Article

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Update to the vascular flora of Mount Limbara: new records from Northern Sardinia

Abstract

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Three years after the publication of the vascular flora of Mount Limbara, we present a revised floristic list with new records of 34 taxa in the study area. Specifically, 15 of these newly recorded taxa are native, while 19 are alien species. Additionally, we have removed 7 taxa from the previous list due to incorrect assignments. Furthermore, we have comprehensively revised the nomenclature, chorology, and distribution of additional 74 taxa within the study area. The inclusion of new alien taxa in our findings increases the already significant number of non-native taxa identified in this area. Following this revision, the vascular flora of Mount Limbara currently comprises 1,175 taxa, classified into 125 families and 500 genera. The endemic and subendemic taxa are 89, while the alien flora includes 134 taxa. In this report, we highlight the discovery of four casual aliens that are new to the Sardinian flora: *Hyacinthoides hispanica*, *Koelreuteria paniculata*, *Leucanthemum* ×*superbum*, *Ulex europaeus* subsp. *europaeus*. Additionally, we present the first report for the flora of Italy of *Eucalyptus* ×*trabutii* (casual alien). Moreover, we confirm the presence of *Hyacinthus orientalis* for the Sardinian flora, and we exclude *Cuscuta cesattiana* from the flora of the island. Finally, we remark the invasive status of *Abies cephalonica* and *Xanthium orientale* in the area.

Key words: alien taxa, endemic taxa, invasive taxa, native taxa, Sardinian flora.

Introduction

A flora, along with vegetation landscapes and ecosystems, is not a static entity, as is often demonstrated by updates in checklists at both local and broader levels (e.g., Fois & al. 2022; Bartolucci & al. 2018a; Galasso & al. 2018). Conversely, a flora constitutes a dynamic system that undergoes various, sometimes gradual or rapid, changes resulting from external and internal factors. These factors encompass both natural events (as climatic phenomena, genetic drift, successional evolution, colonization, migrations), and, most significantly, anthropogenic pressures and alterations (Iamonico & al. 2012; Gianguzzi & al. 2013; Carta & al. 2018; Cambria & al. 2023). Furthermore, new scientific discoveries and updates can supply additional information to bridge gaps in previous knowledge,

thereby enhancing what initially appeared to be a comprehensive and well-rounded effort (Bedini & al. 2016).

In 2020, we published the vascular flora of Mount Limbara (northern Sardinia, Italy), highlighting its species richness and the precarious situation arising from a high abundance of non-native species (Calvia & Ruggero 2020). Three years later, recent field findings, the analysis of new herbarium samples, in conjunction with the re-evaluation of some previously collected specimens, along with nomenclatural and chorological changes occurred for various taxa, prompted us to revise our original list.

Materials and methods

We updated the floristic list published by Calvia & Ruggero (2020), after the collection of new floristic data during the years 2021-2023. Also, some specimens already collected in the past have been revised. Herbarium specimens are preserved at our personal herbaria (Roma-Marzio & al. 2018). Nomenclature generally follows the checklists of the Italian native (Bartolucci & al. 2018a) and alien (Galasso & al. 2018) vascular flora, except in few cases specified in the notes. Taxa are categorized in native and alien, and ordered per families and genera, as in the previous version. For each taxon, the following information is provided: family, current accepted name, biological type, chorology, abundance (expressed as in Calvia & Ruggero 2020), habitat, elevation range. For all the updated and added taxa we also reported additional notes. For some taxa we also added the citation of the first report in the area. For the alien taxa we reported the current invasiveness status (A = adventitious; P = planted; CAS = Casual; NAT = naturalised; INV = invasive; OP = only planted). Regarding the decision to include only planted taxa, our rationale is rooted in the acknowledgment that comprehending taxa with the potential to spread in the near future, under favourable environmental conditions, is crucial for monitoring the vascular flora of an area (Celesti-Grapow & al. 2010). While we have opted to create a distinct list exclusively for planted taxa, we recognize and consider them as integral components of the active vascular flora of Mount Limbara.

In the current list (Electronic Supplementary File 1, ESF1), scientific names of native taxa are presented in both bold and italics, whereas those classified as alien taxa are displayed in italics only. We have marked all newly reported taxa with the symbol (+), taxa that have been removed from the previous list are indicated with (–), distributional updates of previously documented taxa are highlighted with (*), and denoted chorological and nomenclatural changes are marked with (§). An ecological analysis based on the four altitudinal belts proposed by Canu & al. (2015) is here presented.

