Mapping Invasion by Alien Plants in Europe

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Invasions by alien plants differ among habitats, as some are more vulnerable to invasion than others (Chytrý et al. 2005, 2008b). Recent research shows that the role of habitat is crucial in determining how many alien species successfully invade; it is even more important than the role of other factors such as propagule pressure (i.e., how many alien species are in the surroundings of the target site) and climate (in temperate and boreal zone, areas with warmer climate are more prone to invasions) (Chytrý et al. 2008a). From this it follows that how much a region is invaded by alien plants depends to a considerable extent on its habitat composition; areas with large proportion of vulnerable habitats harbour more alien species, which are usually also more abundant, than areas consisting of resistant habitats.

Within the ALARM project, the role of habitats was paid special attention, for both scientific and practical reasons. Knowing which habitats are most endangered by alien plants is not only interesting from the scientific point of view but also of practical relevance, because it enables local authorities and landscape managers to spend resources efficiently by targeting habitats that impose the highest risk of further spread of invasive species.

A comparative study of invasions in habitats was carried out in three regions representing distinct European climates along the north-south and west-east climatic gradients: United Kingdom as a representative of the oceanic climate, Czech Republic of the subcontinental climate and Catalonia of the Mediterranean climate. We used data from a large number of vegetation plots, collected by vegetation scientists for the purpose of vegetation classification and monitoring; for the three above regions, there were 16,362, 20,468 and 15,650 vegetation plots, respectively, which made a very robust basis for the analyses. The plots were classified to habitats by using the standard EUNIS habitats classification system, which allowed to compare the three regions in terms of the level of invasion of each habitat present. The *level of invasion* is a measure of how much a habitat, or a plant community growing in it, is invaded by alien plants; in our study it was expressed as the average proportion of alien species from the total number of plant species recorded in plots assigned to a given habitat type (Chytrý et al. 2008a).

We focus here on the proportion of *neophytes*, which are plant species introduced to the three regions studied in the last five hundred years since the discovery of America. This is because this group of alien plants is more relevant in terms of practical importance than *archaeophytes*, the second group of aliens distinguished in Europe on the basis of the time of arrival, which was between the beginning of Neolithic agriculture and ca 1,500 AD (Pyšek et al. 2005). Neophytes are the group from which most noxious plant invaders recruit.

The level of invasion is different from *invasibility*, which reflects the inherent vulnerability of a habitat (or a plant community, ecosystem, region) to invasion. A habitat can be resistant to invasion but if it is located in a site exposed to a high propagule pressure (meaning that there is a constant and intensive influx of propagules of alien species), its resistance may be overcome and the habitat may harbour more alien species than another, less resistant habitat located in area with a low propagule pressure (Chytrý et al. 2008a).

The comparison of the three European regions has shown that the pattern of plant invasions is consistent across the continent, meaning that the same habitats that are highly invaded in

Figure 1. Examples of European habitats prone to invasion: (a) ruderal vegetation (Slovenia), (b) riverine scrub (Sicily, Italy) and resistant to invasion: (c) alpine vegetation (Belianske Tatry Mts, Slovakia), (d) Mediterranean heathland (Korsica, France). Photos: Milan Chytrý.

the subcontinental climate of Central Europe, have high proportions of alien species also in the zones of oceanic and Mediterranean climate (Figure **1**). The habitats with the lowest proportions of neophytes are on soils with constantly low nutrient availability, such as mires (bogs, poor fens, base-rich fens), some grasslands (alpine grasslands, woodland fringes), heathlands and scrub (subalpine scrub, temperate heaths) and evergreen Mediterranean vegetation (maquis, garrigue, Mediterranean heaths, evergreeen woodland). The habitats with the greatest proportion of neophytes in all regions are anthropogenic habitats (arable land, ruderal vegetation, trampled areas), coastal, littoral and riverine habitats (coastal sediments, sedge-reed beds, wet scrub) (Chytrý et al. 2008b) (Figure **2**).

The among-regional consistency of the pattern of habitat invasions, as well as results from various local studies of habitat invasions from different areas of Europe, suggest that the data from the three regions studied are probably also valid for those regions from which the data on habitat invasions are not available. It is highly probable that habitats with low nutrients are little invaded, while frequently disturbed habitats with fluctuating resource availability are highly invaded in the whole Europe. This assumption allows to extrapolate the results from the three model regions to other parts of Europe with similar climates and upscale the available data to the continental level.

