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Is plant collecting in Germany coming to an end?

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Abstract: We analysed plant collecting in Germany between 1826 and 2014 by counting specimens of common, rare, and invasive species deposited in the herbaria of Munich during that period. Plant collecting increased in the late 1940s and continued until the mid-1980s, but has since declined to levels similar to 1900. In spite of the decline in collecting, the number of specimens of invasive species has strongly increased. The only other attempt to analyse botanical collecting in a large European region, an analysis of botanical recording in the British Isles 1836 to 1988, did not find a decline by the mid-1980s. For the United States, an analysis of collecting between the 1890s and 1999 found that it peaked in the 1930s. Museum time-series (representing the same species collected at different times) have been integral to identifying temporal responses to environmental change, for example, changed flowering times in response to an earlier onset of spring and the change of a region's floristic composition. A possible way to combat the likely loss of time-series in European herbaria is for collection personal to engage with biology teachers at high schools and universities to encourage the collecting of local plants as part of courses in the life sciences.

Key words: time series, change detection, herbarium specimen, museum collection, species distribution, invasive plant, neophyte, Central Europe, Germany

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The value of collections and their associated label-data is that they can provide a baseline for environmental conditions before accelerated rates of anthropogenic habitat modification. To test for changings in collecting, Gardner and colleagues (2014) recently analysed specimen deposition in collections over 150 years (1860–2010) for a representative group of Australia's passerines. They found that collecting of *Meliphagoidea* species, both common and rare, peaked around 1910, declined rapidly thereafter, and remained low through the periods of the two World Wars. Resurgence in collecting began during the late 1940s and continued until the mid-1980s, after which a gradual and sustained decline began, continuing to 2010, the end of their analysis. Current collecting of these birds is at levels equivalent to those of the early 1800s before collecting began in earnest in Australia.

Here we study plant-collecting efforts in C Europe, a region with a much longer history of collecting than Australia, but under some of the same historical influences, including the two World Wars and the molecular-biological revolution starting in the mid-1950s that likely contributed to less effort spent on re-collecting the fauna and flora of developed countries. Using Bavarian specimens from the two Munich herbaria, M and MSB (Thiers [continuously updated]; together 3.2 million specimens, with a historical focus on C Europe and the Alps), we quantified changes in specimen accumulation of 15 common species, 15 rare species, and 15 species introduced to Germany after 1492 (neophytes) that are invasive (i.e. capable of rapid range expansion and suppression of native species). The 45 species were selected to represent different life forms, habitats, and families (Table 1). With

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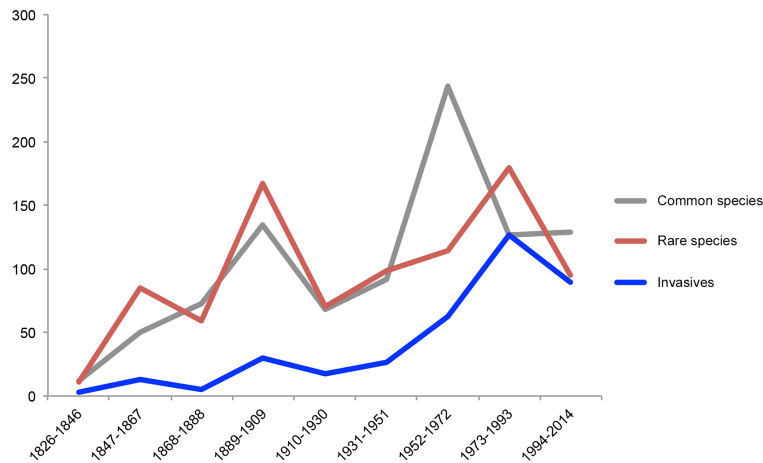


Fig. 1. Collecting activity in Bavaria between 1826 and 2014 as documented by the number of specimens deposited in the two largest Bavarian herbaria (M & MSB). The names of the 45 species included are shown in Table 1.

