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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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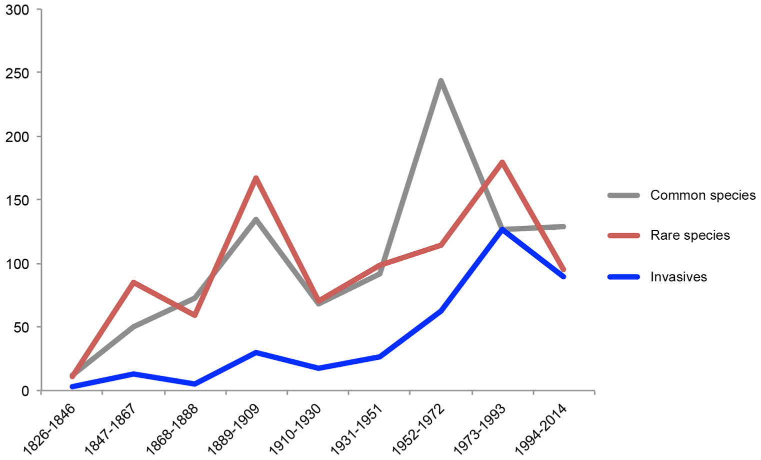

Fig. 1. Collecting activity in Bavaria between 1826 and 2014 as documented by the number of specimens deposited in the two largest Bavarian herbaria (M & MSB). The names of the 45 species included are shown in Table 1.

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.

70 500 km^2, 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

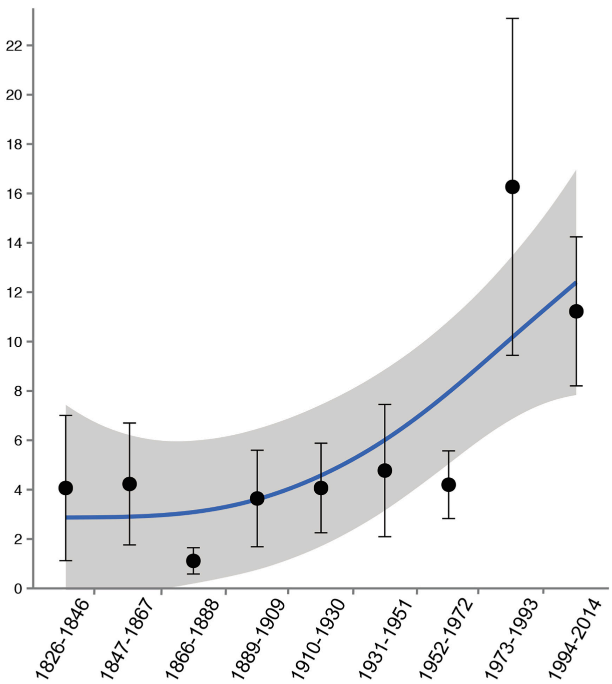

Fig. 2. Specimens of invasive neophyte species deposited in the two largest Bavarian herbaria (M & MSB) between 1826 and 2014 (species names in Table 1). To correct for uneven collecting efforts, we divided the number of invasives collected in each 20-year bin by the numbers of common and rare species 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.

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

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