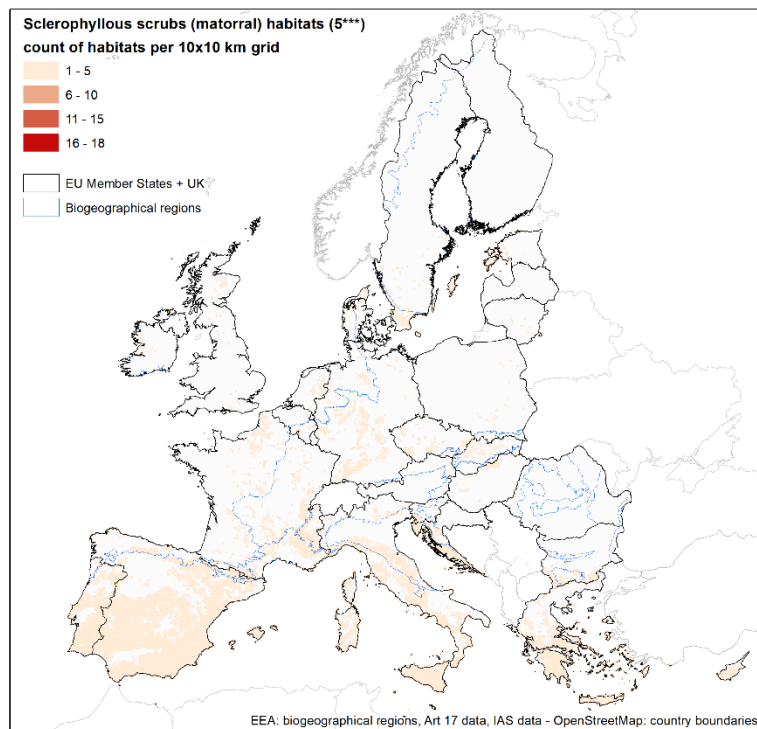


Figure 4 Heat map of Sclerophyllous scrubs habitat types - 10 x 10 km² reference grid

Temperate heath and scrub (4*)**

The habitat types within the habitat group “Temperate heath and scrub” ranked third by Kudrnovsky et al. (2020), are distributed across Europe with some spatial foci in coastal regions of western Europe and mountain areas in the Alps and Scandinavia (Fig. 8).

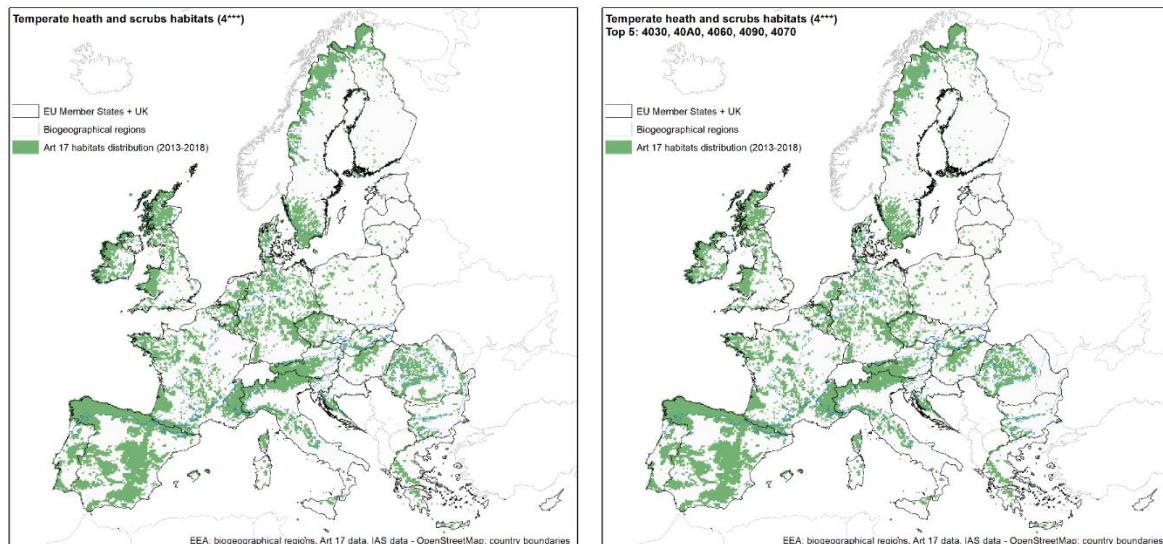


Figure 8 and 9 Overall (left) and Top Five (right) distribution of “Temperate heath and scrubs habitats” per 10 x 10 km² reference grid

The Top Five ranked habitat types are 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*) indicate the same spatial distribution as the whole habitat group. The habitat 4030 includes mesophile or xerophile heaths on siliceous, podsolic soils in moist Atlantic and sub-Atlantic climates of plains and low mountains of western, central and northern Europe. The other four habitats are located more in European mountain ranges in all climate regions. There is no obvious difference in the distribution of the Top Five compared to the complete habitat group (Fig. 9).

A heat map of the number of habitat types per grid cell within the “Temperate heath and scrub” group indicates a patchy pattern with some foci in higher altitudes and an atlantic climate (Fig. 10).

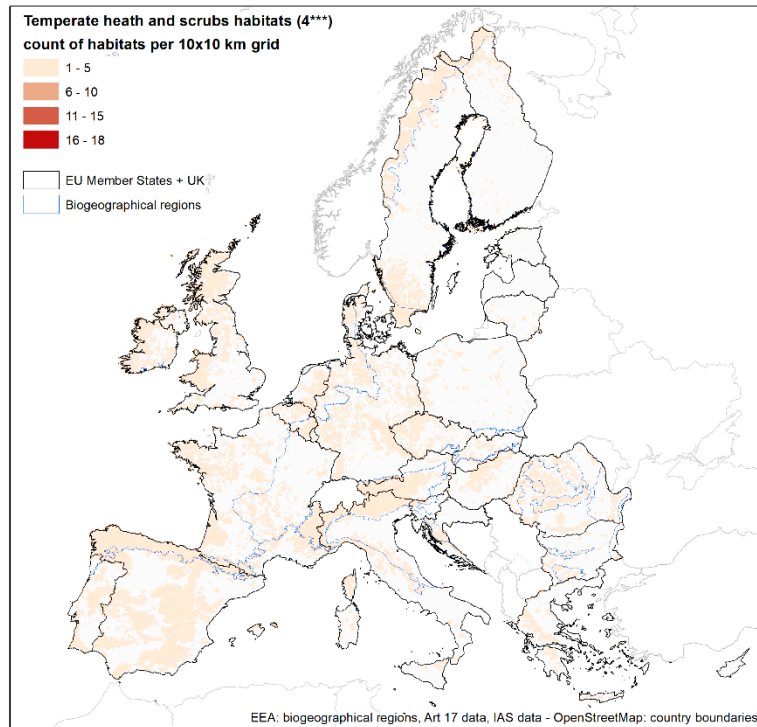


Figure 5 Heat map of Temperate heath and scrubs habitat types - 10 x 10 km² reference grid

Raised bogs, mires and fens habitats (7*)**

The core areas of the raised bogs, mires and fens habitat group are situated in north and northwest Europe as well as in mountain ranges such as the Alps, Carpathians and Pyrenees (Fig. 11).

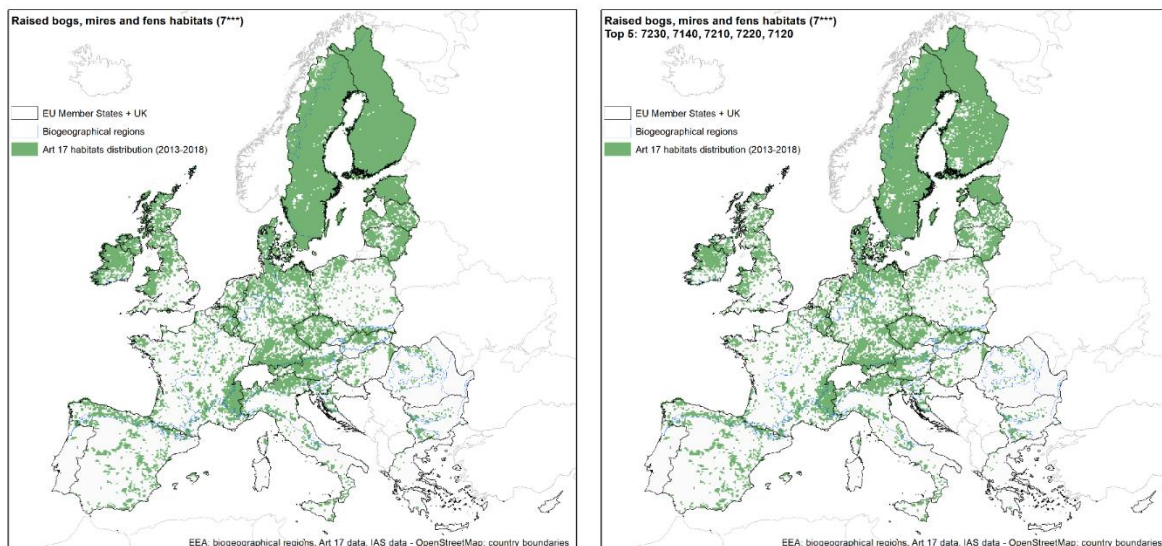


Figure 11 and 12 Overall (left) and Top Five (right) distribution of “Raised bogs, mires, and fens habitats” per 10 x 10 km² reference grid

The Top Five habitat types within this habitat group are 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. These habitat types show the same spatial extent as the complete habitat group.

A heat map of the number of habitat types per grid cell within the “Raised bogs, mires and fens” habitat group indicates a focus in the Boreal biogeographic region and a reduction in the Mediterranean south (Fig. 13).

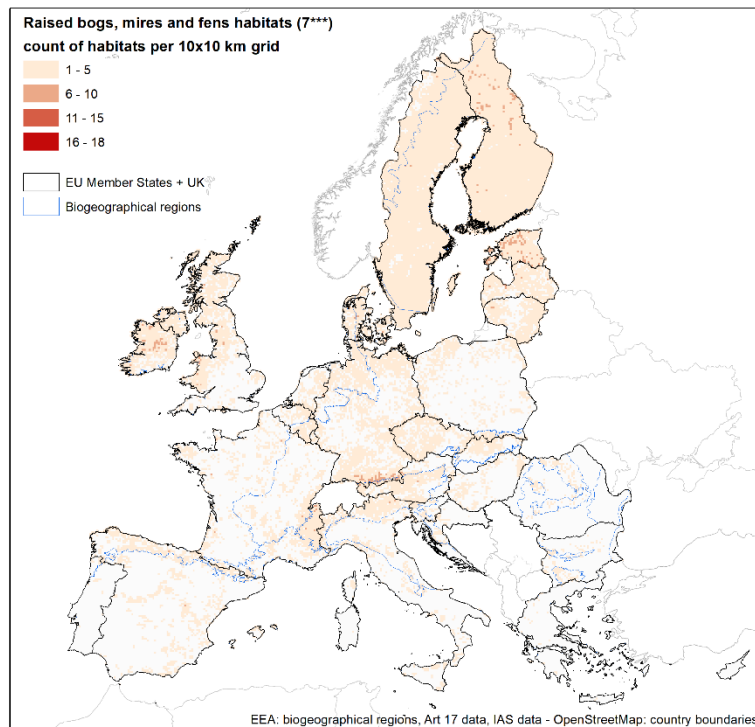


Figure 6 Heat map of Raised bogs, mires and fens habitat types - 10 x 10 km² reference grid

Forests habitats (9***)

Forest habitats cover all of Europe (Fig. 14). The Top Five ranked forest habitat types are 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). These Top Five forest habitat types show a more continental and less Mediterranean spatial distribution (Fig. 15).

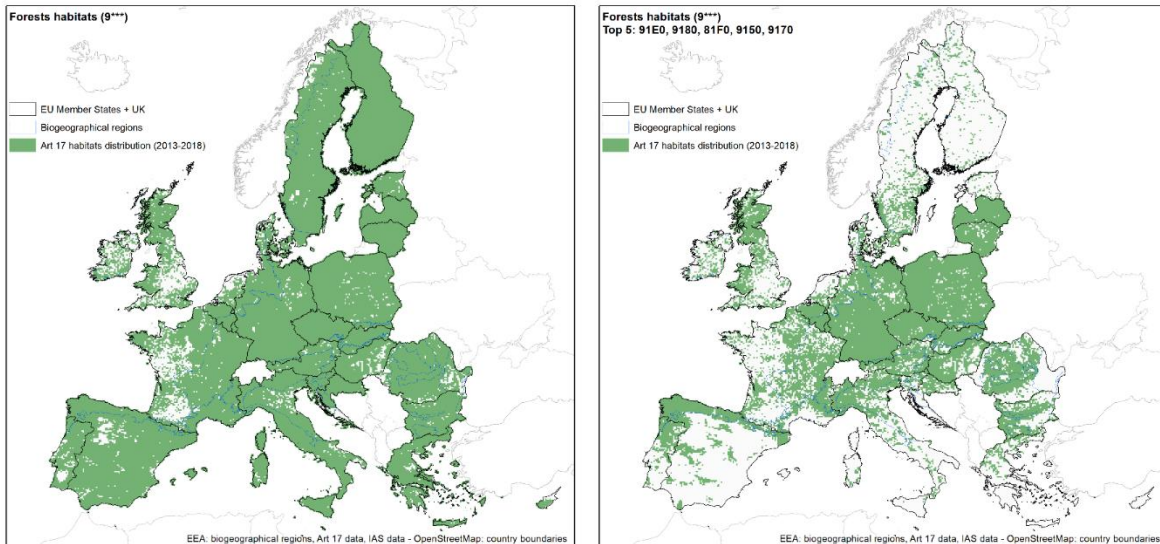


Figure 14 and 15 Overall (left) and Top Five (right) distribution of “Forest habitats” per 10 x 10 km² reference grid

A heat map of the number of habitat types per grid cell within the “Forest habitats” indicates some scattered foci, e.g. in southern Scandinavia and the Baltic countries, western Poland and in some of the European mountain ranges (Fig. 16).

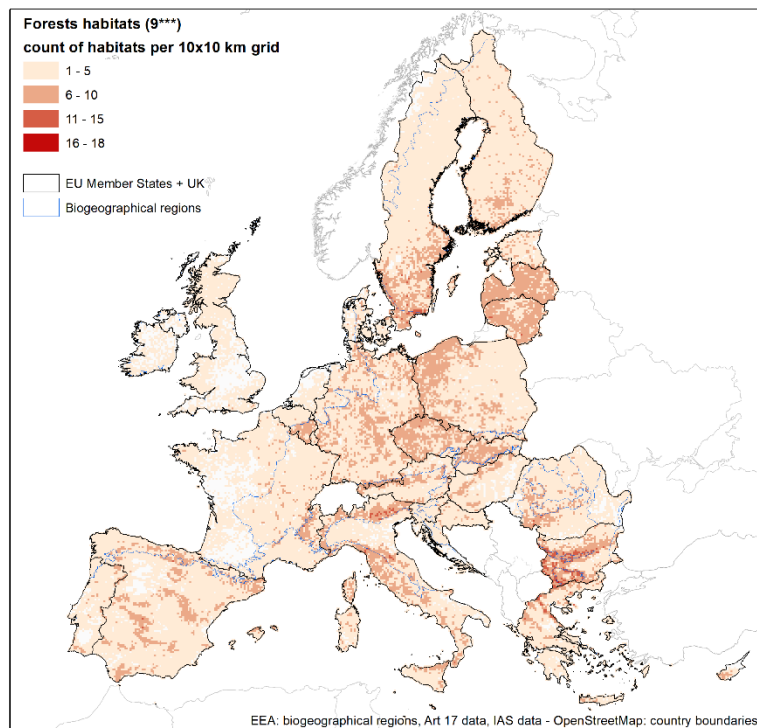


Figure 7 Heat map of Forest habitat types - 10 x 10 km² reference grid

Coastal sand dunes and inland sand dunes (2***)

The overall distribution of coastal sand dunes and inland sand dunes habitat types shows occurrences along the European coastlines and scattered inland occurrences (Fig. 17).