70 500 km², Bavaria is the largest of the 16 German Federal Lands, and it harbours the majority of the vascular plant species known from Germany. Between 1826 (a suitable starting point because of the history of the collection) and 2014, collectors deposited 931 specimens of the common species, 371 of the invasive species, and 882 of the rare species. Similar to Australian bird collecting, plant collecting in Germany increased in the late 1940s and continued until the mid-1980s, but has declined since (Fig. 1). For common species, collecting

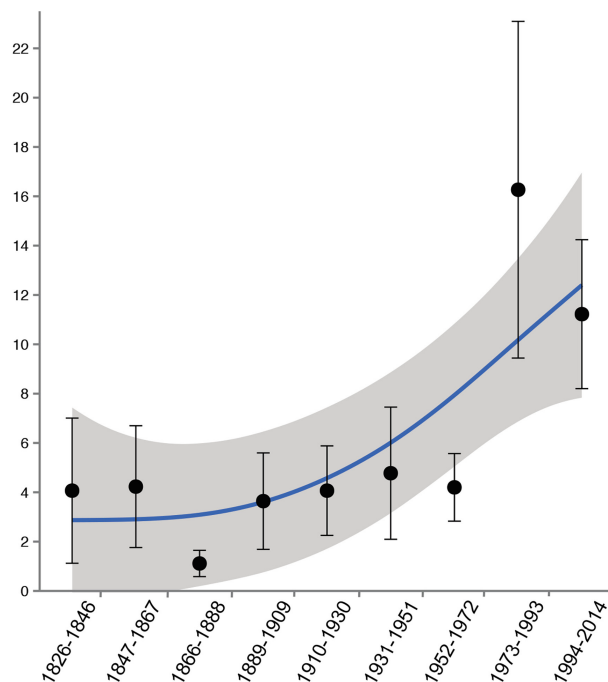


Fig. 2. Specimens of invasive neophyte species deposited in the two largest Bavarian herbaria (M & MSB) between 1826 and 2014 (species names in Table 1). To correct for uneven collecting efforts, we divided the number of invasives collected in each 20-year bin by the numbers of common and rare species collected in the same period. The line represents the fitted Generalized Additive Model (GAM) with the grey area depicting the 95% confidence interval, and points and bars the mean and standard error.

in Germany is now at the same level as it was around 1900. In spite of the decline in collecting, the number of specimens of the invasive species deposited in 20-year bins between 1826 and 2014 has increased (Fig. 2), suggesting that invasive plants have extended their ranges in Bavaria, causing botanists to document new occurrences. Other studies (e.g. Chauvel & al. 2006; Crawford & Hoagl 2009) have also found that range extensions of invasive species can be traced in herbaria, in spite of uneven collecting efforts over time.

The only other attempt to analyse botanical collecting in a large European region that we are aware of is an analysis of botanical recording in the British Isles between 1836 and 1988 (Rich 2006). Rich found that

the number of botanists increased steadily to the 1930s and then five-fold after World War II. Between 1870 and 1914, the number of herbarium specimens increased three-fold, it then decreased during the war periods, but showed a rapid increase in the 1930s, 10 years earlier than bird collecting in Australia and plant collecting Germany. Since Rich's analysis stops in 1988, it remains unclear if collecting has declined since then. For the United States, Prather & al. (2004) analysed specimen accumulation for species in nine genera in 71 herbaria until 1999 and found a strong decline in local collecting, with specimen deposition in most herbaria peaking in the 1930s, although a few herbaria peaked in the 1960s and 1970s.

