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Data Paper

The checklist of alien and cryptogenic bryophytes in Austria (2nd edition)

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Abstract

We present the second edition of the checklist of alien and cryptogenic bryophytes (Bryophyta) in Austria. In total, four alien bryophyte species are reported, of which three are established, and for one it is unknown if it is casual or established. In addition, four cryptogenic species (i.e. species that are likely alien, but their biogeographic status is uncertain) are included, of which one is casual and one is extinct. In comparison with the first checklist of alien bryophyte species for Austria published in 2002, the number of alien or cryptogenic bryophytes has risen by four species. Most alien or cryptogenic bryophytes in Austria are native to continents of the Southern Hemisphere. Most invaded ecosytems in Austria are man-made habitats, fields, forests and mires. One species (*Campylopus introflexus*) is assumed to locally cause negative environmental impacts.

Key words: alien flora, biological invasions, Bryophyta, inventory

Introduction

Worldwide, numbers of alien species are increasing rapidly, a finding which appears to be robust to variable sampling effort (Seebens et al. 2017). In the plant kingdom, by far the highest numbers of alien species are reported for vascular plants (van Kleunen et al. 2015), and invasion science has been heavily focused on this taxonomic group. In contrast to vascular plants, for which invasion patterns and driving forces are extensively studied, global bryophyte invasions have so far attracted much less attention (Essl et al. 2011). Despite the fact that the common definition of an alien species is sometimes hard to apply to bryophytes, recent research has shown that also numbers of alien bryophytes are increasing (Essl et al. 2015a), and that some bryophyte species do exert quantifiable impacts on invaded ecosystems (Essl et al. 2014).

Thus, a first inventory of alien bryophytes in Europe (Essl and Lambdon 2009) and subsequently, a first global checklist of alien bryophytes has been compiled (Essl et al. 2013). For Austria, a first inventory of alien bryophytes has been published in 2002 (Zechmeister et al. 2002) as part of the cross-

taxonomic national inventory of alien species (Essl and Rabitsch 2002). As a consequence of an increasing number of faunistic and floristic investigations in recent years, many records of new alien species have been made in Austria, and thus a second edition of the national inventory of alien species has been initiated in 2018 (Rabitsch and Essl *ined.*).

Here, we present the second edition of the checklist of alien bryophytes. We discuss key findings and the changes of the alien bryophyte flora between the first and second editions of the Austrian checklist.

Materials and methods

Bryophytes (Bryophyta) include mosses (Bryopsida), liverworts (Hepaticopsida) and the species-poor hornworts (Anthoceratopsida) (Hodgetts et al. 2020). For the second edition of the checklist of alien and cryptogenic bryophytes, we updated the checklist of alien bryophytes for Austria based on a comprehensive literature research, and by adding additional unpublished data obtained from field work. For each species, we collected the following data (if available): species name, important (i.e. widely or until recently used) synonyms, region of origin (continents according to the TDWG classification, Brummit 2001), distribution in the nine federal states of Austria, year of first record in Austria, recent population trend in Austria, biogeographic status in Austria (alien, i.e. established, casual, or unknown if established / casual; cryptogenic), pathways of introduction (according to Hulme et al. 2008), invaded ecosystems, negative impacts on the environment, and main sources.

The definition of "alien", "established" and "casual" follows Essl et al. (2018). We also included cryptogenic species, i.e. species that are likely alien but whose biogeographic status is uncertain, by following the definition provided in Essl et al. (2018); identifying such cryptogenic species is often particularly difficult (Essl et al. 2015b; Patiño and Vanderpoorten 2015). Species nomenclature and taxonomy follow the most recent checklist of European bryophytes (Hodgetts et al. 2020).

Results

In total, four bryophyte species are reported as alien for Austria; three of these are definitely established (*Campylopus introflexus, Lunularia cruciata, Orthodontium lineare*), and one is probably casual (*Chenia leptophylla*) (Table S1). A further four cryptogenic species are recorded for Austria; one species is casual (*Nogopterium gracile*), one is considered extinct (*Sphaerocarpos michelii*), and one species is likely established (*Spherocarpos europaeus*), and one species is established (*Campylopus pyriformis*). Most species are native to continents of the Southern Hemisphere, i.e. Africa (five species) and South America (four species), the Mediterranean part of Europe (five species) and North America (three species).

Four of these species were recorded for the first time in Austria in the 19th century, one species in the late 20th century, and three species in the last two decades (Table S1). A few of the alien and cryptogenic bryophytes are widespread and occur in most or all of the nine federal states of Austria (*Campylopus introflexus, C. pyriformis, Lunularia cruciata*), of which the latter two are native and widespread in suboceanic and submediterranean parts of Europe. Occurrences of the remaining species are restricted to at most two federal states. While one species is clearly expanding in Austria (*Campylopus introflexus*), three have stable distributions (*Campylopus pyrifomis, Orthodontium lineare, Lunularia cruciata*) and for the remaining ones, population trends are unknown.