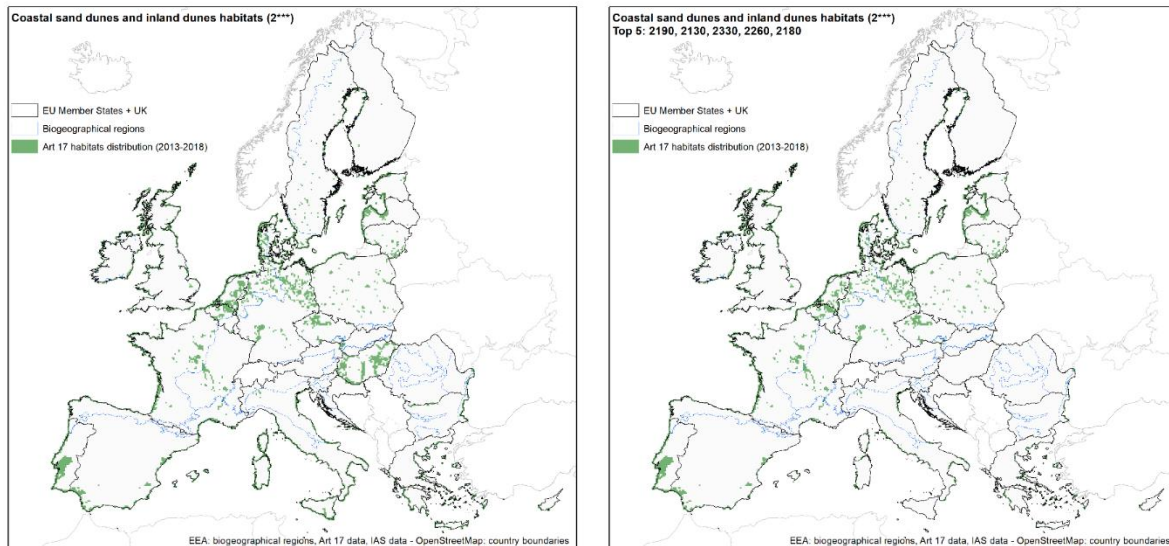


Figure 17 and 18 Overall (left) and Top Five (right) distribution of “Coastal sand dunes and inland dunes habitats” per 10 x 10 km² reference grid

The Top Five ranked habitat types are 2190 Humid dune slacks, 2130 Fixed coastal dunes with herbaceous vegetation (“grey dunes”), 2330 Inland dunes with open *Corynephorus* and *Agrostis* grasslands, 2260 Cisto-Lavenduletalia dune sclerophyllous scrubs, 2180 Wooded dunes of the Atlantic, Continental and Boreal region. These habitat types show a very similar spatial extent as the complete habitat group. An important difference is that habitat type 2340* Pannonic inland dunes is not ranked as a Top Five habitat and opens a gap in the pannonian biogeographical region (Fig. 18). Also, the heatmap of the number of habitat types per grid cell within the “Coastal sand dunes and inland dunes habitats” has a similar appearance (Fig. 19).

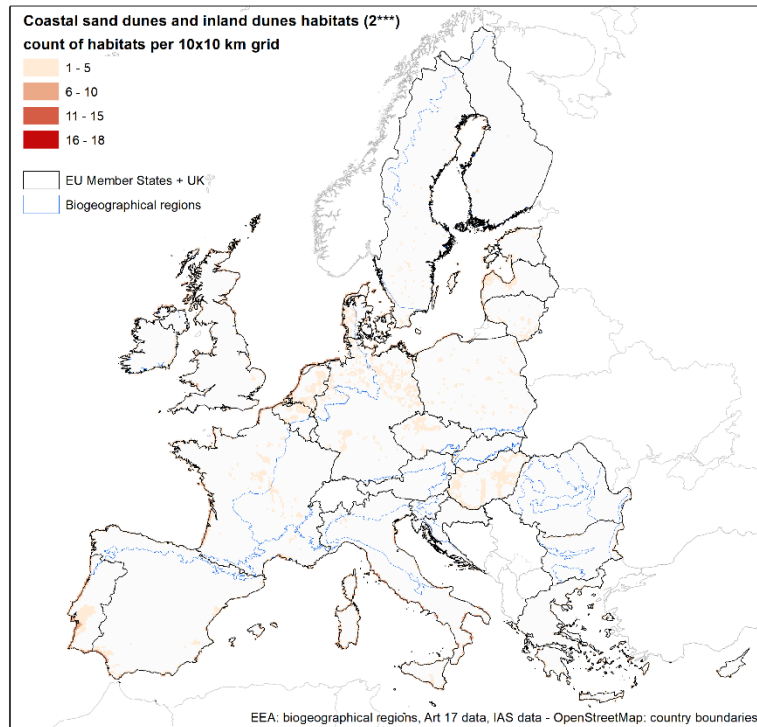


Figure 8 Heat map of Coastal sand dunes and inland dunes habitat types - 10 x 10 km² reference grid

Coastal and halophytic habitats (1***)

The Coastal and halophytic habitat group is heterogeneous and includes marine as well inland habitat types. As the marine habitat subgroup is not relevant for pollinators, only the inland habitat types are considered here. These are scattered over Europe with some regional foci in Hungary and Spain (Fig. 20).

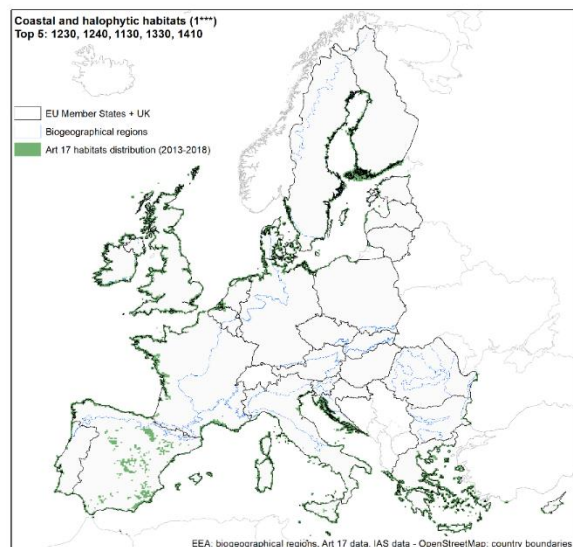
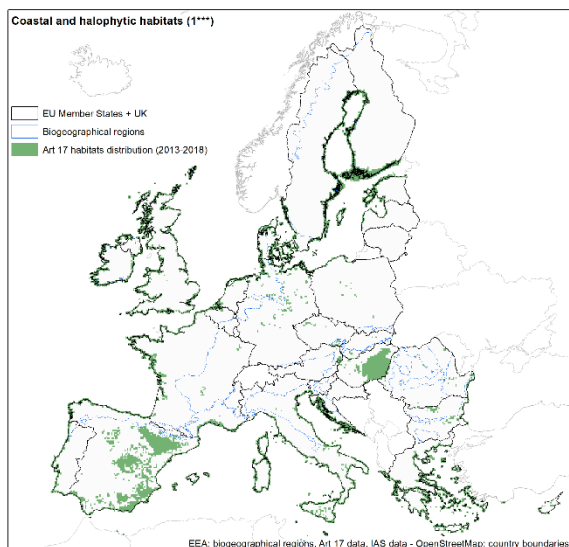


Figure 20 and 21 Overall (left) and Top Five (right) distribution of “Coastal and halophytic habitats” per 10 x 10 km² reference grid

The Top Five ranked habitat types are 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*). These habitats are situated along the European coast lines and inland in central Spain (Fig. 21). A heat map of the number of habitat types per grid cell within the “Coastal and halophytic habitat group” reveals a similar picture than the overall distribution (Fig. 22).

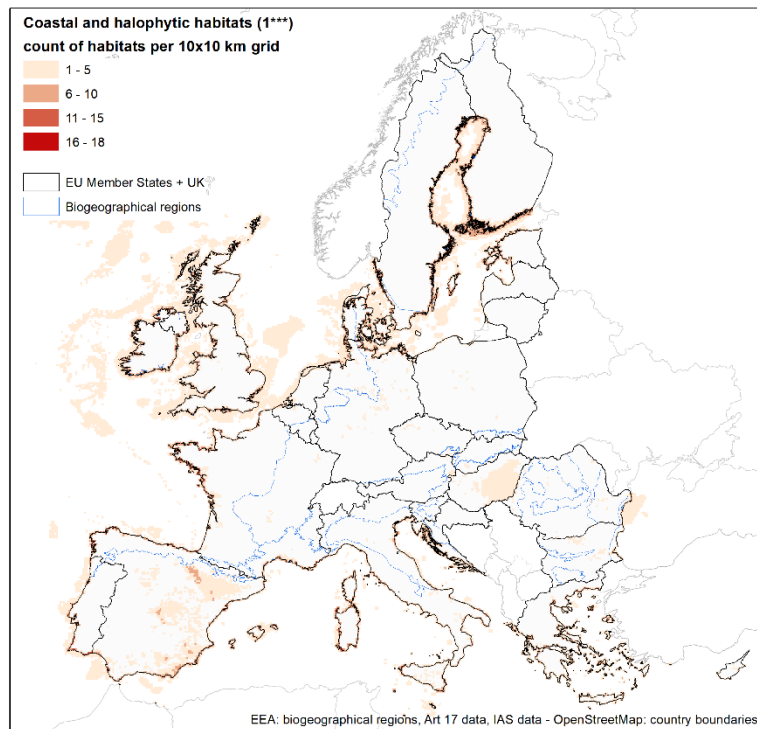


Figure 9 Heat map of Coastal and halophytic habitat types - 10 x 10 km² reference grid

Freshwater habitats (3***)

The overall distribution of freshwater habitats (including still and running waters) shows occurrences across Europe (Fig. 23).

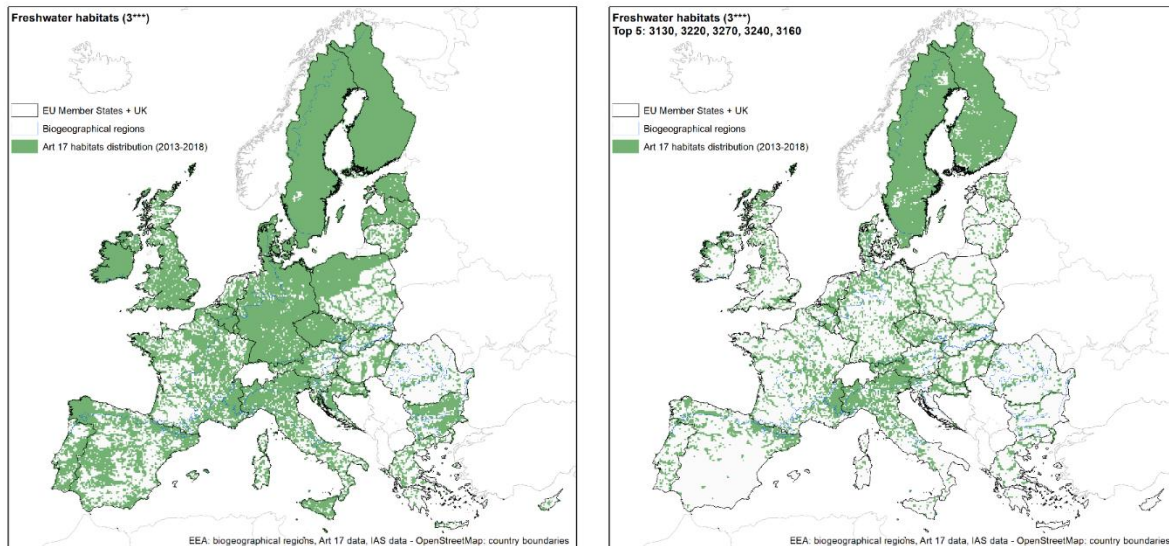


Figure 23 and 24 Overall (left) and Top Five (right) distribution of “Freshwater habitats” per 10 x 10 km² reference grid

The Top Five ranked habitats are 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 *Chenopodium rubri* p.p. and *Bidention* p.p. vegetation, 3240 Alpine rivers and their ligneous vegetation with *Salix elaeagnos*, 3160 Natural dystrophic lakes and ponds. These habitats show a high spatial density in Northern Europe, a thinning in Central Europe and a fading out in Southern Europe (Fig. 24). A heat map of the number of habitat types per grid cell within the “Freshwater habitats” reveals a very broad coverage and distribution across Europe (Fig. 25).

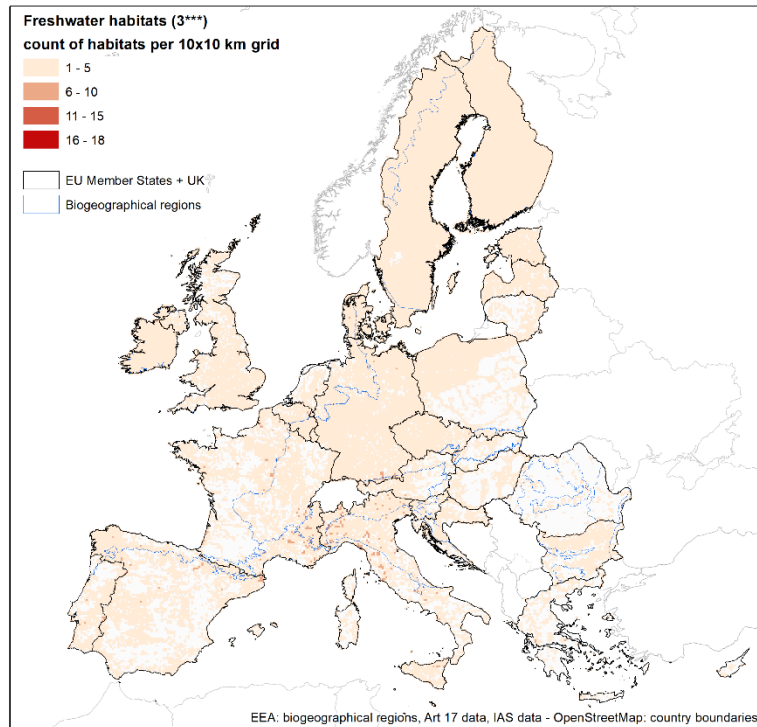


Figure 10 Heat map of Freshwater habitat types - 10 x 10 km² reference grid

Rocky habitats (8***)

The overall distribution of rocky habitat types shows clusters in mountain regions across Europe (Fig. 26).

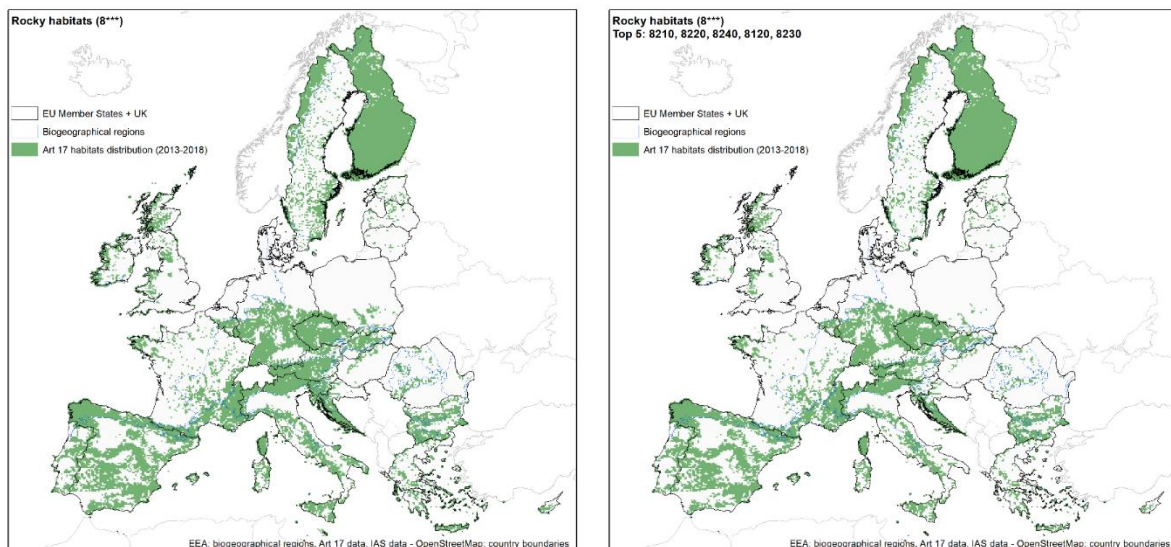


Figure 26 and 27 Overall (left) and Top Five (right) distribution of “Rocky habitats” per 10 x 10 km² reference grid

The Top Five ranked habitats are 8210 Calcareous rocky slopes with chasmophytic vegetation, 8220 Siliceous rocky slopes with chasmophytic vegetation, 8240 Limestone pavements, 8120 Calcareous and calcshist screes of the montane to alpine levels (*Thlaspietea rotundifolii*), 8230 Siliceous rock with pioneer vegetation of the *Sedo-Scleranthion* or of the *Sedo albi-Veronicion dillenii*. These habitats often are broadly defined and the distribution of the Top Five habitat types is highly correlated with the overall distribution of the rocky habitat group. As well, the heat map of the number of habitat types per grid cell within the “Rocky habitat types group” reveals a similar picture than the overall distribution (Fig. 28).

