Red Listing plants under full national responsibility: Extinction risk and threats in the vascular flora endemic to Italy

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A B S T R A C T

Taxa endemic to a country are key elements for setting national conservation priorities and for driving conservation strategies, since their persistence is entirely dependent on national policy. We applied the IUCN Red List categories to all Italian endemic vascular plants (1340 taxa) to assess their current risk of extinction and to highlight their major threats. Our results revealed that six taxa are already extinct and that 22.4% (300 taxa) are threatened with extinction, while 18.4% (247; especially belonging to apomictic groups) have been categorized as Data Deficient. Italian endemic vascular plants are primarily threatened by natural habitat modification due to agriculture, residential and tourism development. Taxa occurring in coastal areas and lowlands, where anthropogenic impacts and habitat destruction are concentrated, display the greatest population decline and extinction. The national network of protected areas could be considered effective in protecting endemic-rich areas

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(ERAs) and endemic taxa, but ineffective in protecting narrow endemic-rich areas (NERAs), accordingly changes to the existing network may increase the effectiveness of protection. For the first time in the Mediterranean Basin biodiversity hotspot, we present a comprehensive extinction assessment for endemic plants under the full responsibility of a single country. This would provide an important step towards the prioritization and conservation of threatened endemic flora at Italian, European, and Mediterranean level. A successful conservation strategy of the Italian endemic vascular flora should implement the protected area system, solve some taxonomical criticism in poorly known genera, and should rely on monitoring threatened species, and on developing species-specific action plans.

1. Introduction

Due to their restricted distribution, endemic taxa (i.e. showing a natural range restricted to a well-defined area, Anderson, 1994; Casagranda and Lizarralde de Grosso, 2013) may be intrinsically threatened (Ellstrand and Elam, 1993; Işik, 2011), and are therefore highly important in the global, national, and local (regional) prioritization of conservation efforts (Das et al., 2006; Huang et al., 2016). Indeed, the decline of plant species and populations may induce the extinction of endemic taxa, causing a loss of unique evolutionary history and ecosystem services (Isaac et al., 2007). Several international initiatives are in place to reduce the loss of biodiversity, including international treaties (i.e. Convention on Biological Diversity's 2020 target) and conservation policies (i.e. Directive 1992/43/EEC in Europe). Nevertheless, a national approach to biodiversity protection is the most effective way for a country to protect its endemic flora, since "it is at regional and local scales that human actions and biodiversity collide" (Pimm et al., 2001). The choice in applying the concept of endemism to artificial borders like national boundaries has some limitations. Species endemic to a country tend by definition to be placed away from countries' boundaries, while taxa of conservation interest for a certain biogeographic region falling between the boundaries among two or more countries will remain excluded. However, this political scale has also an immediate practical reflection, given that most conservation decisions and policies have to be met at national level and, consequently, the global chance of survival for species endemic to a country is entirely dependent on its national policy. Thus, endemic taxa are key elements for setting national conservation priorities and for assigning conservation tasks (Schmeller et al., 2008; Brundu et al., 2017). In general, the higher the number of taxa endemic to a country, the greater the responsibility of that country in preserving global biodiversity. However, in megadiverse countries (e.g., Brazil or Mexico; Canhos et al., 2015; Sarukhán et al., 2015) the high number of endemic species may require a prioritization of conservation efforts.

This also can be applied to Italy, a country placed in the heart of the Mediterranean Basin, a region considered one of the most threatened global biodiversity hotspots, due to the high rate of endemism and to the high human impact (Vogiatzakis et al., 2006; Cuttelod et al., 2008; Médail, 2017). This "political" choice shows in Italy less shortcomings compared to other countries, given that the geographical position of the Italian peninsula and the limited area (i.e. Alps) shared with neighbouring countries. In Italy, according to the most recent checklist, the native vascular flora consists of 8195 taxa, 1707 of which are endemic to Italy, Italy and Corsica (France), or Italy and Malta (Bartolucci et al., 2018). Among these taxa, 1340 (16.4%) are narrow endemics confined to Italy (subspecies of *Hieracium* and *Pilosella* excluded, see also Peruzzi et al., 2014, 2015, continuously updated online). These include four endemic genera: *Eokochia* (Amaranthaceae), *Rhizobotrya* (Brassicaceae), *Petagnaea* and *Siculosciadium* (Apiaceae). Considering the high number of endemic species occurring in Italy, and in other countries within biodiversity hotspots, it is urgent to focus on conservation priorities, at global, national, and regional level, as well as on stimulating conservation actions and raising public awareness.