Results

After the recent findings of the last three years, the new floristic list consists of 1,175 taxa, which are divided as follows: 1,021 native (86.9%), and 134 (11.4%) alien taxa (details in Appendix 1). An additional 20 taxa are OP (1.7%). The flora includes 125 families (17 of which are represented by alien/OP taxa only) and 500 genera (72 of which are

alien/OP taxa only). The taxa at the species level are 874, while 285 are subspecies, 12 are hybrids and 4 are varieties. Pteridophytes consist of 14 families, 18 genera, 33 taxa. Gymnosperms are divided in 3 families, 12 genera and 23 taxa (19 of them introduced). Angiosperms are 108 families, 471 genera and 1,129 taxa: 16 families, 118 genera and 282 taxa are Monocots (24 non-native); 92 families, 353 genera and 847 taxa are Dicots (111 non-native). The most represented families are *Asteraceae* (139 taxa), *Poaceae* (126), *Fabaceae* (110), *Caryophyllaceae* (38), *Rosaceae* (37), *Apiaceae* and *Lamiaceae* (36).

The endemic contingent of Mount Limbara currently amounts to 89 taxa. All the vascular endemics found are Angiosperms, with 67 Dicots and 22 Monocots.

Sardo-Corsican endemics are the most frequent (32 taxa, 35.9%), followed by Sardinian endemics (25, 28.1%), Sardinian, Corsican and Tuscan Archipelago (14, 15.7%) and Sardinian, Corsican and Italian endemics (11, 12.4%), while the other endemic and subendemic taxa are 7 (7.9%). Currently, 4 taxa are exclusive to Limbara (*Genista salzmannii* subsp. *limbarae* Bacch., Brullo & Giusso, *Hieracium mattirolianum* subsp. *martellianum* (Zahn) Greuter, *H. racemosum* subsp. *limbarae* (Arrigoni) Greuter, *Rubus limbarae* Camarda) representing 3.5% of the entire endemic flora. Furthermore, 8 endemic taxa (9.3% of the total) have their *locus classicus* in the area: *Barbarea rupicola* Moris, *Festuca sardoa* (Hack.) K. Richt., *Genista salzmannii* subsp. *limbarae* (Bacchetta & al. 2020), *Hieracium bernardii* subsp. *gallurense* (Arrigoni) Greuter, *H. mattirolianum* subsp. *martellianum*, *H. racemosum* subsp. *limbarae*, *Romulea* × *limbarae* Bég., *Rubus limbarae*, *Viola corsica* subsp. *limbarae* Merxm. & W. Lippert.

Alien plant taxa on Mount Limbara are documented at 154 in total, comprising 51 classified as CAS, 75 as NAT, 8 as INV, and 20 as OP. American taxa dominate with 42 (including 6 OP), followed by Mediterranean taxa (19, including 2 OP), and Asian taxa with 15 (including 3 OP).

The updated biological spectrum of the current floristic list demonstrates a richness in therophytes (464) and hemicryptophytes (341), followed by phanerophytes/nanophanerophytes (158) and geophytes (152). Chamaephytes, hydrophytes, and helophytes are represented by 38, 22, and 2 taxa, respectively.

The biological spectrum of alien taxa highlights a predominance of phanerophytes, totalling 70 (including OP). Therophytes are the next most abundant, with 33 taxa. Hemicryptophytes follow with 21 taxa, geophytes with 18, chamaephytes with 10, and hydrophytes with 2.

Among the most noteworthy updates since the previous list, we present 6 new taxa for the flora of Sardinia. Notably, one of these findings also marks the first-ever occurrence in the Italian flora (see also the new list in ESF1):

Eucalyptus × *trabutii* H. Vilm. (a hybrid between *E. camaldulensis* Labill. and *E. botryoides* Sm.): several young trees and saplings now thrive in the vicinity of an ancient shepherd's settlement, where an old tree of this taxon also grows. This marks the first recorded occurrence of this taxon as an adventitious species in Italy.

Hyacinthoides hispanica (Mill.) Rothm.: in spring 2023, a few plants were discovered along a country road on the northern side of the mountain. This is the first report of the taxon as a casual alien in the flora of Sardinia.

Hyacinthus orientalis L.: several plants were observed starting in April 2021 on a former military base that was decommissioned in 1993. This confirms the presence of

the taxon as a casual alien in Sardinia, dispelling earlier doubts raised by Bartolucci & al. (2018a).