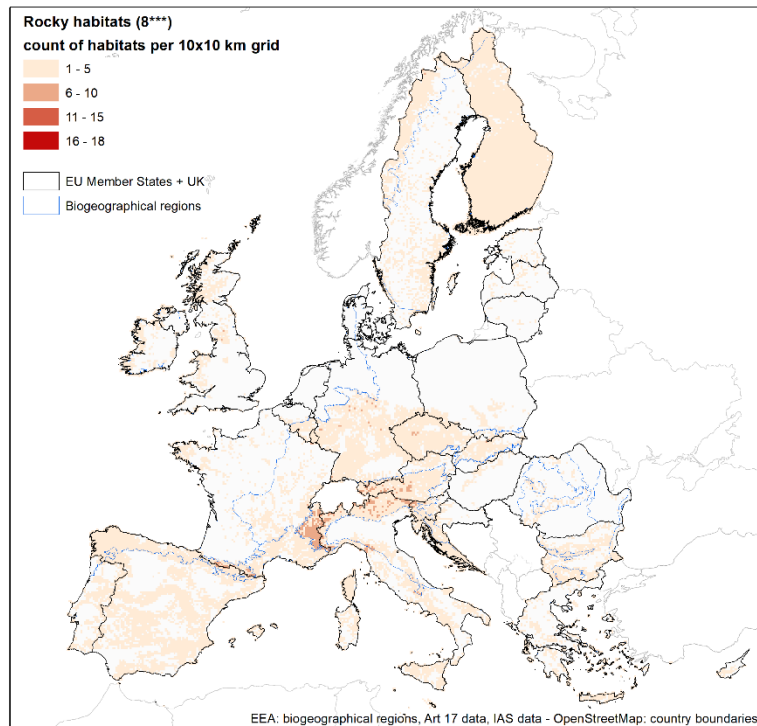


Figure 11 Heat map of Rocky habitat types - 10 x 10 km² reference grid

3.2 Invasive alien plant species

Alternanthera philoxeroides shows scattered and isolated occurrences in France and Italy (Fig. 29). The alligator weed grows as a weed in both aquatic and terrestrial habitats, and often grows at the interface between these two environments. In natural and semi-natural habitats it is prone to become invasive principally in forests, riverbanks and wetlands. It can be found growing along canals, rivers, swamps, lakes, dams, ditches, and wetlands, being rooted to the ground and emerging above the water surface. However, it can also be found in riparian habitats free-floating in dense mats on the water surface. *Alternanthera philoxeroides* is also an important weed of wetter pastures and irrigated crops (CABI 2021a).

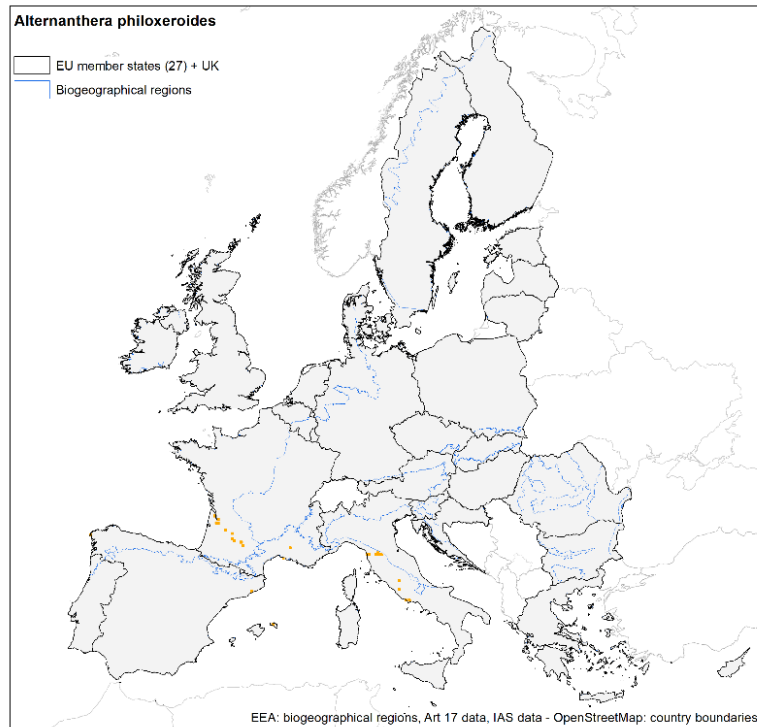


Figure 12 **Reported *Alternanthera philoxeroides* distribution in the 10 x 10 km² reference grid**

Asclepias syriaca is reported as very common and widely distributed in Hungary and in a more scattered way in several other Member States (Fig. 30). The common milkweed colonizes a variety of habitat groups from woodlands to cleared grasslands and marshlands. It grows in clumps or patches in meadows, fencerows, roadsides, railways, waste places, reduced-tillage fields, and other open habitats (CABI 2021b).

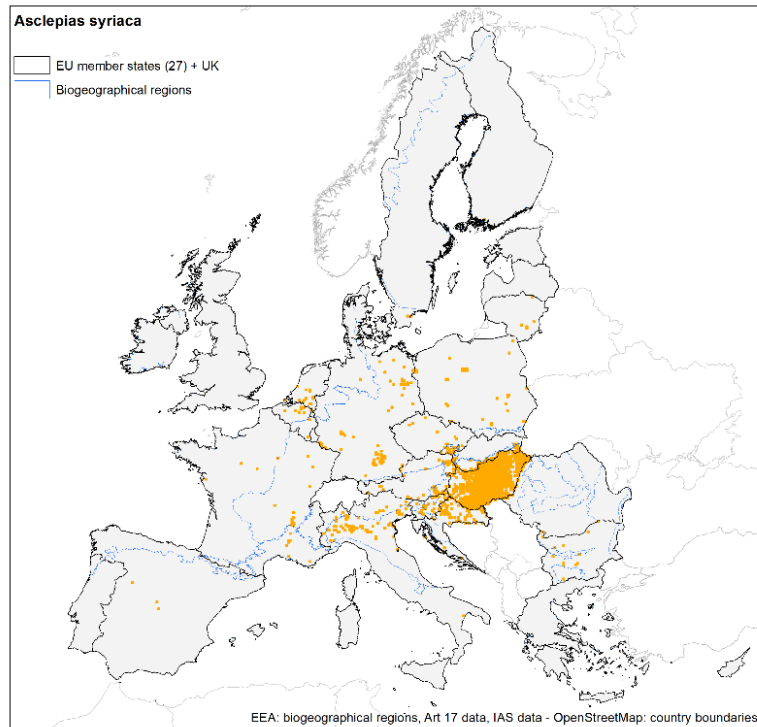


Figure 13 Reported *Asclepias syriaca* distribution in the 10 x 10 km² reference grid

Baccharis halimifolia is mainly reported for coastal regions in the Atlantic biogeographic region in Belgium, France, and Spain and the Mediterranean biogeographic region in France and Italy (Fig. 31). The groundsel-bush grows on beaches and marshes near the shore, and in various inland habitats including pastures, old fields, ditches and roadsides (CABI 2021c).

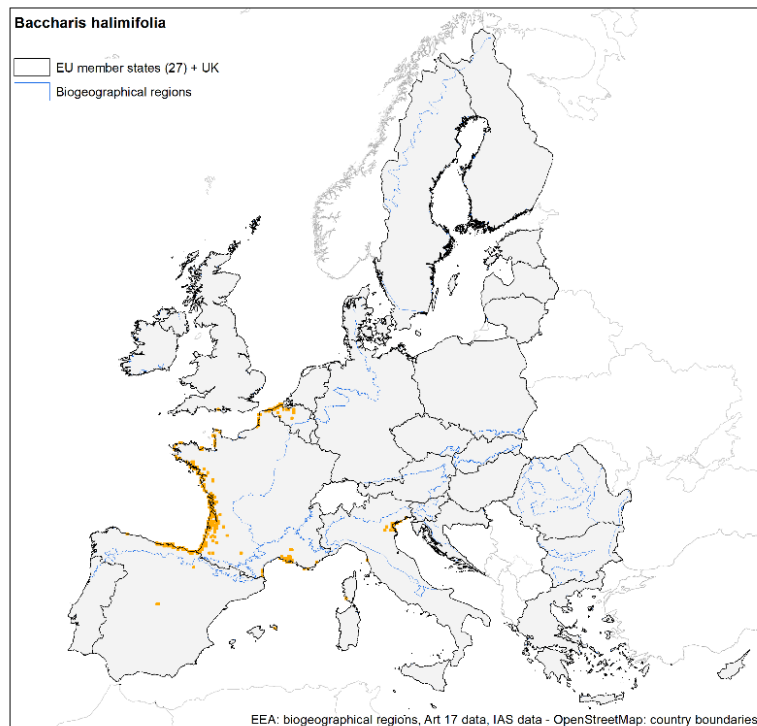


Figure 14 Reported *Baccharis halimifolia* distribution in the 10 x 10 km² reference grid

Gunnera tinctoria is common and widely distributed in Ireland and the United Kingdom and is also reported from the northwest coastal region of France (Fig. 32). The giant rhubarb is found on coastal cliffs, riparian zones, forests and wetlands as well as in areas that have been transformed by human activity such as former agricultural fields, quarries and road sides (CABI 2021d; EPPO 2021).

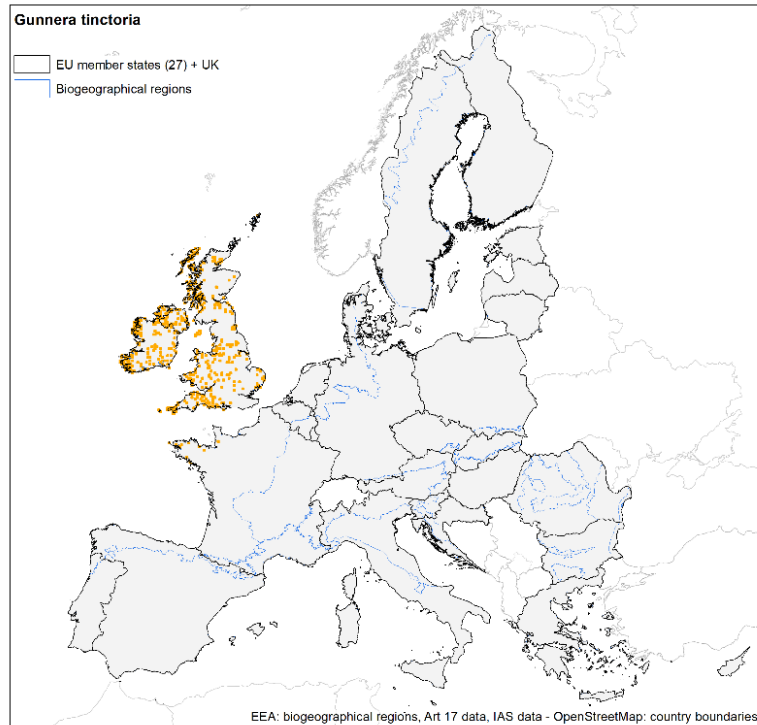


Figure 15 Reported *Gunnera tinctoria* distribution in the 10 x 10 km² reference grid

In several Member States (e.g. Belgium, Czech Republic, the Netherlands, Denmark, southern Finland, Estonia) and in the United Kingdom, *Heracleum mantegazzianum* is reported as very widely present, whereas in other Member States a more scattered distribution is reported (Fig. 33). As already pointed out by Rabitsch et al. (2020), this is partly due to missing information and data artefacts. The giant hogweed has been commonly introduced to gardens as an ornamental and has spread to invade a variety of habitat types, especially along roadsides, river banks, railways, woodland fringes, grasslands and arable fields, scrublands and ruderal sites such as rubbish dumps and waste ground. It is also increasingly found in abandoned or extensively managed grasslands (CABI 2021e).

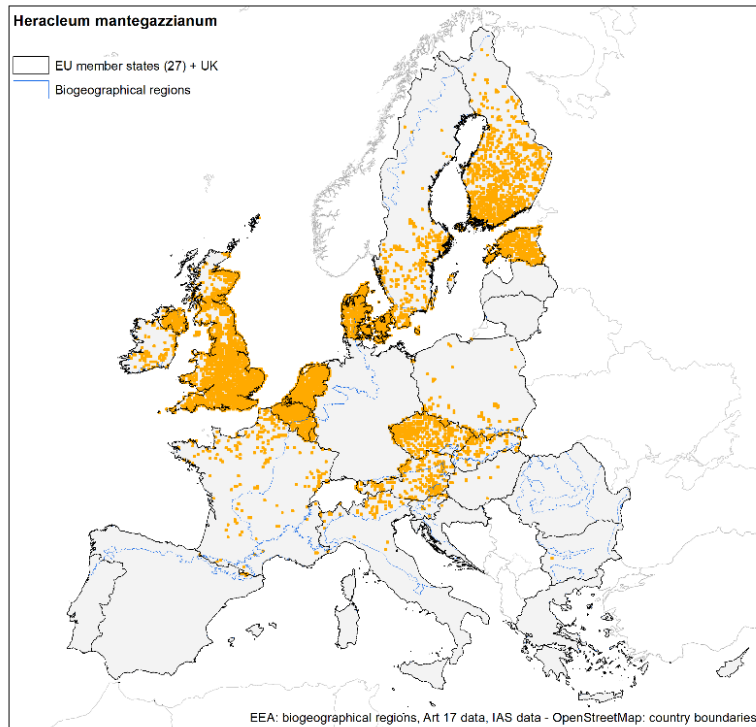


Figure 16 **Reported *Heracleum mantegazzianum* distribution in the 10 x 10 km² reference grid**

Heracleum persicum is reported only from the Boreal biogeographic region in Sweden, Finland and Estonia (Fig. 34). The Persian hogweed generally occupies the same habitats as *H. mantegazzianum*. These are disturbed and semi-natural habitats, such as roadsides and railroads, as well as meadows, grasslands, disused agricultural land, ruderal areas, coastal beaches and along streams and rivers (CABI 2021f).

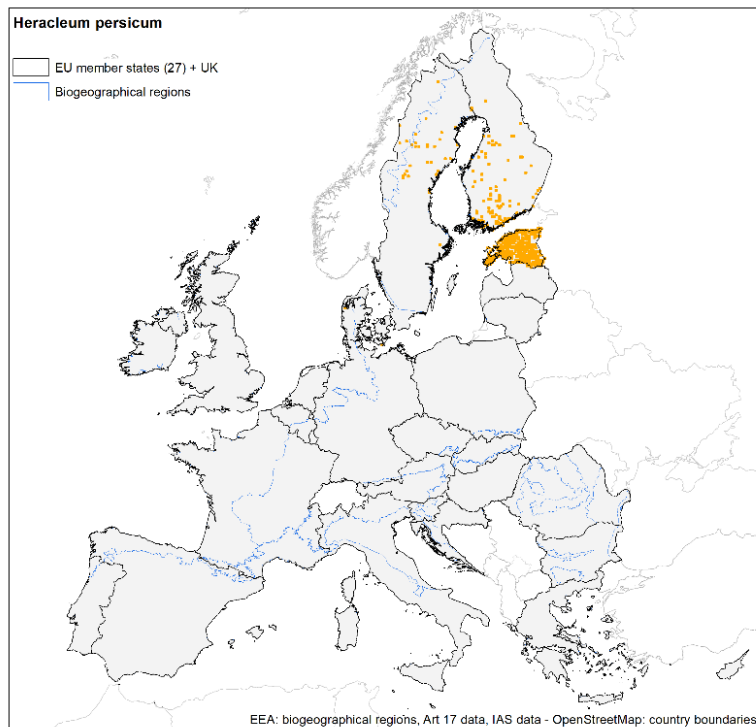


Figure 17 **Reported *Heracleum persicum* distribution in the 10 x 10 km² reference grid**

Heracleum sosnowskyi is reported from Poland and the Baltic countries (Fig. 35). Sosnowskyi's hogweed is mostly found in artificial habitats (roadsides, disturbed areas, agricultural fields, abandoned farmyards and gardens) and semi-natural habitats (bushes, grasslands, parks, pastures, abandoned orchards) (CABI 2021g).