We agree with Gardner and colleagues (2014) that the decline in collecting effort probably relates to dwindling funding for the research component of natural history collections, but also societal perception that collecting of the local fauna and flora is unnecessary, perhaps even detrimental to the biota because of conservation concerns. This is occurring at the same time as our ability to isolate DNA from herbarium specimens is turning herbaria into veritable DNA-storage units (Telle & Thines 2008; Sebastian & al. 2010; Chomiccki and Renner 2015) and as geo-referenced GBIF specimens are making possible ever more sophisticated niche modelling and fore-and hind-casting of range changes under climate change scenarios (Pompe & al. 2008; Beck & al. 2013). Museum time-series have been integral in identifying temporal responses to environmental change (Table 1 of Gardner & al. 2014; Borchert 1996; Zohner & Renner 2014) and are important for both basic and applied science.

One way to combat the likely loss of time-series in European herbaria is to join local groups that focus on collecting (in Germany, for example, the Gesellschaft zur Erforschung der Flora Deutschlands, <http://www.flora-deutschlands.de>). Another is to try and strengthen the ties between biology teachers at high schools and herbaria and universities to encourage the collecting of local plants as a component of courses in the life sciences (Fig. 3).

Table 1. The 45 common, rare, and invasive species analysed in this study. Information on traits and habitats from Rothmaler & Jäger (2011), and Lippert & Meierott (2014).

Scientific name	Family	Life history	Category	Habitat
<i>Bellis perennis</i>	Asteraceae	Herbaceous perennial	Common	Fresh meadows and pastures; lawns
<i>Campanula rapunculoides</i>	Campanulaceae	Herbaceous perennial	Common	Dry forest edges; agricultural sites; roadsides; ruderal sites
<i>Capsella bursa-pastoris</i>	Brassicaceae	Annual	Common	Dry to moderately fresh agricultural sites; ruderal sites
<i>Carex hirta</i>	Cyperaceae	Herbaceous perennial	Common	Nutrient-rich and fresh meadows and pastures; ruderal sites; forest edges
<i>Convallaria majalis</i>	Ruscaceae	Herbaceous perennial	Common	Dry to fresh forests and forest edges; parks; gardens
<i>Convolvulus arvensis</i>	Convolvulaceae	Herbaceous perennial	Common	Dry grassland; nutrient-rich and dry to fresh agricultural sites; gardens
<i>Geranium robertianum</i>	Geraniaceae	Annual	Common	Fresh forests; forest edges; ruderal sites
<i>Papaver rhoeas</i>	Papaveraceae	Annual	Common	Loamy and nutrient-rich agricultural sites; ruderal sites
<i>Plantago lanceolata</i>	Plantaginaceae	Herbaceous perennial	Common	Fresh meadows and pastures; agricultural sites; ruderal sites
<i>Poa annua</i>	Poaceae	Annual	Common	Fresh and nutrient-rich agricultural sites; ruderal sites; gardens
<i>Rumex obtusifolius</i>	Polygonaceae	Herbaceous perennial	Common	Nutrient-rich and disturbed meadows and pastures; fresh ruderal sites; road-sides; forest edges
<i>Sambucus nigra</i>	Adoxaceae	Shrub/tree	Common	Nutrient-rich and fresh to wet forests; forest edges; ruderal sites
<i>Sisymbrium officinale</i>	Brassicaceae	Annual	Common	Nutrient-rich agricultural sites, gardens; ruderal sites
<i>Trifolium repens</i>	Fabaceae	Herbaceous perennial	Common	Nutrient-rich fresh meadows and pastures; agricultural sites; lawns
<i>Urtica dioica</i>	Urticaceae	Herbaceous perennial	Common	Nutrient-rich and fresh to wet herbaceous vegetation; forest edges; road-sides; ruderal sites
<i>Adonis flammea</i>	Ranunculaceae	Annual	Rare	Dry and loamy agricultural sites
<i>Cephalanthera rubra</i>	Orchidaceae	Herbaceous perennial	Rare	Moderately dry to fresh forests; forest edges
<i>Crocus vernus</i> subsp. <i>albiflorus</i>	Irididaceae	Herbaceous perennial	Rare	Fresh mountain meadows and pastures
<i>Cyanus segetum</i>	Asteraceae	Annual	Rare	Sandy and loamy agricultural sites; ruderal sites
<i>Dianthus superbus</i>	Caryophyllaceae	Herbaceous perennial	Rare	Fresh to wet lowland meadows; alpine meadows; forests
<i>Empetrum nigrum</i>	Ericaceae	Shrub	Rare	Fresh to wet montane and coastal moors; forests
<i>Equisetum pratense</i>	Equisetaceae	Herbaceous perennial	Rare	Nutrient-rich alluvial forests; forest edges
<i>Eriophorum gracile</i>	Cyperaceae	Herbaceous perennial	Rare	Moors