Koelreuteria paniculata Laxm.: several young trees and saplings now thrive along the northern border of the study area. This is the first documented occurrence of this species as an alien in the flora of Sardinia.

Leucanthemum ×superbum (Bergmans ex J. W. Ingram) D. H. Kent: this is the correct binomial name for the taxon previously reported as *Leucanthemum* sp. and is the first recorded occurrence of this taxon as an alien in Sardinia.

Ulex europaeus L.: in September 2023, we found a small shrub and two seedlings of this species along a forestry road. This marks the first recorded occurrence of this taxon as a casual alien in Sardinia.

Additionally, we confirm the presence of *Cuscuta campestris* Yunck. as a naturalised species in Sardinia, while we exclude the presence of *Cuscuta cesattiana* Bertol., *Scrophularia umbrosa* Dumort., and *Sedum villosum* L. from both the study area and Sardinia as a whole.

The lowermost area of the mountain, covering approximately 102.11 km² and influenced by the Oceanic Pluviseasonal Mediterranean bioclimate (data exerted from Canu & al. 2015), from an elevation of roughly 160 m to 500 m, is the most taxonomically rich, housing 950 taxa, which corresponds to 80.9% of the entire flora.

The second belt, which marks the transition between hillside and low mountain areas (500-800 m a.s.l.) and is influenced by a transitional bioclimate shifting from the upper meso-Mediterranean to the supra-Mediterranean thermotype, particularly evident on northern slopes, remains diverse with 908 taxa (constituting 77.2% of the total flora). The lower number of taxa in this portion of the study area, despite its slightly larger size (110.75 km²), can be attributed to a more uniform presence of woodlands, reforestations, and dense *Arbutus unedo* L. and *Erica arborea* L. high shrublands. These habitats limit diversity, and consequently, species richness (Bacchetta & al. 2009).

The lower mountain belt (800-1,200 m a.s.l., covering 47 km²), characterized by the supra-Mediterranean thermotype within the sub-Mediterranean variant, is less rich in comparison to the previous belts but still boasts 766 taxa, accounting for 65.1% of the total flora.

Lastly, the uppermost zone, spanning from 1,200 m to 1,359 m a.s.l. and covering the smallest area (2.6 km²), which is influenced by the oceanic temperate bioclimate, currently houses 455 taxa (representing 38.7% of the total flora and increased from the previous count of 440, as documented in Calvia & Ruggero 2020).

Discussion and conclusions

The updated vascular flora of the Limbara massif now comprises 1,175 taxa, which accounts for approximately 40% of the entire Sardinian flora, as indicated by Galasso & al. (2018). Of these, the 1,021 native taxa represent approximately 42% of the native flora of the island, as reported by Bartolucci & al. (2018a). Unfortunately, the already high number of non-native taxa (119, excluding OP, as detailed in Calvia & Ruggero 2020) has further increased to 134 taxa, constituting around 23% of the alien flora found in Sardinia, according to Galasso & al. (2018).

When considering the four belts as if they were distinct floras, categorized by elevation, it becomes evident, from both a biological and a chorological perspective, how the highest region of the mountain differs from the Mediterranean context that surrounds it (see also Tables S1, S2). This observation aligns with previous findings by Farris & al. (2018) for Anela.

The H/T ratio, which serves as an indicator of the Mediterranean (H/T < 1) or continental (H/T > 1) nature of the flora (Sabato & Valenzano 1975; Cannucci & al. 2017), reaffirms the low continentality of the uppermost region of the mountain and a consistent increase in the index from the base (0.61) to the summit: the belt between 500 and 800 m a.s.l. records an index of 0.78, while the lower mountain area, ranging from 800 to 1,200 m, reaches 0.82. Notably, the newly discovered data reveals a slight uptick in the value at the highest peaks, now at 1.06 (compared to 1.04 in Calvia & Ruggero 2020), further confirming the low continentality at the mountain' summits. Nonetheless, this value remains lower than that of the Gennargentu massif (1.25, as reported by Arrigoni & Camarda 2015), whose peaks are almost 500 m higher than those of Limbara.