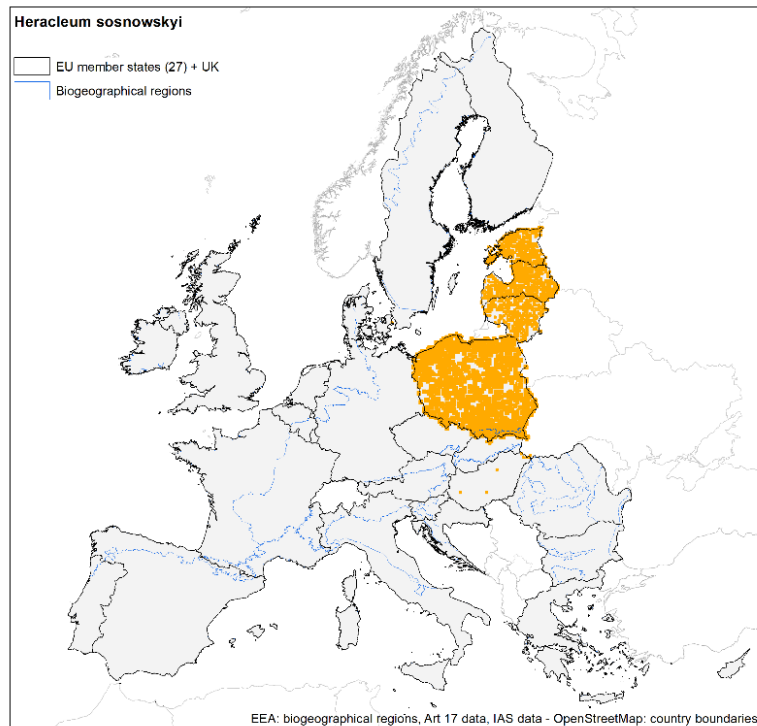


Figure 18 **Reported *Heracleum sosnowskyi* distribution in the 10 x 10 km² reference grid**

Hydrocotyle ranunculoides is reported being widely distributed in Belgium, the Netherlands and the United Kingdom (England). In other Member States there are only scattered occurrences (Fig. 36). The floating pennywort occurs at the margins of still or slow-flowing watercourses (CABI 2021h).

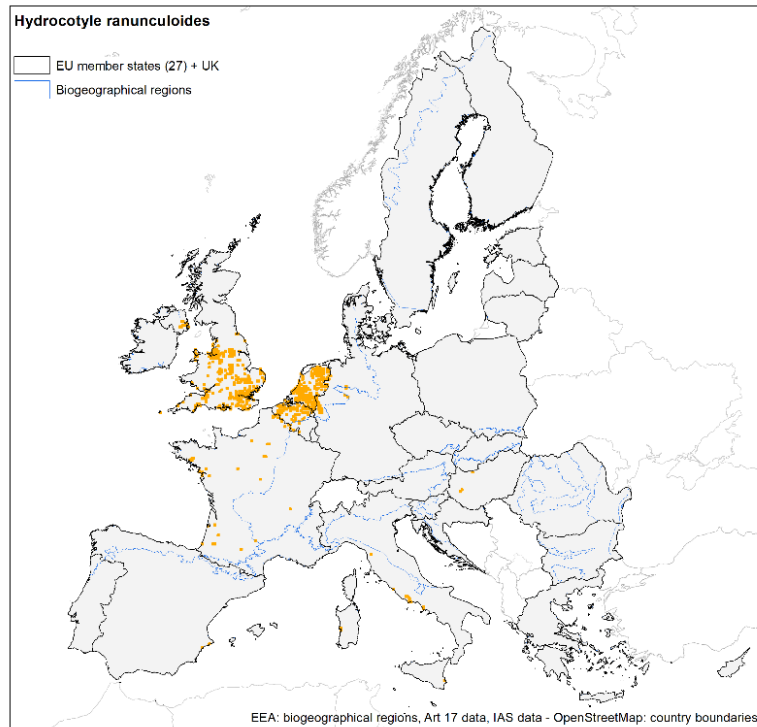


Figure 19 **Reported *Hydrocotyle ranunculoides* distribution in the 10 x 10 km² reference grid**

Impatiens glandulifera is widely distributed across the EU (e.g. Austria, Belgium, Czech Republic, Germany, Ireland, Netherlands) and in the United Kingdom, with fewer records in the Mediterranean biogeographical region (Fig. 37). The Himalayan balsam is predominantly a weed of riparian systems where it can form dense monocultures along river banks. It is also found in damp natural woodland, forest plantations, forest clearings, railway embankments, waste ground, urban areas, roadside ditches and wet meadows (CABI 2021i).

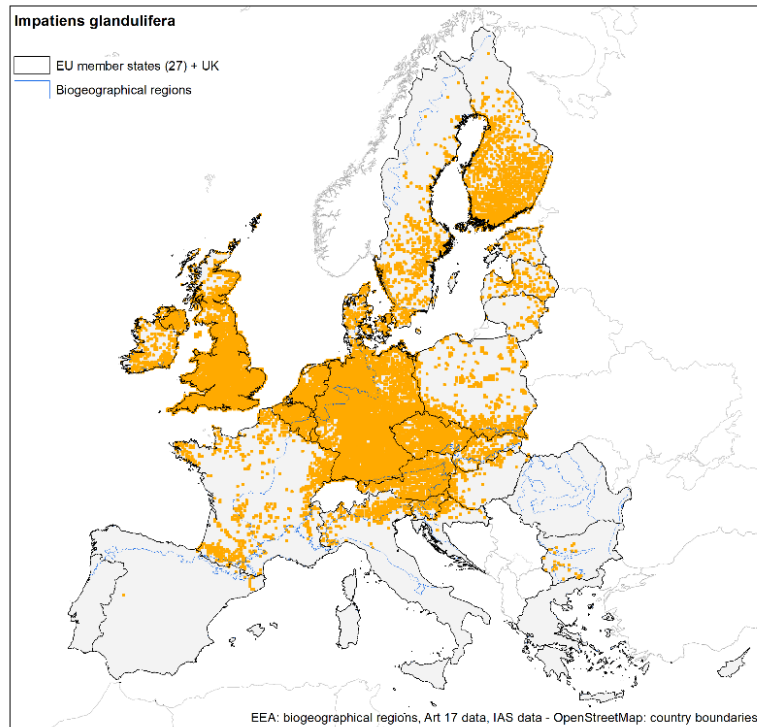


Figure 20 Reported *Impatiens glandulifera* distribution in the 10 x 10 km² reference grid

Ludwigia grandiflora is reported at a higher density in Belgium, the Netherlands and Western France, with more scattered records in several other Member States (Fig. 38). The water primrose is often found growing in freshwater wetlands, in slow-moving rivers and streams, on lake and reservoir shorelines and in shallow canals and on floodplains. The plant invades different habitats, e.g. emergent marshes and swamps in permanently pooled bottomland depressions that experience periodic flooding, shorelines and shallow bays, and sandy banks and gravel bars of shallow streams (CABI 2021j).

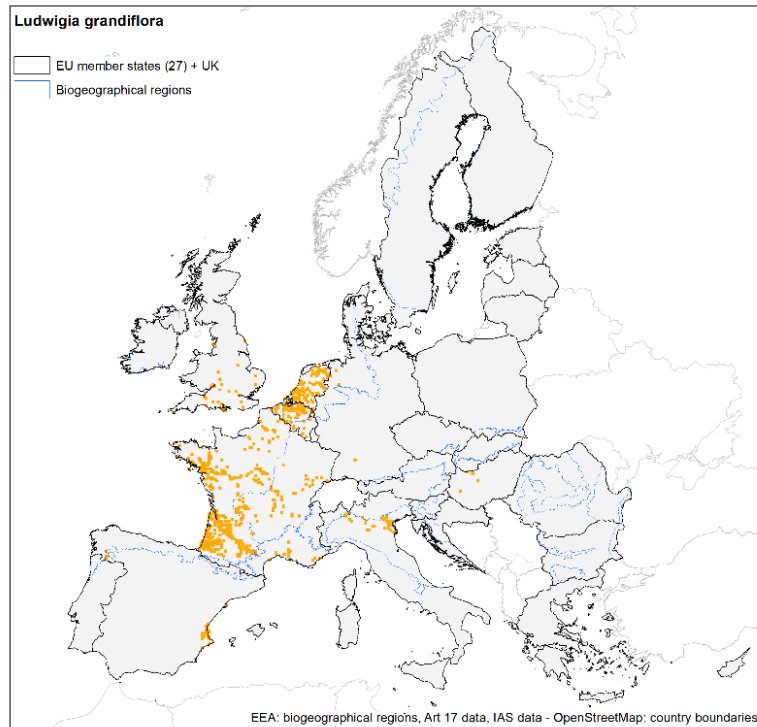


Figure 21 Reported *Ludwigia grandiflora* distribution in the 10 x 10 km² reference grid

Ludwigia peploides is reported at a higher density in western and southern France, the Padan Plain in Italy, with more scattered records in several other Member States (Fig. 39). Floating primrose-willow can be found in wetlands, on shorelines, in slow-flowing rivers, ponds, rice fields, marshes and in other freshwater environments (CABI 2021k).

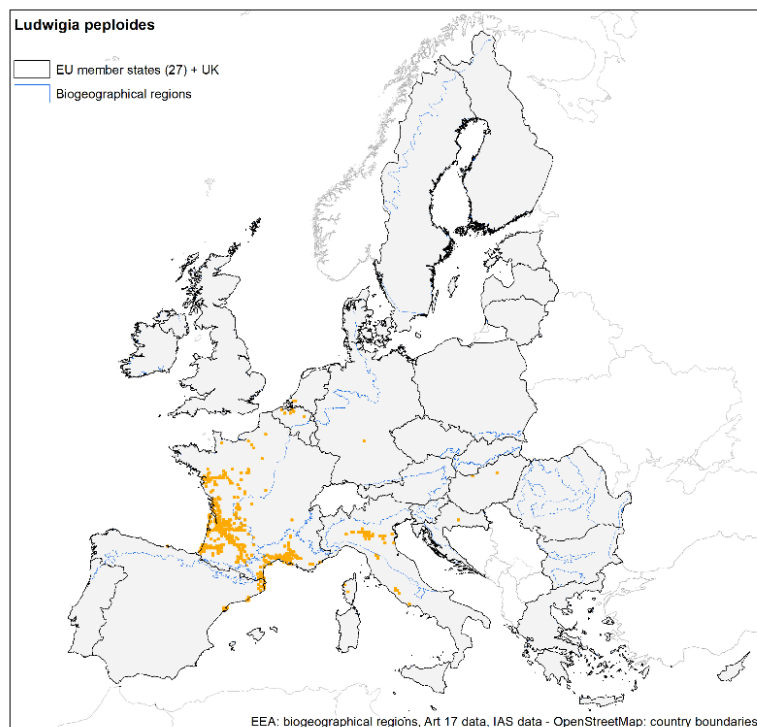


Figure 22 Reported *Ludwigia peploides* distribution in the 10 x 10 km² reference grid

Lysichiton americanus is relatively common in the United Kingdom and has scattered records in the northwestern EU (e.g. Ireland, Belgium, Netherlands, Germany, southern Sweden and Finland) (Fig. 40). The American skunk cabbage has a rather wide ecological amplitude as long as the habitat is wet. It grows in shady forested bogs, in peatbogs, in swamps in full sun, and in shallow brooks with flowing water (CABI 2021I).

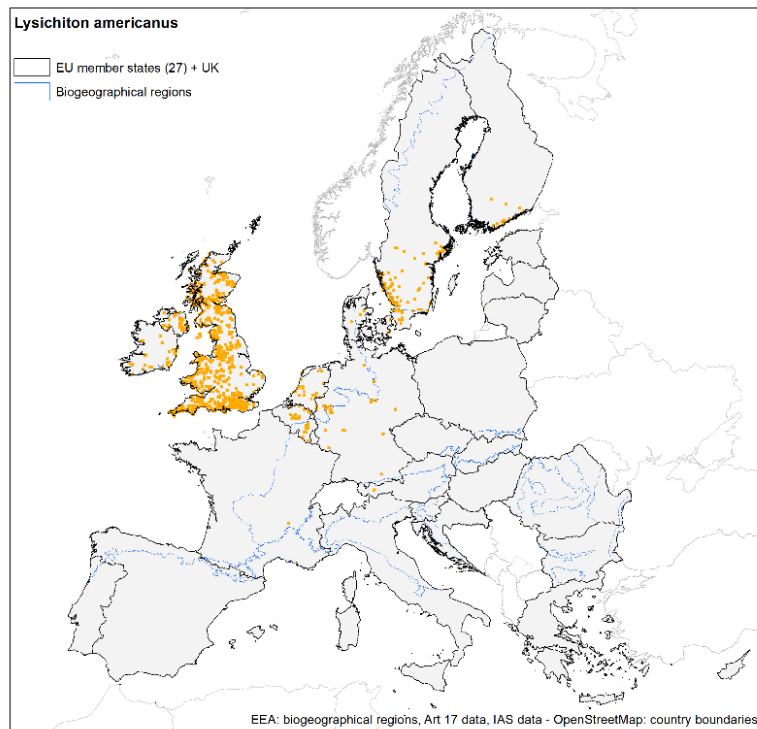


Figure 23 **Reported *Lysichiton americanus* distribution in the 10 x 10 km² reference grid**

Myriophyllum aquaticum is reported in a high density from western France, Belgium, the Netherlands and the United Kingdom, with some more scattered records in several other Member States (Fig. 41). Parrot's feather is typically found in freshwater lakes, ponds, streams, and canals and appears to be adapted to high nutrient environments (CABI 2021m).

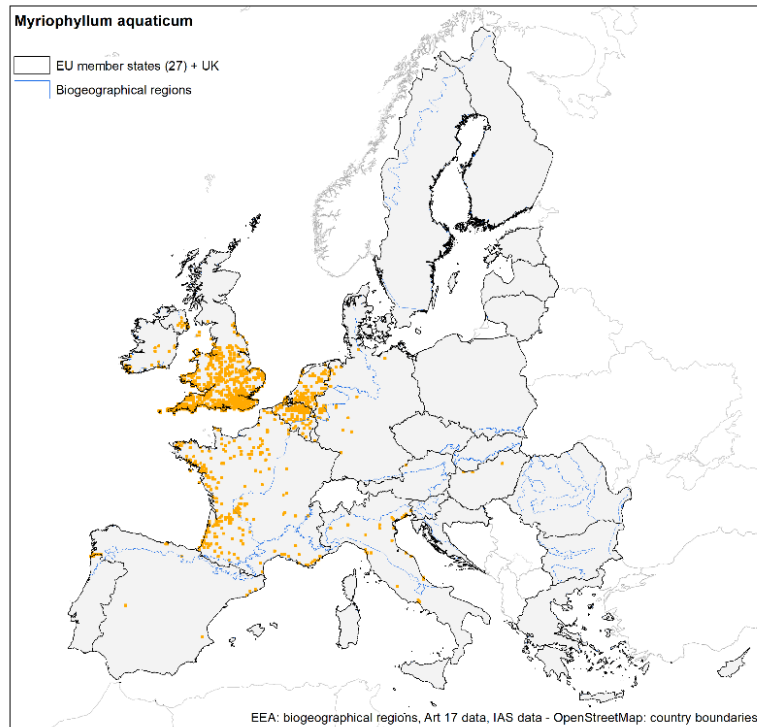


Figure 24 Reported *Myriophyllum aquaticum* distribution in the 10 x 10 km² reference grid

Pennisetum setaceum is recorded in the Mediterranean biogeographical region from coastal regions in Spain, France, Italy, Malta and Cyprus (Fig. 42). The fountain grass favours arid to semi-arid environments but occurs in mesic sites as well. It often grows in disturbed areas such as along roadsides, grasslands and railroad embankments and in mined areas (CABI 2021n).

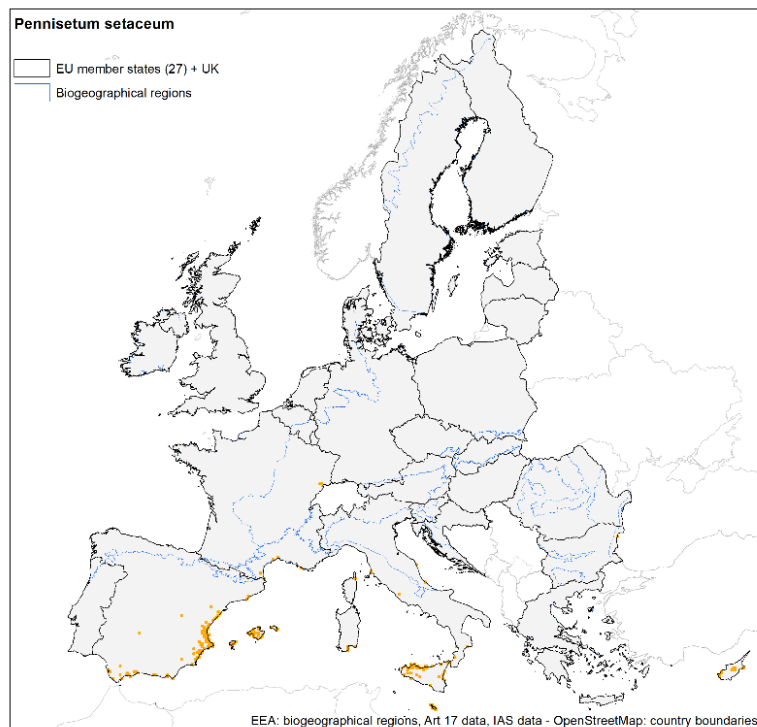


Figure 25 Reported *Pennisetum setaceum* distribution in the 10 x 10 km² reference grid

Pueraria montana var. *lobata* is reported only from northern Italy (Fig 43). Kudzu vine is an opportunistic climbing vine that grows in numerous habitats including woods, plantation forests, along rivers and roads, on the borders of fields, in abandoned fields, on embankments and along fencerows (CABI 2021o).