The most invaded ecosystems are man-made habitats and fields (five species), followed by mires, and forests (two species). For most species, the pathway of introduction is unknown, while for two species (*Lunularia cruciata, Nogopterium gracile*) there is evidence that introduction occurred as contaminant and stowaway. For one species (*Campylopus introflexus*) it is assumed that negative impacts on invaded habitats (i.e. heatlands, disturbed mires) do occur.

Discussion

The updated checklist of alien and cryptogenic bryophytes in Austria includes now eight species in total, which is four more than included in the first edition of this checklist (Zechmeister et al. 2002). One of this newly included species (*Chenia leptophylla*) was recorded for the first time in Austria in 2004 (Zechmeister *ined.*) and thus after the completion of the first checklist of alien bryophytes and it is therefore new to the checklist. Among the cryptogenic species, *Spharocarpos michelii, S. europaeus* and *Campylopus pyriformis* were included newly. Furthermore, *Orthodontium lineare* was recorded in 2019 for the first time outside a horticultural facility (e.g. greenhouses) (Zechmeister et al. 2020); however, this species was already listed in the first edition of the checklist of alien bryophytes in Austria.

The historic occurance of *Sphaerocarpos michelii* might be doubtful and could be based on a mis-identification with *S. europaeus* (Köckinger 2017). However, the latter species was confirmed two times in recent years (Köckinger 2017; Zechmeister et al. 2017). In any case, both species occur frequently in the Mediterranean, and spread into more northern regions as a consequence of climate change seems possible. A similar case is the occurrence of *Nogopterium gracile* in Austria: the historic native range (Dalla Torre and Sarnthein 1904) was restricted to regions south of the Alps, while the recent record in Austria was made in the historical garden of the Belvedere castle in Vienna, where it was likely introduced (Hohenwallner and Zechmeister 2001). The uncertainties regarding the way of introduction reflect the difficulties in disentangling natural and

anthropogenic contributions of range expansion in bryophytes (see discussion in Essl et al. 2015b and Patiño and Vanderpoorten 2015). Further, scientific advances have shed new light on the biogeographic status of particular bryophytes. For instance, *Campylopus pyriformis* was previously thought to be an alien species; however, molecular studies provide some evidence that range-expansion was driven by natural spread (Stech and Wagner 2005), and thus we re-classified the species as cryptogenic.

Compared to other European countries with a well-documented alien bryophyte flora, the number of alien and cryptogenic bryophytes in Austria falls into the middle range (Essl and Lambdon 2009; Essl et al. 2013). This supports the finding of Essl and Lambdon (2009), who report highest numbers of alien bryophytes for Western European countries with oceanic climates, and lowest numbers for East European countries with rather continental climates. Compared to the alien vascular plant flora of Austria (1110 taxa, Rabitsch and Essl 2006), the number of alien bryophytes is more than two orders of magnitude smaller.

The predominance of alien bryophytes with native ranges on continents on the Southern Hemisphere is in line with results from other European countries (Essl and Lambdon 2009). The most likely reason for this is that bryophytes can effect efficient long-distance dispersal by natural means (i.e. anemochory) between continents of the same hemisphere. However, crossing of the tropics by natural means is nevertheless difficult for temperate species due to prevailing air currents of the intertropical convergence zone (Essl and Lambdon 2009).

The high number of species that were already reported in the 19th century in Austria is rather unusual, as on a global scale, most first records of alien bryophytes were made only rather recently (Essl et al. 2014). The habitat affiliation of alien and cryptogenic bryophytes in Austria mirrors the overall European habitat preferences with man-made habitats, fields, forests and mires being the ones with most alien bryophytes (Essl and Lambdon 2009). One species (*Campylopus introflexus*) is considered to locally exert negative environmental impacts on invaded mires and on rare bryophyte communities on bare soils poor in nutrients in Austria; in oceanic climates in Western Europe and—to a lesser degree—in Central Europe, this species can become very abundant in coastal dunes (in Western Europe) and (disturbed) mires (Hassel and Söderström 2005; Klinck 2009; Mikulášková et al. 2012). In contrast to vascular plants which are predominantly introduced as ornamental species (van Kleunen et al. 2018, 2020), for alien bryophytes horticulture and economic uses play a moderate role (but note that several alien bryophytes in Western Europe have been introduced as epiphytes on Australasian tree ferns, Holyoak and Lockhart 2009). In many cases, the pathways are unknown.

While bryophytes only have low numbers of alien species compared to vascular plants, the underlying patterns differ substantially from those of

vascular plants. Therefore, making—and regularly updating—checklists of alien and cryptogenic bryophytes is important as transferring insights derived from vascular plants to other plant groups is not appropriate.

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Supplementary material

The following supplementary material is available for this article:

Table S1. Checklist (2nd edition) of alien and cryptogenic bryophytes in Austria.

This material is available as part of online article from:
http://www.reabic.net/journals/bir/2021/Supplements/BIR_2021_Essl_Zechmeister_SupplementaryMaterial.xlsx