Specifically, when examining the chorological data, including alien, endemic, paleotemperate, Circum-Mediterranean, and Euro-Mediterranean taxa (refer to Table S2), it becomes evident that the floral composition undergoes significant changes along the gradient. Sardinian and Sardinian-Corsican endemics consistently increase from a minimum of 0.4% and 1.4% in the basal zones to 2.2% and 5.5% at the mountain' summits. Conversely, American and Asian taxa decline from 3.5% and 1.4% to 0.4% each.

At a broader scale, Circum-Mediterranean taxa dominate the entire flora, particularly in the basal belt, closely followed by Euro-Mediterranean taxa. However, the percentage of Circum-Mediterranean taxa decreases from 19.4% in the lowest belt to 12.3% at the highest elevation. Conversely, although the presence of Euro-Mediterranean taxa remains relatively constant along the gradient (as indicated in Table S2), their peak is observed in the uppermost region, at 19.1%. In this area, Euro-Mediterranean taxa predominate.

Furthermore, the reduced influence of the Mediterranean bioclimate at the highest elevation is evident through the increasing percentages of Circumboreal, Euro-Caucasian, and Paleo-temperate taxa. In these cases, their percentage consistently rises along the gradient, transitioning from 1.8%, 1.7%, and 6.3% to 3.3%, 3.1%, and 7.5%, respectively. It is worth noting that several species belonging to these chorological types are often found at lower elevations due to the cooler conditions created by gallery forests (Sanz & al. 2009; Calvia & al. 2023). Otherwise, we could speculate that this gap in distribution might have been even more pronounced.

As mentioned previously, the plant diversity on Mount Limbara is influenced by climatic and environmental factors. However, in the overall composition of the flora, human influence emerges as a significant factor that underscores the impact of human activities on the presence of non-native and endemic taxa within each belt and along the elevation gradient (Angiolini & al. 2013; Fois & al. 2020).

On one hand, in the basal belt (160-500 m) there are 99 alien taxa, accounting for 10.4% of the entire flora in this zone, while endemic taxa make up only 5% (48). This particular area is characterized by the presence of human settlements and various activities that exert a notable influence on the landscape and, consequently, on the floristic diversity. This influence stems from the introduction of cultivated plant species, which serve agricultural, crop, and

ornamental purposes, contributing to the observed changes in the flora. In addition to these, there are random introductions resulting from activities such as earthworks, road construction, building sites, and artisanal and industrial areas (Dimitrakopoulos & al. 2020).

On the other hand, at the mountain summits (1,200-1,359 m), the number of non-native taxa decreases significantly to just 24, comprising just 5.3% of the flora. This data marks a slight increase from the 4.7% reported in Calvia & Ruggero (2020). Meanwhile, the presence of endemic taxa rises to 57, accounting for 12.5% of the total. However, it is worth noting that the species richness in the highest area of Mount Limbara is still influenced by human activities. This is evident through the presence of synanthropic and invasive alien taxa along roads, within military bases, radio-television communication centres, and parking areas. Additionally, a number of taxa are spreading from extensive reforestations in neighbouring areas and lower elevations (as documented in Calvia & Ruggero 2020).

Nevertheless, the endemic taxa in this same area are more closely associated with less disturbed habitats, such as mountain meadows, garrigues, wet sites, rocks, and crevices, as one might expect. Future efforts to monitor the environmental stability of the mountain will primarily focus on the conservation of these habitats, which have acted as "islands" fostering the differentiation and speciation of endemic taxa (Esposito 2015; Steinbauer 2016; Itescu 2019; Flantua & al. 2020). However, they are currently facing concerning invasions. In fact, among the previously reported alien taxa, it is worth highlighting that *Abies cephalonica* Loudon has now become invasive in the central parts of the mountain. This raises new concerns regarding future colonization in the uppermost areas of the massif, as it coincides with the simultaneous invasion of taxa like *Pinus nigra* subsp. *laricio* Palib. ex Maire and *Cytisus scoparius* (L.) Link (as documented by Bartolucci & al. 2018b and Galasso & al. 2019).

At the lower extreme of the study area, we report the presence of another invasive species: *Xanthium orientale* L., which is colonising the shores of lake Coghinas and the neighbouring sandy areas.

Furthermore, with this update, we provide valuable information on 74 taxa for which we now have a clearer distributional overview, updated nomenclature, and well-documented chorological changes (e.g., Bacchetta & al. 2020; El Mokni & Pasta 2021; Miguez & al. 2021; Bartolucci & al. 2022; Fois & al. 2022; Jiménez-López & al. 2022; Marchenko & Kuzovkina 2022).

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