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Scientific name	Family	Life history	Category	Habitat
<i>Euphorbia angulata</i>	Euphorbiaceae	Herbaceous perennial	Rare	Meadows and pastures; montane forest edges
<i>Gentiana clusii</i>	Gentianaceae	Herbaceous perennial	Rare	Montane grassland; moors
<i>Legousia speculum-veneris</i>	Campanulaceae	Annual	Rare	Loamy to clayey agricultural sites; ruderal sites
<i>Leontopodium nivale</i>	Asteraceae	Herbaceous perennial	Rare	Stony montane grassland; rock crevices
<i>Orobanche coerulescens</i>	Orobanchaceae	Herbaceous perennial; parasitizing <i>Artemisia campestris</i> (Asteraceae)	Rare	Sandy dry grassland
<i>Staphylea pinnata</i>	Staphyleaceae	Shrub	Rare	Moderately fresh to dry forests
<i>Stipa pulcherrima</i>	Poaceae	Herbaceous perennial	Rare	Dry grassland; rock vegetation
<i>Ailanthus altissima</i>	Simaroubaceae	Tree	Invasive	Parks; roadsides; urban ruderal sites; alluvial forests
<i>Ambrosia artemisiifolia</i>	Asteraceae	Annual	Invasive	Ruderal sites; roadsides
<i>Buddleja davidii</i>	Scrophulariaceae	Shrub	Invasive	Ruderal sites; roadsides
<i>Bunias orientalis</i>	Brassicaceae	Herbaceous perennial	Invasive	Agricultural sites; ruderal sites; roadsides
<i>Dipsacus strigosus</i>	Dipsacaceae	Herbaceous perennial	Invasive	Fresh and nutrient-rich agricultural sites; ruderal sites
<i>Elodea nuttallii</i>	Hydrocharitaceae	Herbaceous perennial	Invasive	Eutrophic bodies of standing water
<i>Fallopia japonica</i>	Polygonaceae	Herbaceous perennial	Invasive	Riverbanks; nutrient-rich ruderal sites
<i>Heracleum mantegazzianum</i>	Apiaceae	Herbaceous perennial	Invasive	Riverbanks; wet ruderal sites; parks; gardens
<i>Impatiens glandulifera</i>	Balsaminaceae	Annual	Invasive	Water meadows; riverbanks; alluvial forests
<i>Nicandra physalodes</i>	Solanaceae	Annual	Invasive	Ruderal sites; roadsides; cornfields
<i>Prunus serotina</i>	Rosaceae	Tree	Invasive	Forests; forest edges; ruderal sites
<i>Robinia pseudoacacia</i>	Fabaceae	Tree	Invasive	Forests; forest edges; parks; dry grassland; ruderal sites
<i>Setaria faberi</i>	Poaceae	Annual	Invasive	Agricultural sites; ruderal sites; roadsides
<i>Solidago canadensis</i>	Asteraceae	Herbaceous perennial	Invasive	Forests; forest edges; meadows; ruderal sites; roadsides; moors
<i>Veronica filiformis</i>	Plantaginaceae	Annual	Invasive	Lawns; meadows and pastures



Fig. 3. Collecting local plants, either as a component of courses in the life sciences or as an interesting hobby, can be made more attractive by adding photos, including of the collectors, the plant's habitat, or morphological details.

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