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BiolFlor — a new plant-trait database as a tool for plant invasion ecology

Many studies focus on traits of invasive species as a step towards a better prediction of invasions (e.g. Noble, 1989; Mack, 1992; Pyšek *et al.*, 1995; Tucker & Richardson, 1995; Crawley *et al.*, 1996; Rejmánek & Richardson, 1996; Williamson & Fitter, 1996; Reichard & Hamilton, 1997; Daehler, 1998; Pyšek, 1998; Goodwin *et al.*, 1999; Grotkopp *et al.*, 2002; Prinzing *et al.*, 2002).

Despite some progress, a predictive framework for predicting invasiveness remains illusive, except for the fact that being invasive elsewhere, having a broad native range, and exhibiting rapid dispersal suggest a high risk of invasiveness (e.g. Williamson, 1996; Alpert *et al.*, 2000; Heger & Trepl, 2003). Indeed, whether a robust predictive framework is possible for plant invasion ecology is controversial (Lodge, 1993; Smith *et al.*, 1999; Williamson, 1999; but see Rejmánek *et al.*, 2004). One promising approach is to compare successful and unsuccessful invaders from a source area from which species were introduced into a target region (Prinzing *et al.*, 2002; Pyšek *et al.*, 2004b). This means that the source species pool from which invading species originate is the object of analysis rather than the flora of the target area. For all these kinds of analyses, the definition of the correct species pool is crucial (Cassey *et al.*, 2004; Pyšek *et al.*, 2004b).

The source pool of species may often be unknown. Even if the species pool is known, the traits of many species are often unknown. However, many invasive species across temperate regions of the world are of Central European origin (e.g. Crosby, 1986; di Castri, 1989; Roy *et al.*, 1998; Kalin Arroyo *et al.*, 2000; Richardson *et al.*, 2000a; Prinzing *et al.*, 2002; Pauchard & Alaback, 2004; Villasenor & Espinosa-Garcia, 2004). The flora of Central Europe is thus a very important source species pool for the analysis of traits of invasive species (Pyšek *et al.*, 2004b). A new database that is available for such analyses was released recently as a book and CD-ROM: 'BiolFlor' — a database on biological and ecological traits of the vascular flora of Germany (Klotz *et al.*, 2002). A beta version of BiolFlor (in English and German) is now available on the Internet (see below). The flora of Germany covers the majority of Central European plant species, and BiolFlor is the most comprehensive database of Central European plant species traits. We therefore consider BiolFlor to be a valuable tool for identifying traits related to invasiveness by defining the appropriate species pool.

BIOLFLOR

Content of BiolFlor

BiolFlor has more than 450,000 records and covers 3659 species. The species are classified into natives and aliens; aliens are divided according to their residence status into archaeophytes (introduced to Germany before 1500) and neophytes (introduced to Germany after 1500) and according to their degree of naturalization into casuals (which do not form self-replacing populations) and naturalized plants (which sustain self-replacing populations) (Richardson *et al.*, 2000b; Pyšek *et al.*, 2004a). The German flora comprises of 2743 natives, 40 uncertain archaeophytes (i.e. they also might be native), 218 archaeophytes and 470 naturalized neophytes (according to BiolFlor). Furthermore, information on 185 casual neophytes is provided.

We included all species in BiolFlor that are native to Germany or that are naturalized according to Wisskirchen & Haeupler (1998) or Schubert & Vent (1990). Additionally, BiolFlor contains frequent casual species. These are species which are repeatedly introduced and grow in several locations in Germany outside of cultivation. BiolFlor thus excludes most of the > 12,000 species known to have been introduced to Germany (Sukopp, 1976) but that rarely occur in the wild. An extensive synonymy is provided (using Wisskirchen & Haeupler, 1998).

The 66 different traits included in BiolFlor are outlined in Appendix S1. Most of the traits were compiled from the literature. However, traits like morphological parameters, leaf characteristics, and seed traits were mostly measured by our collaborators.

Each of these traits may have several states, i.e. the actual specification of the trait 'pollen vector' might be 'insects', 'wind', etc. For most of the species attributes (species with their characteristic trait state) we also provide qualifiers that may provide further information, e.g. whether a state of a trait is rare or common, or whether the information on a species range refers to its natural or anthropogenic range, etc. For more recently sourced data, we also provide the source of information of a specific record.

One important trait in BiolFlor is the 'phylogeny'. We compiled a phylogenetic supertree for all species included from more than 200 sources. The phylogeny is compatible with CAIC (Purvis & Rambaut, 1995), facilitating statistical analyses of phylogenetic independent contrasts (e.g. Felsenstein, 1985; Burt, 1989; Harvey & Pagel, 1991).

Although the publication by Klotz *et al.* (2002) is in German, all chapters have an English summary, table and figures have English captions, and all traits are listed in English.

Options of BiolFlor

Users can get an overview of the database, i.e. they are able to browse through families, genera and species and explore all data on traits that are available for a particular species. Furthermore it is possible to get an overview of all groups of traits and singular traits including their states, data types and definitions. Database entries displayed are usually cross referenced to the traits definition for easier use.

Search options include the ability to search for a species by name or (combinations of) traits. All species that match the search criteria can be transferred to a 'species cart'. The resulting search (species and traits) can be exported in a format which can be easily imported into most statistical packages or spreadsheet programs. Moreover, search criteria themselves can also be saved. Searches can also be restricted to a predefined species list (e.g. local species pool) which can be imported into the species cart. The species cart itself can be modified, saved and reloaded.