Such extrapolation was done in another study conducted within the ALARM project (Chytrý et al. 2009), in which the European map of alien plant invasions was produced. Using habitats as mapping units is suitable because it allows the extrapolation of quantitative estimates of the level of invasion to other regions with similar climate. Since there is no spatially-explicit information on the distribution of the EUNIS habitat types across Europe, these types had to be transferred to the CORINE land-cover classes to allow mapping. Since most of the CORINE classes correspond to more than one EUNIS habitat, proportional contribution of the relevant EUNIS habitats was estimated for each CORINE land-cover class and its level of invasion was calculated as an average value of the corresponding EUNIS habitats, weighted by their proportional contributions. Extrapolations were constrained by European biogeographical regions in order to account for biogeographical and climatic effects on the patterns of plant invasion among different parts of Europe (Chytrý et al. 2009).

The resulting European map of the level of invasion by neophytes (Figure **3**) projects the highest levels of invasion in moderately dry and warm lowland areas of western Europe (e.g., southeastern England or northwestern France) and in agricultural regions of central and eastern Europe (e.g., northern Germany, Poland, Czech Republic, Hungary and the lower Danube valley). In contrast, low levels of invasion are projected for the Boreal biogeographical region, Scotland, montane zones throughout the continent, and the Mediterranean region (including the sub-Mediterranean zone) where higher levels of invasion are projected only along the coastline, in areas with irrigated agricultural land and along rivers (Chytrý et al. 2009). The map (Figure **3**) reflects the current state of plant invasions in Europe, but also provides a solid background for the assessment of future risk and for modelling future changes under various scenarios of climate and land-use change (Pyšek et al. 2010).

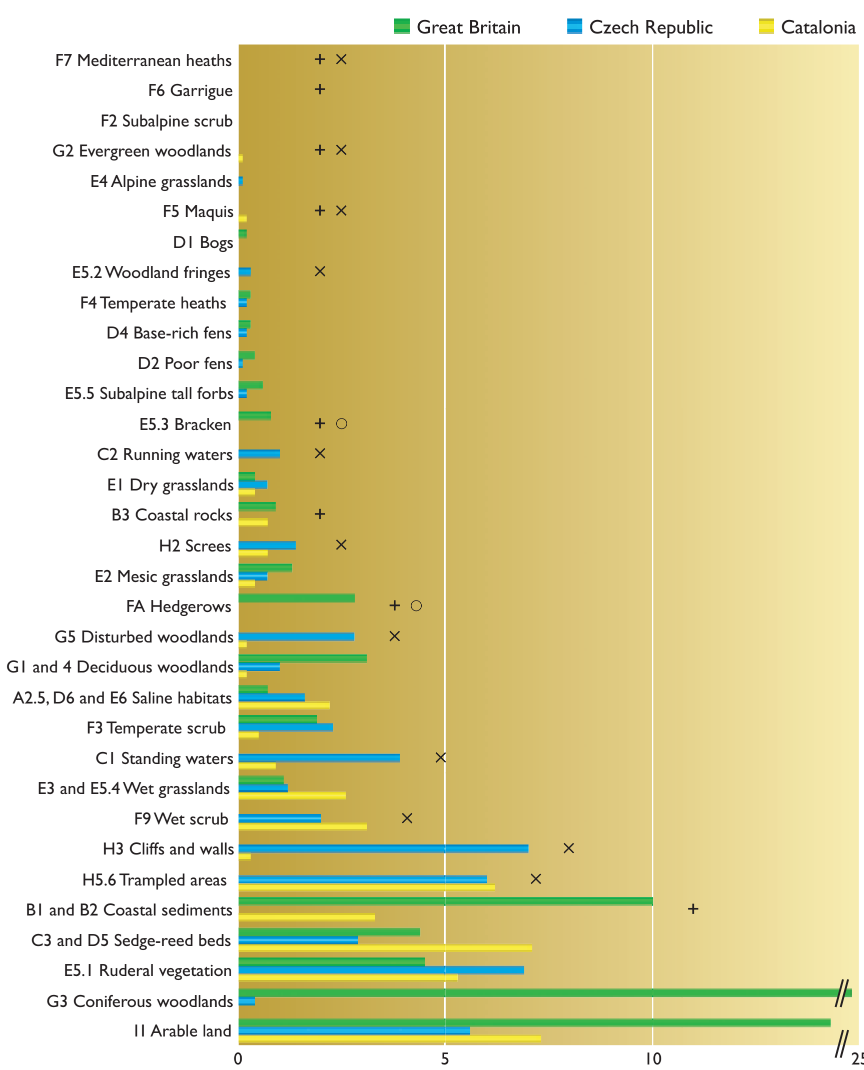

Figure 2. Level of invasion (mean percentage of neophytes among the total number of species recorded in vegetation plots) in EUNIS habitats in the three European regions considered. Habitats are ordered by increasing sum of mean values from the three regions. Based on data from Chytrý et al. (2008 b), see this source for complete values. Mean values are similar among regions for most habitats, except G3 (Coniferous woodlands; high values in Britain) and H3 (Cliffs and walls; high values in the Czech Republic). Habitats not present or from which data are not available are indicated: × Great Britain, + Czech Republic, ○ Catalonia.