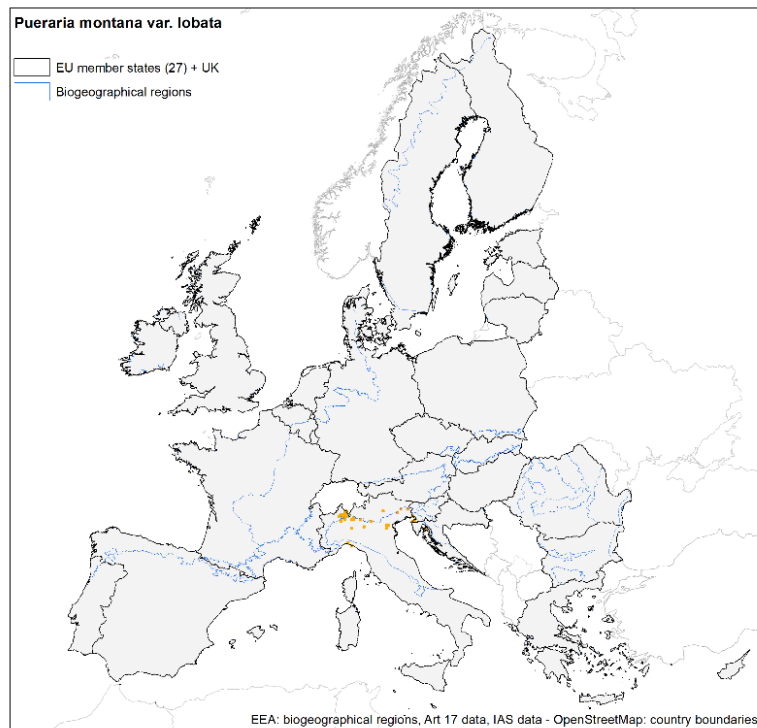


Figure 26 **Reported *Pueraria montana* var. *lobata* distribution in the 10 x 10 km² reference grid**

A heat map combining the recorded distribution of these 15 invasive alien plant species based on the 10 x 10 km² reference grid indicates hotspots in Belgium and the Netherlands, Estonia, southern Finland and Sweden, western France, and United Kingdom (Fig. 44).

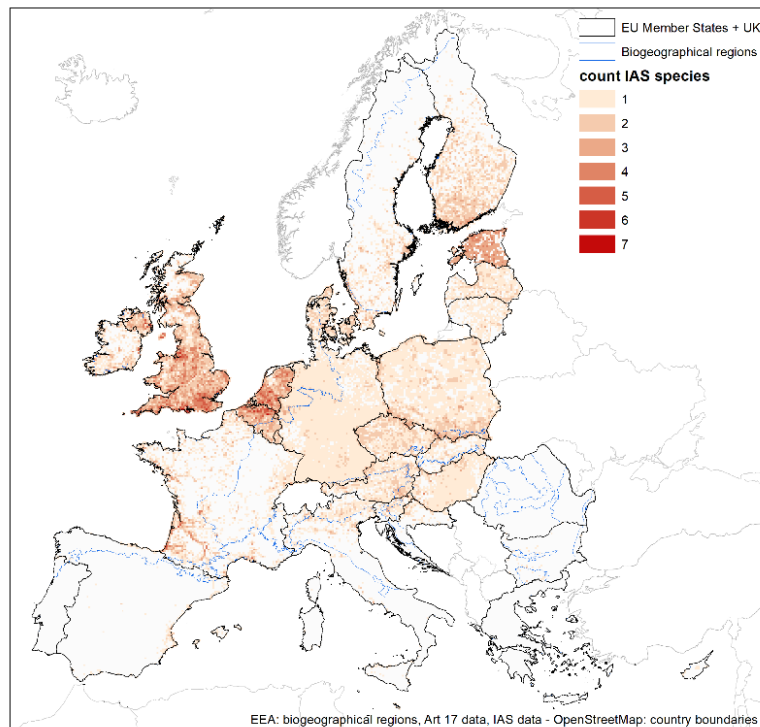


Figure 27 Overall number of selected invasive alien plant species (max. 15) per 10 x 10 km² reference grid

3.3 Invasive alien plant species and habitats of the Habitat Directive

3.3.1 At the EU- (+UK) level

The combination of the reported distribution of the 15 selected invasive alien plant species (see Table 1) and the eight selected habitat groups, important for pollinating species (see chapter 4.1.2), at the EU (plus UK) level (Fig. 45) reveals patterns that need careful interpretation. As discussed by Rabitsch et al. (2020), the reported distribution of invasive alien plant species includes some gaps and biases, possibly due to misidentifications (e.g. for *Heracleum*) or different expert opinions and knowledge within Member States. Distributions cover a broad range from widespread species (e.g. *Impatiens glandulifera*, Fig. 37) to species with a more localized distribution (e.g. *Alternanthera philoxeroides*, Fig. 29; *Pueraria montana* var. *lobata*, Fig. 43), suggesting possible impacts on habitat types important for pollinators at the local and at the regional spatial scale. According to Kudrnovsky et al. (2020), grassland habitats, sclerophyllous scrubs and temperate heath habitats are the top-ranked groups of habitat types with highest importance for pollinating insects (Figs. 4, 7, and 10). While grassland habitats and temperate heath habitats are relatively widely spread across the EU, sclerophyllous scrubs prevail in the mediterranean south.

Figure 45 depicts a bivariate heatmap of the numbers of invasive alien plant species and the numbers of habitat types important for pollinators. In general, the numbers of invasive alien plant species (red colours, see also Fig. 44) are lower in the Mediterranean than in parts of the Atlantic (Belgium, Netherlands, United Kingdom and southwestern France), Boreal (south Finland and Estonia) and most of the Continental biogeographical regions. Habitat types important for pollinators are widely distributed across the EU, but the data also indicate areas with lower numbers, e.g. in England and Northern Ireland, France, the Po valley in Italy, Romania and Greece. Several of these areas (light blue

colours) overlap with high numbers of alien plant species (red colours), e.g. in coastal and southwestern France, southern Ireland and central and eastern Poland. Areas with a high number of habitat types important for pollinators (darker blue colours) are present across the EU, and coincide with either low numbers of invasive alien plants (light red colour) (e.g. in Spain and in the Alpine biogeographical region) and high numbers of invasive alien plants (dark red colour) (e.g. in southern Finland and Estonia).

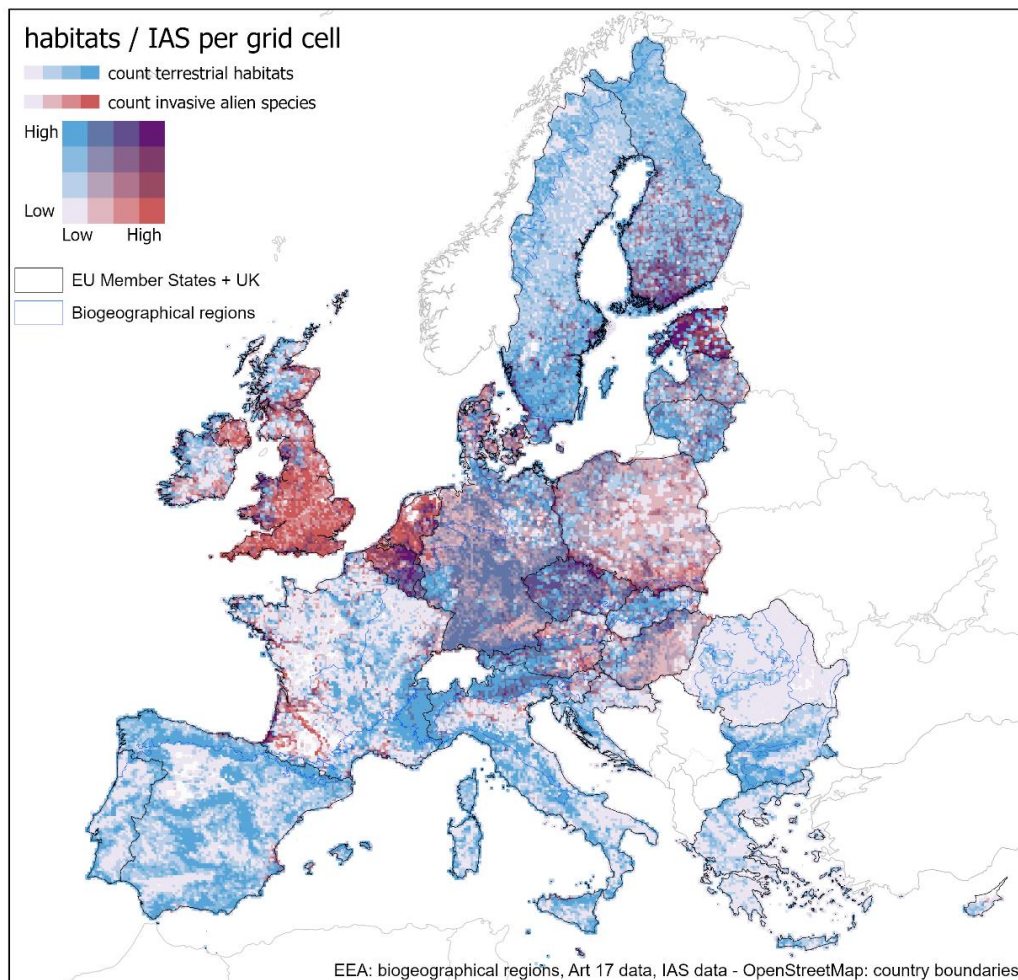


Figure 28 Bivariate count heat map of invasive alien plant species and all terrestrial habitat types of the Habitat Directive by 10 x 10 km² reference grid

3.3.2 At the regional level

With the aim of providing a more focused perspective, the following figures “zoom” into selected regions. Figure 46 provides a more detailed picture of the European Alps and adjacent regions. It indicates that while there is a high number of habitat types and only few invasive alien plant species in the western Alps in France and Italy, as well as in the Apennine mountains in Italy and the Dinaric Alps in Slovenia and Croatia, there is a high number of invasive alien plant species and a low number of habitat types in the Italian Po valley. This reflects the general trend of decreasing numbers of alien species with altitude, partly as a consequence of increasingly harsh environmental conditions and remoteness from points of introduction (e.g. Becker et al. 2005, Dainese et al. 2014), but also high land-use pressures in the lowlands (for industry and agriculture in this case) with a diminishing number of natural habitat types. In the Swiss Alps, maximum altitude of alien species was found to be

positively related to total area occupied and time since introduction (Becker et al. 2005). In combination with climate change, it has to be assumed that invasive alien plant species will increase in numbers and altitude in the future and therefore increase the risk for habitat types important for pollinators in these regions (Hellmann et al. 2008, Walther et al. 2009, Bellard et al. 2013, Bradley et al. 2018).

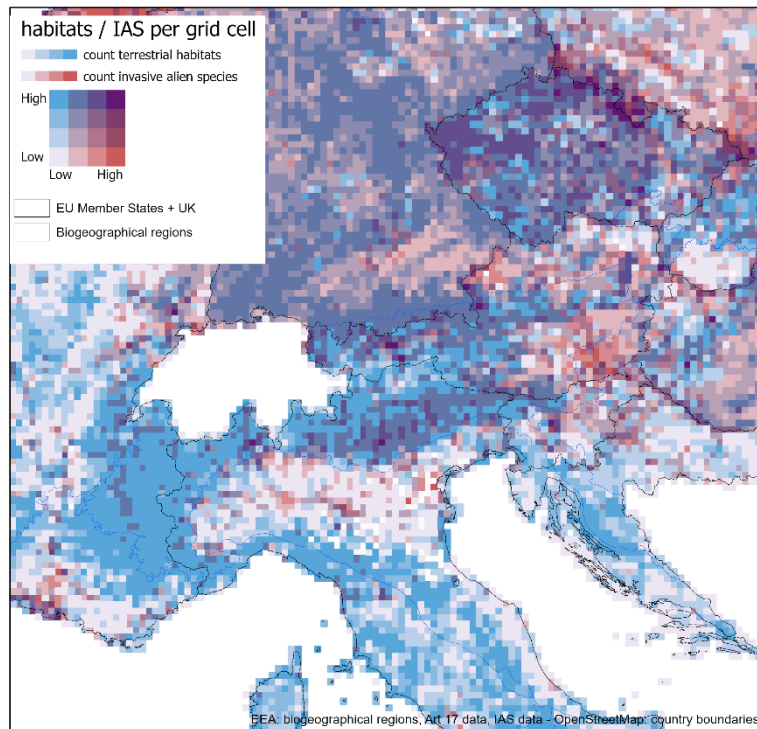


Figure 46 Bivariate count heatmap of invasive alien plant species and habitat types of the Habitat Directive by 10 x 10 km² reference grid in the European Alps and adjacent areas

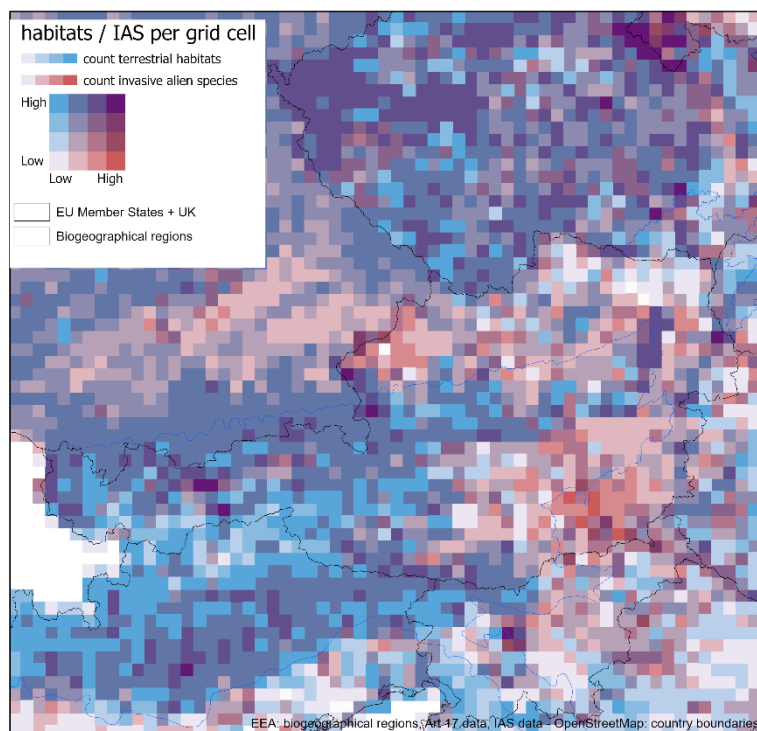


Figure 47 Bivariate count heatmap of invasive alien plant species and habitat types of the Habitat Directive by 10 x 10 km² reference grid for Austria, the Czech Republic and adjacent areas

Figure 47 provides a closer look into the pattern for Austria, Bavaria and the Czech Republic. Two thirds of Austria belong to the Alpine biogeographical region and one third belongs to the Continental biogeographical region. The alpine (western) part is characterized by high numbers of habitat types and a mixture of grid cells showing high or low numbers of invasive alien plants. This could be due to the presence of alien plants in the alpine valleys and their absence at higher altitudes. The continental (eastern) part is characterized by lower numbers of habitat types and higher numbers of alien plants. The colour patterns for Bavaria and the Czech Republic are much more homogeneous, indicating less steep environmental gradients and intermediate (Bavaria) and high (Czech Republic) numbers of habitat types and alien plants.

Figure 48 illustrates the pattern for a large part of central Europe. The homogeneous colour pattern extends to most parts of Germany (with notable exceptions in the provinces Rhineland-Palatinate in the west, Schleswig-Holstein and Mecklenburg-Vorpommern in the north and Saxony-Anhalt and Brandenburg in the east) and also Poland, with a relatively clear contrast at the country borders to Belgium and the Netherlands, and also to Denmark. Such distinct delimitations along national borders often reflect data artefacts rather than environmental factors. Figure 49 further details the pattern for Belgium, the Netherlands and Luxembourg, indicating high numbers of invasive alien plants and high numbers of habitat types along the coast and in the Wallonia region.