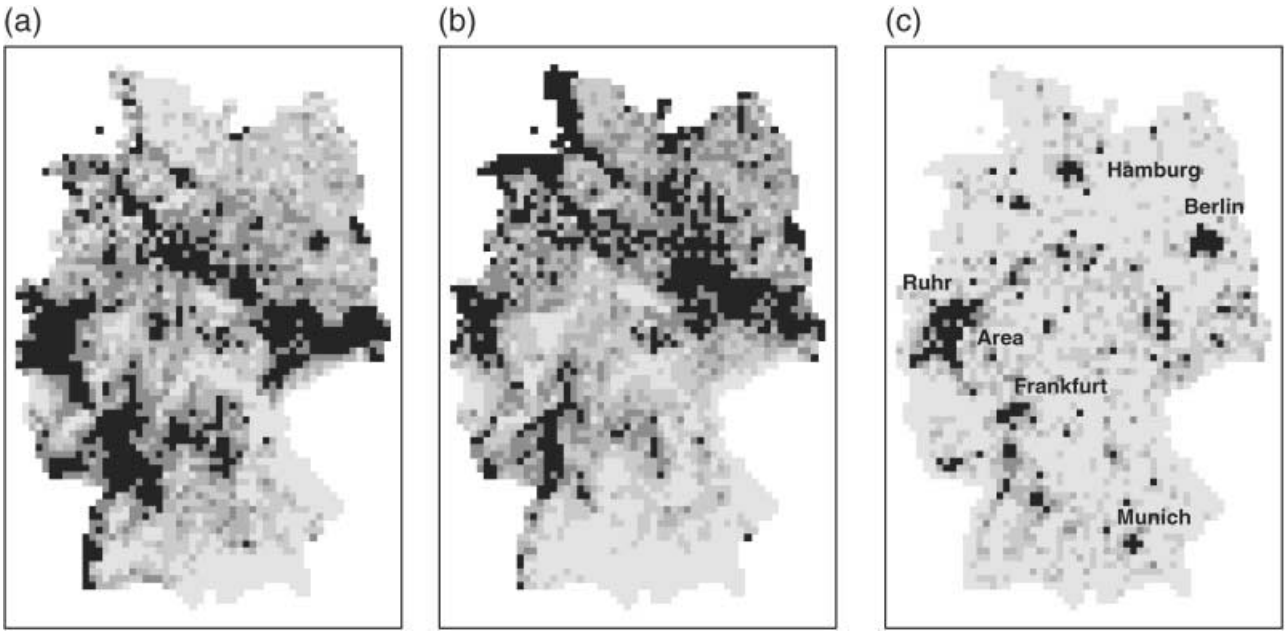

Figure 1 The proportion of (a) alien plant species and (b) annual plant species (natives and annuals) of the flora of Germany per grid cell using the data of BiolFlor (Klotz *et al.*, 2002) and FLORKART (by courtesy of the German Federal Agency for Nature Conservation). Panel (c) shows the proportion of urban land cover, naming major urban areas. The greyscale reflects the proportions in quintiles with the following intervals (from light to dark): (a) 0–0.148; >0.148–0.165; >0.165–0.183; >0.183–0.206; >0.206–0.356; (b) 0–0.196; >0.196–0.218; >0.218–0.231; >0.231–0.245; >0.245–1; and (c) percentages of urban land cover: 0–<5; 5–<10; 10–<15; 15–<20; 20–100. Resolution is 6'longitude × 10'latitude (*c.* 130 km^2).

Updates of BiolFlor are planned to extend the numbers of traits and also the coverage of species. Pyšek (2003) suggested that BiolFlor could also be applied to cover a wider geographical range.

Applications

Besides analysing traits associated with invasiveness, BiolFlor can be used in many other contexts such as deriving functional groups, calculating functional diversity or mapping the distribution of such traits with subsequent analyses. For example, Fig. 1 shows the proportion (as quintiles) of aliens (a) and annuals (b) within the German flora per grid cell using distributional data not included in BiolFlor. Alien species are overrepresented in industrial areas in the West, South-west and East of Germany, along major rivers and the richest agricultural areas. They are underrepresented in mountain ranges. The pattern of annual species is strikingly similar but has another focal area along the North Sea Coast (which is influenced by tides). The correlation of the proportions ($r = 0.6$) between both traits is highly significant ($P < 0.001$) even after correcting for spatial autocorrelation (Dutilleul, 1993). Annuals and aliens positively react on natural and anthropogenic disturbances, *c.* 37% of aliens are annuals.

Availability

BiolFlor is published by the German Federal Agency for Nature Conservation and can be obtained from 'Landwirtschaftsverlag Hiltrup' (http://www.lv-h.com/bfnen). The Internet version is available at http://www.biolflor.de.

Data on seed weight and seed shape will be made available in the LEDA database (Knevel *et al.*, 2003; http://www.leda-traitbase.org).

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SUPPLEMENTARY MATERIAL

The following material is available from http://www.blackwellpublishing.com/products/journals/suppmat/DDI/DDI106/DDI106sm.htm

Appendix S1 Traits included in BiolFlor.

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