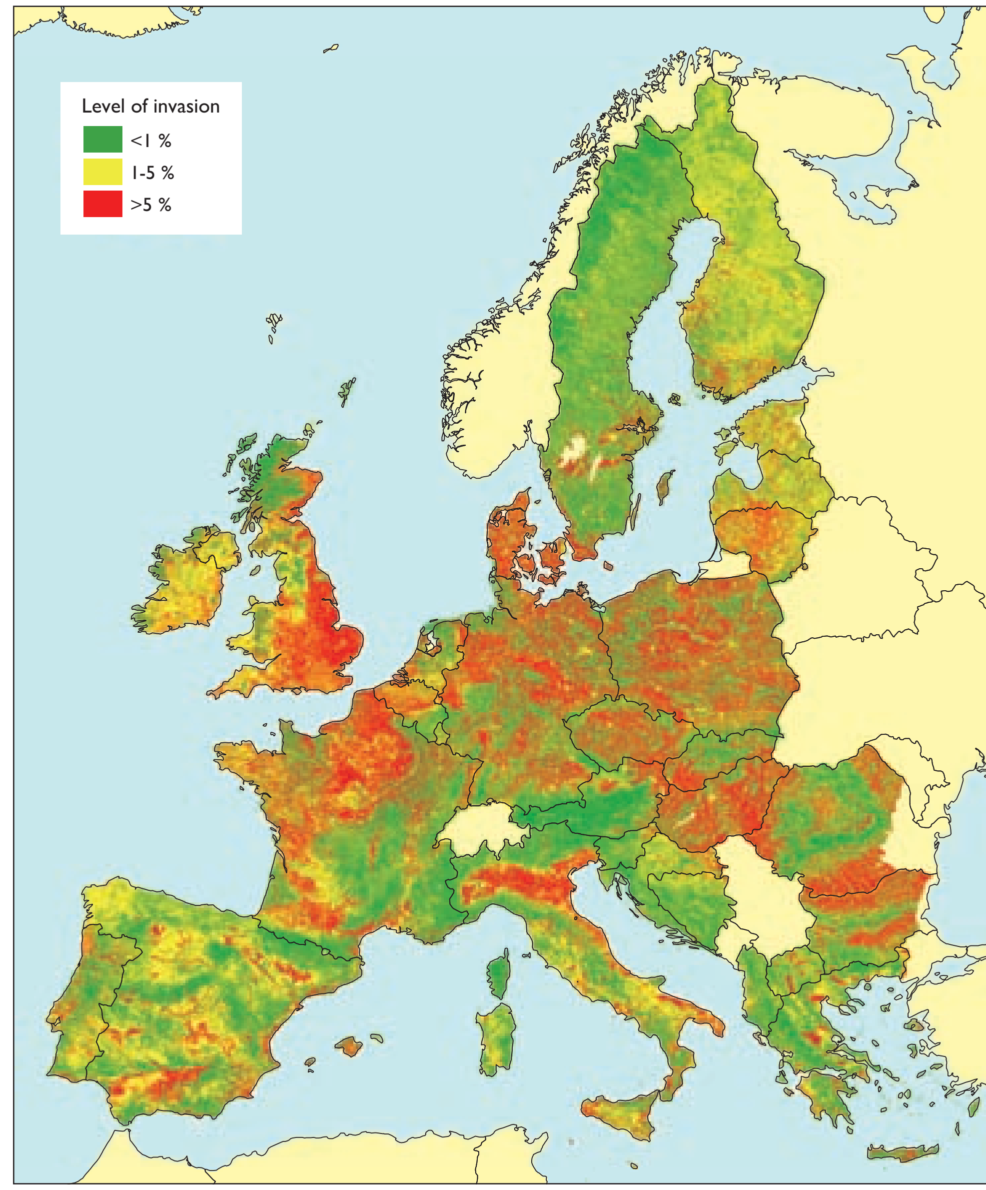

Figure 3. European map estimating the level of invasion by alien plants, based on the mean percentage of neophytes in vegetation plots corresponding to individual CORINE land-cover classes. Within the mapping limits, areas with non-available land-cover data or insufficient vegetation-plot data are blank. Taken from Chytrý et al. (2009), published with courtesy of Blackwell Scientific Publications.

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