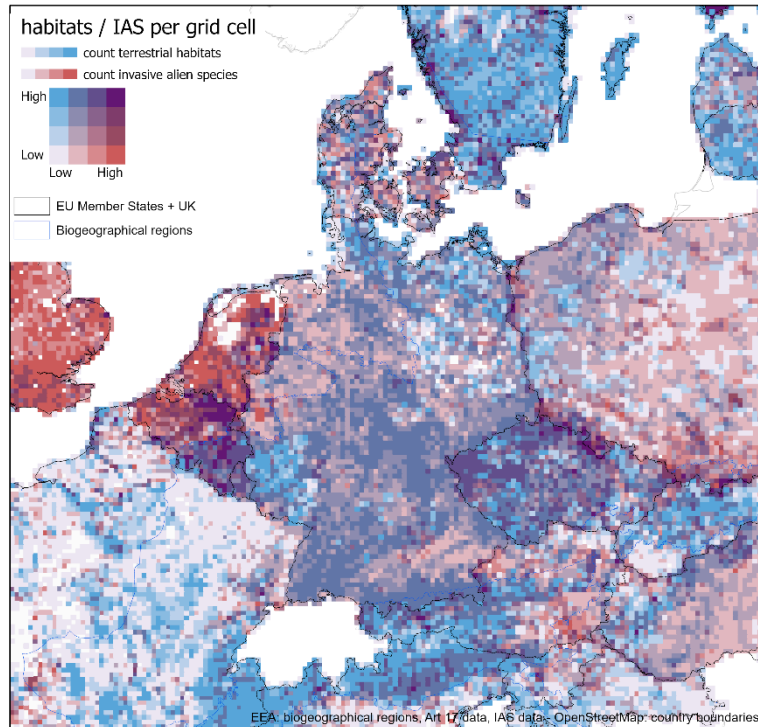


Figure 48 Bivariate count heatmap of invasive alien plant species and habitat types of the Habitat Directive by 10 x 10 km² reference grid for central Europe

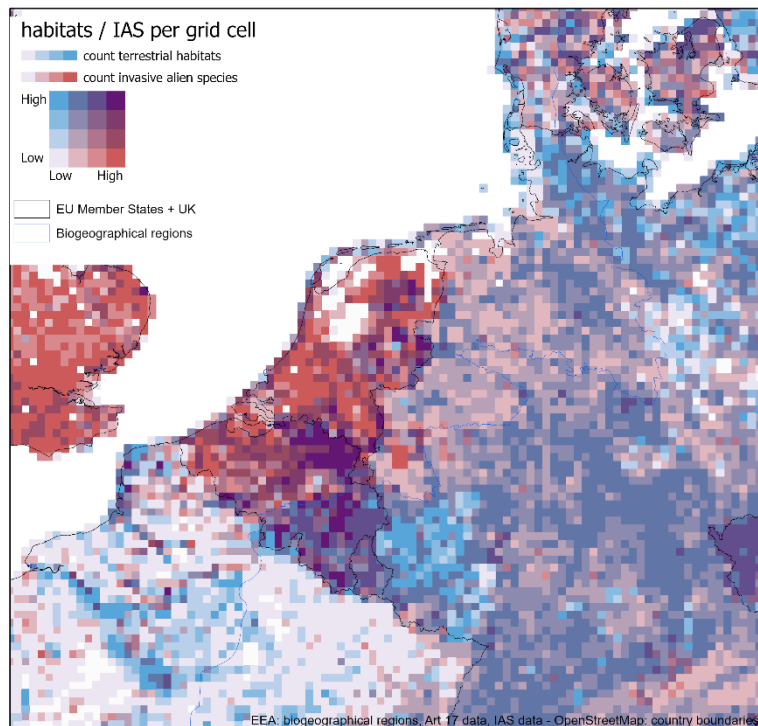


Figure 49 Bivariate count heatmap of invasive alien plant species and habitat types of the Habitat Directive by 10 x 10 km² reference grid for Belgium, the Netherlands and Luxembourg and adjacent areas

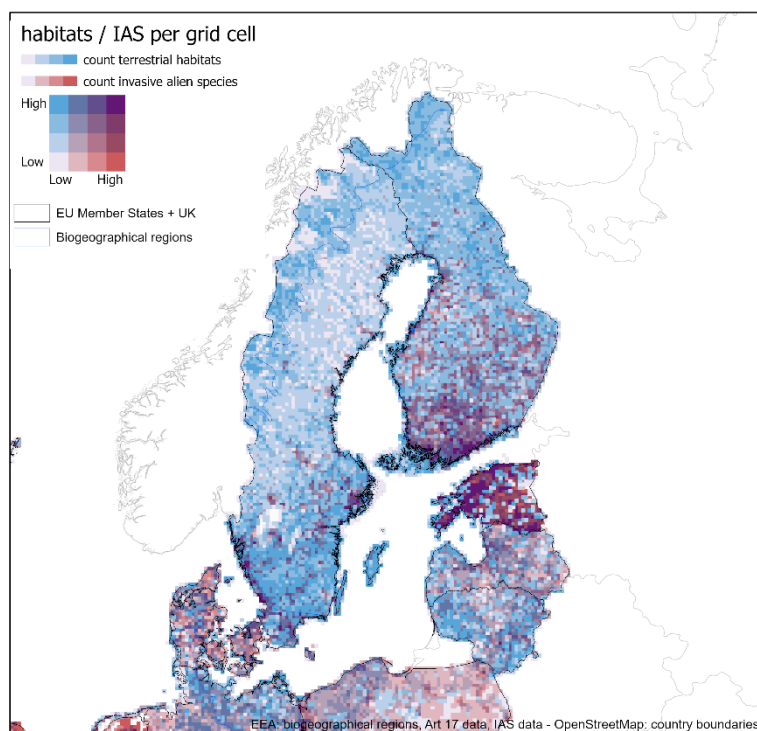


Figure 50 Bivariate count heatmap of invasive alien plant species and habitat types of the Habitat Directive by 10 x 10 km² reference grid for the Boreal biogeographic region

Figure 50 shows the colour pattern for the Boreal biogeographic region. Hotspots of high numbers of invasive alien plants and habitat types are southern Finland, Estonia, and the coastal regions of southern Sweden, while Latvia and Lithuania show a more intermediate colour gradient, but with a higher number of habitat types than adjoining Poland. Large areas of Sweden and northern Finland show relatively low numbers of alien plants and high numbers of habitat types.

Figure 51 depicts the situation for Ireland and the United Kingdom. While high numbers of invasive alien plant species and low numbers of habitat types can be found in southern Ireland, Northern Ireland and England, relatively low numbers of invasive alien plants and high numbers of habitat types are recorded from central Ireland and northern Scotland. The colour pattern for Wales and some coastal regions of Scotland indicate high numbers of invasive alien plants and also high numbers of habitat types.

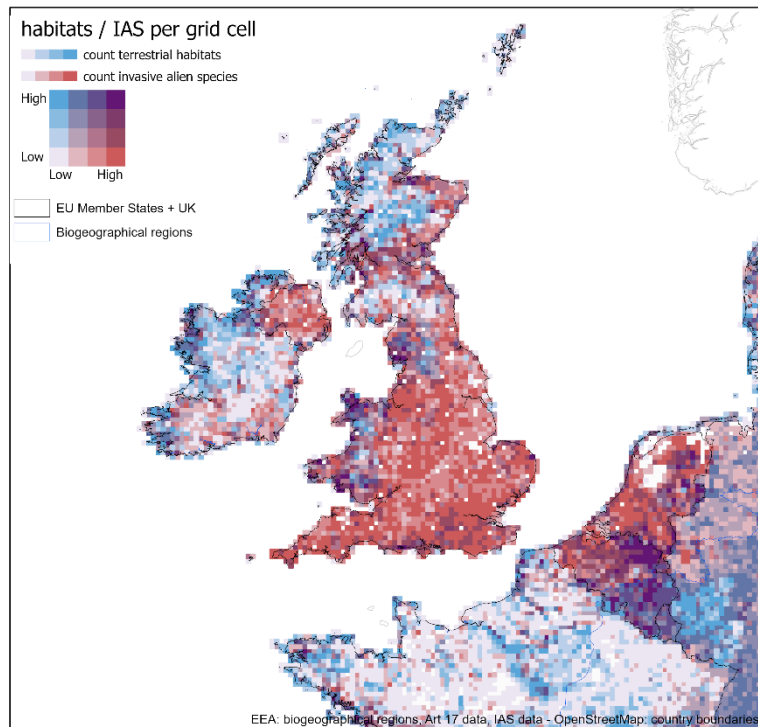


Figure 51 Bivariate count heatmap of invasive alien plant species and habitat types of the Habitat Directive by 10 x 10 km² reference grid for Ireland and the United Kingdom

Figure 52 provides a more detailed picture of the situation in southern France, the Pyrenees and northeastern Spain. Highest numbers of invasive alien plants and habitat types can be found along the Atlantic coast of France, with a steep gradient and a patchy colour pattern in the inland areas. Coastal regions in general, also along the Mediterranean, appear to have higher numbers of invasive alien plants and habitat types than inland areas. Contrary, the Pyrenees and northeastern Spain show a more homogeneous pattern, with high numbers of habitat types and relatively low numbers of invasive alien plants.

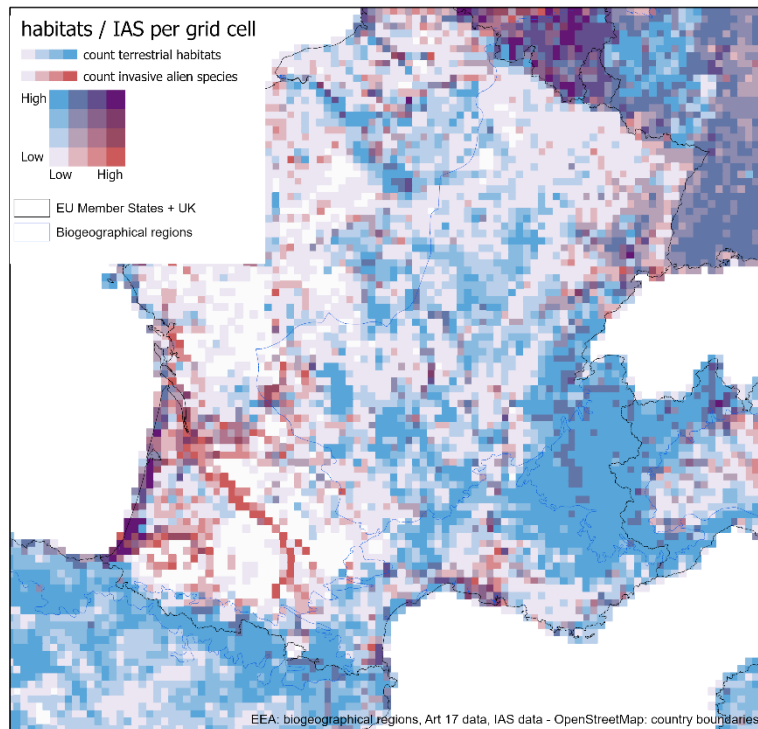


Figure 52 Bivariate count heatmap of invasive alien plant species and habitat types of the Habitat Directive by 10 x 10 km² reference grid for southern France, the Pyrenees and northeastern Spain

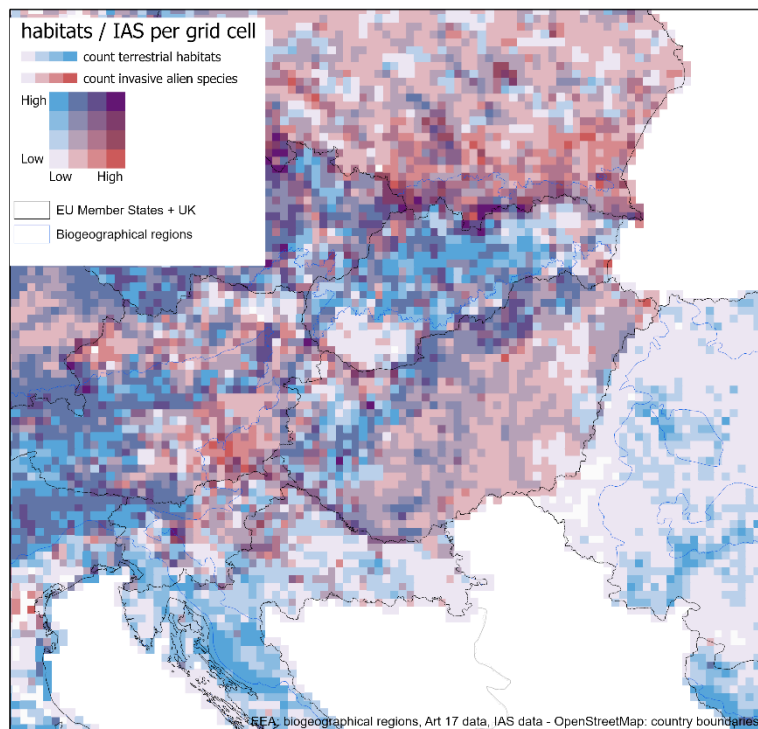


Figure 53 Bivariate count heatmap of invasive alien plant species and habitat types of the Habitat Directive by 10 x 10 km² reference grid for the Pannonian biogeographical region

Figure 53 depicts the Pannonian biogeographical region. The relatively sharp contrast at the national border between Hungary and Romania appears to rather reflect reporting bias than an environmental gradient. The colour pattern for most parts of Hungary is homogeneous with an intermediate number of invasive alien plants and low numbers of habitat types.

Figure 54 shows the situation in Romania, Bulgaria, and Greece, Figure 55 in Italy and Figure 56 in Portugal and Spain. While Bulgaria and Italy, Portugal and Spain appear to have higher numbers of habitat types than Romania and Greece, the numbers of invasive alien plant species appear being low in all these countries.

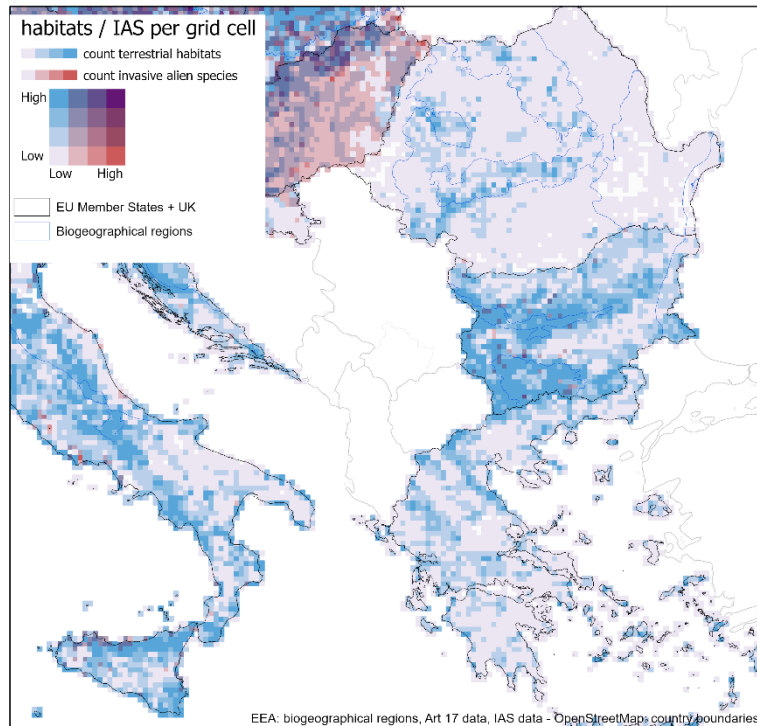


Figure 54 Bivariate count heatmap of invasive alien plant species and habitat types of the Habitat Directive by 10 x 10 km² reference grid for Romania, Bulgaria and Greece

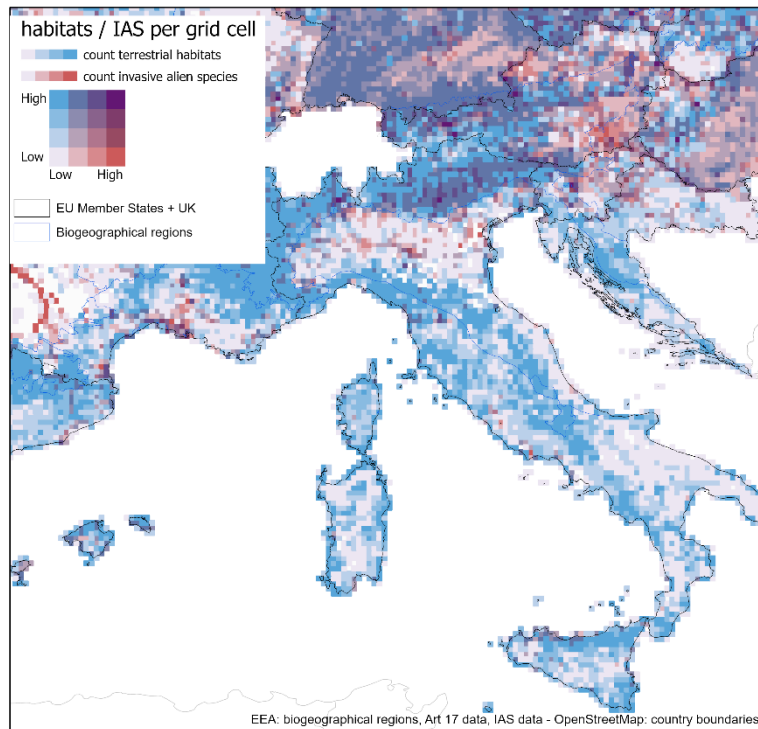


Figure 55 Bivariate count heatmap of invasive alien plant species and habitat types of the Habitat Directive by 10 x 10 km² reference grid for Italy and adjacent areas

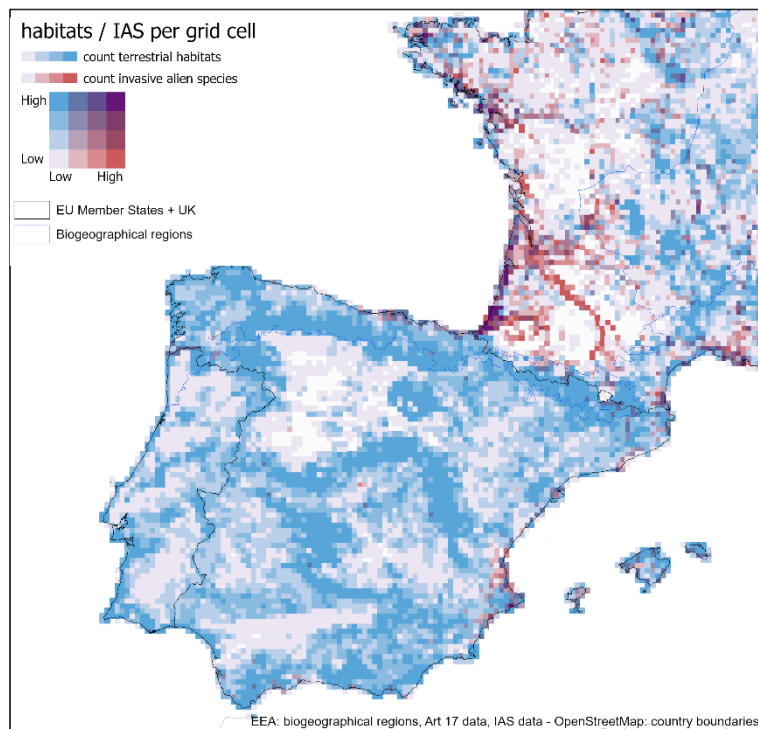


Figure 56 Bivariate count heatmap of invasive alien plant species and habitat types of the Habitat Directive by 10 x 10 km² reference grid for the Iberian peninsula

3.3.3 At the biogeographical level

The bivariate count heatmap allows a simple calculation of the different combinations of “numbers of IAS per grid cell” and “numbers of habitat types important for pollinators”. Table 3 provides this information across the EU (+UK). Highest percentages of grid cells (20,5%) are found for the “low-low” combination, with decreasing percentages with increasing numbers of habitat types and numbers of IAS. It is interesting to note that with decreasing habitat diversity, the numbers of IAS increase. The limited data however do not allow further interpretations about cause or effect of this pattern.

If we assume that a high number of IAS potentially increases the risk for pollinators and pollinating services, regardless if diversity of habitat types is low, medium or high, the data suggest that the risk across the EU (+UK) is relatively low for 87% of the territory and relatively high for 13% of the territory. The increasing numbers of IAS in Europe (e.g. Seebens et al. 2017, 2018), however, indicate no sign of relaxation of potential impacts in the future.

Table 3 Percentages of grid cells assigned to different combinations of “numbers of IAS per grid cell” and “numbers of habitat types important for pollinators” across the EU (+UK)

	IAS – low	IAS – medium low	IAS – medium high	IAS – high	Total
Habitat types – low	20,5	5,9	2,2	1,8	30,4
Habitat types – medium low	16,4	6,9	2,0	1,1	26,5
Habitat types – medium high	13,2	6,5	2,1	0,7	22,5
Habitat types – high	11,4	6,1	2,1	0,9	20,6
Total	61,5	25,5	8,5	4,5	100,0

An analysis of the bivariate count heatmap at the biogeographical level (grid cells sharing two biogeographical regions were counted twice) reveals some further insights (Tables 4–11). The combination “low number of habitat types” and “high number of IAS” was found in <1% of the grid cells in all biogeographical regions, except for the Atlantic biogeographic region, where it reaches almost 10% (Tab. 5). It can be speculated that such a low diversity of habitat types in combination with a high number of IAS places pollinating services in this region at a higher risk than elsewhere in the EU. Also, the total number of grid cells within the “high number of IAS” category is highest in the Atlantic biogeographical region (17%), followed by approx. 5% in the Boreal region and approx. 1% in the Alpine, Continental, and Pannonian regions. Most grid cells (between approx. 40 and 99%) have a “low number of IAS” in most biogeographic regions, except for the Pannonian region, where there are more grid cells in the “medium-low” category (57%) than in the “low” category (32%) (Tab. 10). A relatively high percentage was also found for the Continental region (43 and 46%, respectively) (Tab. 8).

Table 4 Percentages of grid cells assigned to different combinations of “numbers of IAS per grid cell” and “numbers of habitat types important for pollinators” for the Alpine biogeographical region

ALPINE	IAS – low	IAS – medium low	IAS – medium high	IAS – high	Total
Habitat types – low	15,4	2,2	0,8	0,1	18,5
Habitat types – medium low	14,6	3,1	1,4	0,3	19,4
Habitat types – medium high	18,1	3,2	1,5	0,3	23,1
Habitat types – high	25,2	10,8	2,6	0,3	38,9
Total	73,3	19,3	6,3	1,0	100,0

Table 5 Percentages of grid cells assigned to different combinations of “numbers of IAS per grid cell” and “numbers of habitat types important for pollinators” for the Atlantic biogeographical region

ATLANTIC	IAS – low	IAS – medium low	IAS – medium high	IAS – high	Total
Habitat types – low	16,8	9,9	8,4	9,5	44,7
Habitat types – medium low	9,7	7,6	4,5	4,2	26,0
Habitat types – medium high	6,2	4,9	2,2	1,9	15,1
Habitat types – high	7,0	4,2	1,5	1,5	14,2
Total	39,7	26,6	16,5	17,2	100,0

Table 6 Percentages of grid cells assigned to different combinations of “numbers of IAS per grid cell” and “numbers of habitat types important for pollinators” for the Black Sea biogeographical region

BLACK SEA	IAS – low	IAS – medium low	IAS – medium high	IAS – high	Total
Habitat types – low	52,7	0	0	0	52,7
Habitat types – medium low	27,3	0	0	0	27,3
Habitat types – medium high	13,3	0,6	0	0	13,9
Habitat types – high	6,1	0	0	0	6,1
Total	99,4	0,6	0	0	100,0

Table 7 Percentages of grid cells assigned to different combinations of “numbers of IAS per grid cell” and “numbers of habitat types important for pollinators” for the Boreal biogeographical region

BOREAL	IAS – low	IAS – medium low	IAS – medium high	IAS – high	Total
Habitat types – low	6,7	1,1	0,2	0,2	8,2
Habitat types – medium low	22,2	5,5	1,6	1,0	30,5
Habitat types – medium high	23,6	9,6	4,5	1,3	39,0
Habitat types – high	11,4	5,7	3,0	2,2	22,4
Total	63,9	22,0	9,3	4,8	100,0

Table 8 Percentages of grid cells assigned to different combinations of “numbers of IAS per grid cell” and “numbers of habitat types important for pollinators” for the Continental biogeographical region

CONTINENTAL	IAS – low	IAS – medium low	IAS – medium high	IAS – high	Total
Habitat types – low	22,2	10,6	2,0	0,1	35,0
Habitat types – medium low	11,0	11,8	2,4	0,3	25,4
Habitat types – medium high	6,5	10,2	2,1	0,3	19,1
Habitat types – high	6,5	10,1	3,3	0,5	20,5
Total	46,1	42,7	9,9	1,2	100,0

Table 9 Percentages of grid cells assigned to different combinations of “numbers of IAS per grid cell” and “numbers of habitat types important for pollinators” for the Mediterranean biogeographical region

MEDITERRANEAN	IAS – low	IAS – medium low	IAS – medium high	IAS – high	Total
Habitat types – low	32,3	0,6	0,1	<0,1	33,0
Habitat types – medium low	25,4	0,9	0,2	<0,1	26,4
Habitat types – medium high	18,6	0,8	0,1	<0,1	19,6
Habitat types – high	19,7	1,1	0,1	<0,1	21,0
Total	96,0	3,4	0,5	0,1	100,0

Table 10 Percentages of grid cells assigned to different combinations of “numbers of IAS per grid cell” and “numbers of habitat types important for pollinators” for the Pannonian biogeographical region

PANNONIAN	IAS – low	IAS – medium low	IAS – medium high	IAS – high	Total
Habitat types – low	18,9	17,6	0,8	0,2	37,6
Habitat types – medium low	7,5	22,1	2,7	0	32,3
Habitat types – medium high	3,6	10,8	3,4	0,3	18,2
Habitat types – high	1,7	6,9	2,9	0,3	11,9
Total	31,8	57,4	9,9	0,8	100,0

Table 11 Percentages of grid cells assigned to different combinations of “numbers of IAS per grid cell” and “numbers of habitat types important for pollinators” for the Steppic biogeographical region

STEPPIC	IAS – low	IAS – medium low	IAS – medium high	IAS – high	Total
Habitat types – low	90,5	0	0	0	90,5
Habitat types – medium low	6,1	0,2	0	0	6,3
Habitat types – medium high	1,6	0,2	0	0	1,8
Habitat types – high	1,3	0	0	0	1,3
Total	99,5	0,5	0	0	100,0

3.3.4 Limitations of the data

There are several limitations to the data set and the interpretations. As previously discussed by Rabitsch et al. (2020), the distributional data of invasive alien plant species provided by Member States under (EU) Regulation 1143/2014 in 2019 include some inconsistencies and gaps. Similarly, Kudrnovsky et al. (2020) found an imbalance of the reported “typical species” within habitat types (to assess the parameter “Specific structure and functions (including typical species)”, e.g. for habitat type 6210 (Semi-natural dry grasslands and scrubland facies on calcareous substrates), where Germany reported 344 typical species and Estonia reported only three typical species.

There are several thousands of alien plant species known to occur in the EU. Although it is known that only a fraction of these should be considered invasive, i.e. having negative impacts on native biodiversity and ecosystem services, it is evident that the presence of the 15 invasive plants selected for this analysis, cannot provide a complete picture of potential impacts of invasive plants on pollinators and pollination services.

Biological invasions are highly context-dependent and impacts depend greatly on spatial scale, time since introduction, the recipient environmental conditions, and other factors. Generalizations, therefore, are difficult to draw. We may assume a larger impact on pollinators via modification of natural vegetation with increasing numbers of invasive alien plant species, but cannot rule out a severe local impact of a single invasive alien plant species at the local level. If numbers of habitat types

in an area are low, e.g. due to intensified land-use or urbanization, we may also assume a possibly high risk to maintaining the pollinating service, even if just a few invasive alien plant species are present. This is particularly true if a specialized, rare or endemic, habitat- or host-specific pollinator is negatively affected. Therefore, any local effect cannot be predicted from such a large scale spatial analysis. Furthermore, we still know very little about the knock-on effects on pollinator networks and the possible relationships between different insect species in response to a changed host plant community.

3.4 Selected case studies

3.4.1 *Asclepias syriaca*

Common milkweed (*Asclepias syriaca*) is known as invasive plant species in Europe that especially invades extensively used areas, with a preference for sandy soils. Its competitiveness is based on fast growth, high leaf area and seed dispersal ability.

Kelemen et al. (2016) recorded the cover of vascular plants in seven sandy old-fields invaded by milkweed in the largest calcareous sandy region of central Hungary (Great Hungarian Plain, Kiskunság National Park) to explore the effects of milkweed on the species richness and cover of native grassland species. They investigated possible effects on leaf area, plant height, seed mass and clonal spreading ability of the flora which was a mix of milkweed and several native grassland species in an unmanaged area characterized by sparse vegetation (58% total cover on average). Although, there were no effects detected on the total species richness and species richness of native grassland species, cover of native grassland species decreased with increasing milkweed cover. These negative effects on the cover of grassland species especially had an impact on native grassland species with low competitive ability. Without respective management of milkweed these species might disappear in sandy grassland habitats.

According to Bagi (2008), milkweed can detract bees from pollinating sunflower, causing crop loss. Szigeti et al. (2020) compared plant and diurnal pollinator communities between invaded and control sites and found a neutral effect of milkweed on abundance, diversity and community composition between sites. Honey bees and bumble bees showed a preference for milkweed above native plants.

Grasslands are very important to pollinating insects as they are characterized by a high number of flowering species providing pollen and nectar as food source for insects (shown for Annex I grassland habitat types by Kudrnovsky et al. 2020). Although increasing cover of milkweed also promotes availability of food sources, resulting decrease of native grassland species with low competitive ability may have negative effects on pollinating insects being specialist species subjected to the pushed back plant species. Furthermore, invasion of the sandy old fields with milkweed might be the starting point of additional invasion into the surrounding grassland habitats fostering these effects.

3.4.2 *Heracleum mantegazzianum*

Invasion by *Heracleum mantegazzianum* was investigated in different habitats in the Czech Republic in order to test the hypothesis that this invasive alien plant species spreads into the majority of vegetation types regardless of the properties of the recipient vegetation (Pyšek & Pyšek 1995). The study was conducted in western Bohemia in different areas including mesophilous meadows, moist and dry grasslands. Community vulnerability was analysed based on the invader's ability to enter native communities and its ability to spread in a given vegetation type. The results indicated that plant communities invaded by *Heracleum* had a lower species diversity. This is caused by the ability of *Heracleum mantegazzianum* to shade the surrounding vegetation with its huge ground leaves. Native

plants are not able to compete after being shaded which leads to their replacement. On the other hand, communities with a large proportion of woody plants were less susceptible to invasion. Furthermore, species with a high tolerance of shade and low nutrient level and/or acidity resisted the invasion. As *Heracleum mantegazzianum* successfully invades a wide-range of central-European habitats including semi-natural habitats, where species have similar ecological requirements, replacement effects may lead to changed plant communities and a shift in plant-dependent pollinators. Human or climate driven ecologic disturbances may facilitate invasion and impair well established plant-pollinator dependences.

Zumkier (2012) compared the pollinator community (visitation) and plant fitness (seeds set of co-flowering plants) of *H. mantegazzianum* and the native *H. sphondylium* in an experimental garden setup and found low competition between the two species, a neutral effect on seed set, and a high attractiveness of the large *H. mantegazzianum* inflorescences for honeybees. Davis et al. (2018) found no differences in floral resources, but a lower abundance of solitary bees and hoverflies in invaded areas compared to uninvaded areas for *H. mantegazzianum*.

3.4.3 *Impatiens glandulifera*

Indian (or Himalayan) Balsam (*Impatiens glandulifera*) is native in the foothills of the Himalayas. It was introduced to Europe in 1839 for ornamental purposes and subsequently used as pasture for bees ('honey plant'), established in the wild around 1900 and is currently present in almost all Member States and biogeographic regions, where it is particularly abundant in the Atlantic and Continental regions (Fig. 37). It colonizes natural and semi-natural habitats along edges of rivers and lakes, floodplain forests and wet meadows, including several Habitat Directive Annex I habitats, e.g. hydrophilous tall herb fringe communities (6430), alpine rivers and the ligneous vegetation along their banks (3240), alluvial forests (91E0, 91F0), and grasslands (6430, 6510) (see Rabitsch et al. 2020).

It forms dense stands that cover the soil, shade out and replace native annual and perennial plant species because of early germination and rapid growth. *Impatiens glandulifera* is nectar-rich and flowers attract more pollinators, especially bumblebees, than native plants, having a negative effect on the fitness of the native plant species through competition for pollinators, luring pollinators away from native species (Prowse & Goodridge 2000, Chittka & Schürkens 2001).

Lopezaraiza-Mikel et al. (2007) demonstrated the effects of *I. glandulifera* on the community of co-flowering native plants in a field experiment. Invaded plots had significantly higher generalized native pollinator species richness and abundance, but this did not translate into facilitation for pollination of native plants. Nielsen et al. (2008) found in a manipulative field experiment that *I. glandulifera*-invaded sites had significantly higher visitor species richness, visitor abundance and flower visitation than uninvaded sites. However, this did not translate in facilitation for pollination, as more generalized insects were more likely to visit the alien plant. Nienhuis et al. (2009) found highest proportion of visitors for *Bombus* spp. in *Impatiens*-invaded sites and for solitary bees in sites where *Impatiens* has been removed. While no negative impact on general pollinator abundance or functional insect diversity was found, it was suggested that possible impacts on rare or specialised pollinators need to be examined further.

Bartomeus et al. (2010) found no evidence that *I. glandulifera* outcompetes native plants for pollinators, and that pollinator abundances depend on landscape structure, but are modulated by this mass- and late-seasonal floral resource. They found *Impatiens* receiving higher visitation rates than simultaneously flowering native plants, mainly of bumblebees, but no differences of visitation rates for the plant community, except for the honeybee which increased their visits in invaded sites. Cawoy et al. (2012) studied pollinator mediated effects of proximity and abundance of *I. glandulifera*

on visitation rate, insect behaviour, pollen deposition and reproductive success of two native plant species (*Epilobium angustifolium*, *Aconitum napellus* ssp. *lusitanicum*). Proximity and abundance increased bumblebee visitation rates while abundance had a negative effect on honeybee visits to both native plant species. Bumblebees preferred *Impatiens* and deposited considerable quantities of alien pollen on the native plants, without significantly decreasing seed set. Also, Emer et al. (2015) found that the relationship between flower visitation and pollen load or deposition is not straightforward for *Impatiens glandulifera* and pollen transfer networks are more complex.

4 Conclusions

- Invasive alien plant species are distributed across the European Union. Their presence in habitats of importance for pollinators might cause negative impacts on native plants and native pollinators. Such impacts, however, are complex, their directionality not always straightforward and in any case highly context- and time- and scale-dependent.
- The analysis of distributional information based from Member State reporting obligations (EU- IAS-Regulation 1143/2014 and Article 17-Reporting Habitat Directive) provides some preliminary insights into spatial patterns and potential risks to pollinators from invasive alien plant species, but currently does not allow a deeper understanding of the actual risk at different spatial scales, the EU, biogeographical regions or Member States. This would require better distributional data and a more in-depth analysis of potential impacts and their interactions at a smaller spatial scale.
- While the combination “low number of habitat types” and “high number of IAS” was found in <1% of the 10 x10 km² grid cells in all biogeographical regions, it is up to 10% in the Atlantic biogeographic region. Such a low diversity of habitat types in combination with a high number of IAS places pollinating services in this region at a higher risk than elsewhere in the EU. Local effects, for example on rare or endemic habitat- or host-specific pollinators cannot be predicted from such a large scale spatial analysis.
- For future analysis, the distributional information on invasive alien plant species as well as the presence of habitat types and “typical species” within habitat types should be improved and harmonized across Member States to avoid seemingly artificial patterns at national (political) borders.
- In general, we still know very little about the effects of invasive alien plant species on pollinating networks and the possible consequences for pollination services.

5 References

- Albrecht M., Padrón B., Bartomeus I. & Traveset A. (2014): Consequences of plant invasions on compartmentalization and species' roles in plant–pollinator networks. *Proc R Soc B* 281: 20140773.
- Albrecht M., Ramis M.R. & Traveset A. (2016): Pollinator-mediated impacts of alien invasive plants on the pollination of native plants: the role of spatial scale and distinct behaviour among pollinator guilds. *Biol Invasions* 18: 1801-1812.
- Bagi I. (2008): Common milkweed (*Asclepias syriaca* L.). In: Z. Botta-Dukát and L. Balogh (eds) The most important invasive plants in Hungary, pp. 151-159. Institute of Ecology and Botany, Hungarian Academy of Sciences, Vácrátót, Hungary.
- Bartomeus I., Vila M. & Steffan-Dewenter I. (2010): Combined effects of *Impatiens glandulifera* invasion and landscape structure on native plant pollination. *J Ecol* 98: 440-450.
- Bartomeus I., Vila M. & Santamaría L. (2008): Contrasting effects of invasive plants in plant-pollinator networks. *Oecologia* 155: 761-770.
- Becker T., Dietz H., Billeter R., Buschmann H. & Edwards P.J. (2005): Altitudinal distribution of alien plant species in the Swiss Alps. *Perspectives in Plant Ecology, Evolution and Systematics* 7(3): 173-183.
- Bellard C., Thuiller W., Leroy B., Genovesi P., Bakkenes M. & Courchamp F. (2013): Will climate change promote future invasions? *Glob Change Biol* 19(12): 3740-3748.
- BfN (2021): *Hydrocotyle ranunculoides*.
<https://neobiota.bfn.de/handbuch/gefaesspflanzen/hydrocotyle-ranunculoides.html>
- Blackburn T.M., Essl F., Evans T., Hulme P.E., Jeschke J.M., Kühn I., Kumschick S., Marková Z., Mrugala A., Pergl J., Pyšek P., Rabitsch W., Ricciardi A., Richardson D.M., Sendek A., Vilà M., Wilson J.R.U., Winter M., Genovesi P. & Bacher S. (2014): A Unified Classification of Alien Species Based on the Magnitude of their Environmental Impacts. *PLOS Biology* 12(5), e1001850.
- Bradley B.A., Beaury E.M., Fusco E.J., Laginhas B.B., Morelli T.L. & Pasquarella V.J. (2018): Regional invasive species and climate change management challenge: preparing for sleeper species. *Environ Conserv Educ Mater*. <https://doi.org/10.7275/R5F18WXT>
- Brown B.J., Mitchell R.J. & Graham S.A. (2002): Competition for pollination between an invasive species (purple loosestrife) and a native congener. *Ecology* 83: 2328-2336.
- CABI (2021a): *Alternanthera philoxeroides* (alligator weed). Datasheet. Invasive Species Compendium. <https://www.cabi.org/isc/datasheet/4403> [accessed 2021/05/05]
- CABI (2021b): *Asclepias syriaca* (common milkweed). Datasheet. Invasive Species Compendium. <https://www.cabi.org/isc/datasheet/7249> [accessed 2021/05/05]
- CABI (2021c): *Baccharis halimifolia* (groundsel-bush). Datasheet. Invasive Species Compendium. <https://www.cabi.org/isc/datasheet/8164> [accessed 2021/05/05]

- CABI (2021d): *Gunnera tinctoria* (giant rhubarb). Datasheet. Invasive Species Compendium. <https://www.cabi.org/isc/datasheet/107826> [accessed 2021/05/05]
- CABI (2021e): *Heracleum mantegazzianum* (giant hogweed). Datasheet. Invasive Species Compendium. <https://www.cabi.org/isc/datasheet/26911> [accessed 2021/05/05]
- CABI (2021f): *Heracleum persicum* (Persian hogweed). Datasheet. Invasive Species Compendium. <https://www.cabi.org/isc/datasheet/120209> [accessed 2021/05/05]
- CABI (2021g): *Heracleum sosnowskyi* (Sosnowskyi's hogweed). Datasheet. Invasive Species Compendium. <https://www.cabi.org/isc/datasheet/108958> [accessed 2021/05/05]
- CABI (2021h): *Hydrocotyle ranunculoides* (floating pennywort). Datasheet. Invasive Species Compendium. <https://www.cabi.org/isc/datasheet/28068> [accessed 2021/05/05]
- CABI (2021i): *Impatiens glandulifera* (Himalayan balsam). Datasheet. Invasive Species Compendium. <https://www.cabi.org/isc/datasheet/28766> [accessed 2021/05/05]
- CABI (2021j): *Ludwigia grandiflora* (water primrose). Datasheet. Invasive Species Compendium. <https://www.cabi.org/isc/datasheet/109148> [accessed 2021/05/05]
- CABI (2021k): *Ludwigia peploides* (water primrose). Datasheet. Invasive Species Compendium. <https://www.cabi.org/isc/datasheet/31673> [accessed 2021/05/05]
- CABI (2021l): *Lysichiton americanus* (American skunk cabbage). Datasheet. Invasive Species Compendium. <https://www.cabi.org/isc/datasheet/31580> [accessed 2021/05/05]
- CABI (2021m): *Myriophyllum aquaticum* (parrot's feather). Datasheet. Invasive Species Compendium. <https://www.cabi.org/isc/datasheet/34939> [accessed 2021/05/05]
- CABI (2021n): *Pennisetum setaceum* (fountain grass). Datasheet. Invasive Species Compendium. <https://www.cabi.org/isc/datasheet/116202> [accessed 2021/05/05]
- CABI (2021o): *Pueraria montana* var. *lobata* (kudzu). Datasheet. Invasive Species Compendium. <https://www.cabi.org/isc/datasheet/45903> [accessed 2021/05/05]
- Carvell C. (2002): Habitat use and conservation of bumblebees (*Bombus* spp.) under different grassland management regimes. *Biological Conservation* 103: 33-49.
- Cawoy V., Jonard M., Mayer C. & Jacquemart A. (2012): Do abundance and proximity of the alien *Impatiens glandulifera* affect pollination and reproductive success of two sympatric co-flowering native species? *J. Poll. Ecol.* 10: 130-139.
- Chittka L. & Schürkens S. (2001): Successful invasion of a floral market. *Nature* 411: 653-655.
- Dainese M., Kühn I. & Bragazza L. (2014): Alien plant species distribution in the European Alps: influence of species' climatic requirements. *Biol Invasions* 16: 815-831.
- Davis E.S., Kelly R., Maggs C.A. & Stout J.C. (2018): Contrasting impacts of highly invasive plant species on flower-visiting insect communities. *Biodiversity and Conservation* 27: 2069-2085.
- Drossart M., Michez D. & Vanderplanck M. (2017): Invasive plants as potential food resource for native pollinators: a case study with two invasive species and a generalist bumble bee. *Sci Rep* 7: 1-12.

- Ebeling A., Klein A.-M., Schumacher J., Weisser W.W. & Tschardt T. (2008): How does plant richness affect pollinator richness and temporal stability of flower visits, *Oikos* 117: 1808-1815.
- EEA (2021): EEA reference grid.
<https://www.eea.europa.eu/data-and-maps/data/eea-reference-grids-2> [accessed 2021/05/03]
- Emer C., Vaughan I.P., Hiscock S. & Memmott J. (2015): The impact of the invasive alien plant, *Impatiens glandulifera*, on pollen transfer networks. *PLoS ONE* 10(12): e0143532.
- EPPO (2021): Mini data sheet on *Gunnera tinctoria*.
https://gd.eppo.int/download/doc/1126_minids_GUATI.pdf
- EU (2021): Article 17 web tool. <https://nature-art17.eionet.europa.eu/article17/> [accessed 2021/05/03]
- Fenesi A., Vágási C.I., Beldean M. et al (2015): *Solidago canadensis* impacts on native plant and pollinator communities in different-aged old fields. *Basic Appl Ecol* 16: 335-346.
- Fenster C.B., Armbruster W.S., Wilson P., Dudash M.R. & Thomson J.D. (2004): Pollination syndromes and floral specialization, *Annual Review of Ecology Evolution and Systematics* 35: 375-403.
- Goodell K. & Parker I.M. (2017): Invasion of a dominant floral resource: Effects on the floral community and pollination of native plants. *Ecology* 98: 57-69.
- Hatfield R. & LeBuhn G. (2007): Patch and landscape factors shape community assemblage of bumble bees, *Bombus* spp. (Hymenoptera: Apidae), in montane meadows. *Biological Conservation* 139: 150-158.
- Hellmann J.J., Byers J.E., Bierwagen B.G. & Dukes J.S. (2008): Five potential consequences of climate change for invasive species. *Conservation Biology* 22(3): 534-543.
- Kelemen A., Valkó O., Kröel-Dulay Gy., Deák B., Török P., Tóth K., Migléc, T. & Tóthmérész B. (2016): The invasion of common milkweed (*Asclepias syriaca* L.) in sandy old-fields – Is it a threat to the native flora? *Applied Vegetation Science* 19: 218-224.
- Knight M.E., Osborne J.L., Sanderson R.A., Hale R.J., Martin A.P. & Goulson D. (2009): Bumblebee nest density and the scale of available forage in arable landscapes. *Insect Conservation and Diversity* 2: 116-124.
- Kudrnovsky H., Ellmauer T., Götzl M., Paternoster D., Sonderegger G. & Schwaiger E. (2020): Report for a list of Annex I habitat types important for Pollinators. ETC/BD report to the EEA.
- LANUV NRW (2021): Brasilianisches Tausendblatt (*Myriophyllum aquaticum*).
<https://neobiota.naturschutzinformationen-nrw.de/site/nav3/ArtInfo.aspx?ART=Pflanzen&ID=302a5cfd-789b-469b-974b-5df81ee2e578>
 [accessed 2021/05/03]
- Lopezaraiza-Mikel M.E., Hayes R.B., Whalley M.R. & Memmott J. (2007): The impact of an alien plant on a native plant–pollinator network: an experimental approach. *Ecology Letters* 10: 539-550.
- Morales C.L. & Traveset A. (2009): A meta-analysis of impacts of alien vs. native plants on pollinator visitation and reproductive success of co-flowering native plants. *Ecology Letters* 12: 716-728.

- Morales C.L., Sáez A., Garibaldi, L.A. & Aizen, M.A. (2017): Disruption of pollination services by invasive pollinator species. In: Vilá, M. & Hulme, P.E. (eds) Impact of biological invasions on ecosystem services. Springer, Berlin, 203-220.
- Moron D., Lenda M. & Skórka P. et al. (2009): Wild pollinator communities are negatively affected by invasion of alien goldenrods in grassland landscapes. *Biological Conservation* 142: 1322-1332.
- Nehring S. & Hussner A. (2013): Naturschutzfachliche Invasivitätsbewertung *Lagarosiphon major* – Wechselblatt-Wasserpest; erstellt 30.06.2013. – Bundesamt für Naturschutz, Bonn: 2 S.
- Nielsen C., Heimes C. & Kollmann J. (2008): Little evidence for negative effects of an invasive alien plant on pollinator services. *Biological Invasions* 10: 1353-1363.
- Nienhuis C., Dietzsch A.C. & Stout J.C. (2009): The impacts of an invasive alien plant and its removal on native bees. *Apidologie* 40: 450-463.
- Prowse A. & Goodridge F. (2000): Pollinator visitation rates of *Impatiens glandulifera* and other native riparian vegetation. *Aspect. Appl. Biol.* 58: 249-254.
- Pyšek P. & Pyšek A. (1995): Invasion of *Heracleum mantegazzianum* in different habitats in the Czech Republic. *Journal of Vegetation Science* 6: 711-718.
- Pyšek P., Blackburn T.M., García-Berthou E., Perglová I. & Rabitsch W. (2017): Displacement and local extinction of native and endemic species. In: Vila, M. & Hulme, P.E. (eds) Impact of biological invasions on ecosystem services. Springer, Berlin, 157-175.
- Rabitsch W., Aronsson M., Strand M. & Roscher S. (2020): Impacts caused by Invasive Alien Species of Union concern on habitats and species of the Nature Directives and on Natura2000 sites. ETC/BD-Report, 82 pp.
- Seebens H., Blackburn T.M., Dyer E.E., Genovesi P., Hulme P.E., et al. (2017): No saturation in the accumulation of alien species worldwide. *Nature Communications* 8: 14435, 1-9.
- Seebens H., Blackburn T.M., Dyer E.E., Genovesi P., Hulme P.E., et al. (2018): Global rise in emerging alien species results from increased accessibility of new source pools. *Proc. Natl. Acad. Sci.* 115: E2264-2273.
- Stout J.C. & Tiedeken E.J. (2017): Direct interactions between invasive plants and native pollinators: evidence, impacts and approaches. *Functional Ecology* 31: 38-46.
- Szigeti V., Fenesi A., Soltesz Z., Berki B. & Kovacs-Hostyanszki A. (2020): Neutral effect of an invasive plant species with specialized flower structure on native pollinator communities. *Biological Invasions* 22: 3017-3030.
- Traveset A. & Richardson D.M. (2014): Mutualistic interactions and biological invasions. *Annu Rev Ecol Evol Syst* 45: 89-113.
- Vanbergen A.J., Espíndola A. & Aizen M.A. (2018): Risks to pollinators and pollination from invasive alien species. *Nat Ecol Evol* 2: 16-25.
- Vila, M. & Hulme, P.E. (2017): Impact of biological invasions on ecosystem services. Springer, Berlin.

Walther G.-R., Roques A., Hulme P.E., Sykes M.T., Pyšek P., Kühn I., Zobel M. et al. (2009): Alien species in a warmer world: risks and opportunities. *Trends in Ecology and Evolution* 24: 686-693.

Zumkier, U. (2012): Impacts of the invasive alien *Heracleum mantegazzianum* on native plant-pollinator interactions. Thesis Univ. Bielefeld, 116 pp.