The recent State of the World's Plants report from the Royal Botanic Gardens of Kew estimates that 50,000 of the ~390,000 globally known vascular plant species are threatened with extinction (Royal Botanic Gardens, 2016). According to the Global Strategy for Plant Conservation 2011–2020 of the Convention on Biological Diversity (CBD; Objective I, target II; GSPC; https://www.cdb.int/gspc/), one of the key stages is the preliminary assessment of the conservation status of the whole Earth's flora. A reliable evaluation of the conservation patterns of plant species represents an important step not only to evaluate progress towards the CBD's Aichi Targets of the Strategic Plan for Biodiversity 2011–2020 (Pimm et al., 2014), but also to identify effective conservation strategies (Collen et al., 2016). However, the proportion of assessed plant species is still low compared, for instance, to vertebrates (Collen et al., 2016). IUCN Red Listing is widely used to evaluate the global conservation status of species and to estimate their extinction risk (e.g., Mace et al., 2008; Maes et al., 2015). Hence, up-to-date Red Lists are important starting points for conservation actions and provide useful information for monitoring changes in the conservation status of species (e.g., Red List Index; Bubb et al., 2009). Nowadays, the publication of new plant species frequently includes an assessment of their status based on the IUCN criteria. Although some Italian endemic taxa have been recently assessed against the IUCN criteria (e.g., Foggi et al., 2014; Rossi et al., 2016; Orsenigo et al., 2016, 2017; Fenu et al., 2016, 2017a), a comprehensive Red List for the Italian endemic vascular plants is still lacking. The evaluation of the extinction risk of all the Italian endemic plants would provide a powerful tool for driving further conservation steps for these unique organisms. For example, stimulating the improvement of the national network of protected areas, the implementation of a national legislation for the protection of the flora, and the reinforcement of the most threatened species.

In this paper, we present a complete and updated risk assessment of all Italian endemic vascular plants (1340 taxa), using the current IUCN Red List categories and criteria (IUCN, 2012a). This work is based on an exhaustive database, including information from herbarium specimens, literature and field surveys performed in the last fifteen years. With this assessment, we aimed to identify the most threatened endemic plant taxa (and genera) and to highlight those taxa requiring urgent conservation actions, helping to set conservation priorities at national and European level. In particular, our red listing aimed to answer the following questions: 1) what is the current extinction risk of the Italian endemic vascular plants? 2) what are the major threats to Italian endemic plants? 3) does the Italian system of protected areas ensure an adequate protection to endemic vascular plants and endemic-rich areas? This work provides the first comprehensive assessment of the endemic plants for a country in the Mediterranean Basin biodiversity hotspot. Considering that Italian endemic flora significantly contributes to the outstanding biodiversity of the Mediterranean region, our work may provide new and useful information on the general conservation status of the flora of this biodiversity hotspot.

2. Materials and methods

2.1. Endemic species checklist

In the present study, Italian endemic plants are defined as taxa whose distribution is strictly limited to the Italian administrative territory, excluding all vascular plants occurring also in neighbouring countries (e.g., Corsica, Malta, San Marino Republic, Switzerland, etc.).

Given their highly questionable taxonomic status (see Peruzzi et al., 2014, 2015, but also Bartolucci et al., 2018), subspecies within the genera *Hieracium* L. and *Pilosella* Hill (two genera of Asteraceae accounting for hundreds of subspecies considered to be endemic to Italy), all showing insufficient and unreliable distribution data, were excluded from this study to avoid misinterpretation of conservation status. Endemic hybrid taxa, as well as varietal units, were also excluded.

2.2. Red list data

The conservation status of all the Italian endemic vascular plants was assessed according to the IUCN categories and criteria (version 3.1; IUCN, 2012a). Data on species distribution were collected from herbarium specimens, published and unpublished data, and recent field surveys since the early 2000s, representing all the rich, but often dispersed, Italian floristic knowledge. For taxa occurring in pristine habitats (e.g., vertical cliffs), data since the early 1990s were also used. All records were validated by a dedicated working group of botanists, including regional and taxonomic specialists (Rossi et al., 2013; MATTM, 2018). The compilation of distribution and threat data was followed by a draft assessment, which underwent a process of peer review during workshops promoted by the working group for Nature Conservation of the Italian Botanical Society (Rossi et al., 2014).

A total of 19,468 records were georeferenced and organized in QGIS ver. 2.18, including sites of occurrence, population trends, and the main threats at local level identified on expert-based observations and literature sources. Threats were categorized according to the IUCN threats classification scheme (version 3.2; IUCN, 2012b). These data were used to evaluate the major threatening processes affecting endemic vascular plants in Italy.

Given the different level of accuracy of the distribution data, each georeferenced record was rescaled to a 2 km × 2 km fixed grid and superimposed on a map of Italy (Gargano, 2011). Cell size was chosen as the best resolution for standardizing data from different sources and for ensuring a reliable calculation of the Area of Occupancy (AOO) under subcriterion B2 (IUCN, 2012a). Assessments were mostly based on criterion B, however, when consistent data on population size and/or trends were available, other criteria were also applied (i.e., A, C, and D; IUCN, 2012a). To apply sub-criteria under the criterion B, distribution data have been used to define the number of locations and the occurrence of severe fragmentation for each taxon according to IUCN (2013) guidelines. A single location included one or more sites of occurrence in a given area. Indeed, following the indications of local experts, each location has been designed to include all the sites of a taxon potentially affected by the same major threat. The occurrence of severe fragmentation has been evaluated by estimating the fraction of the taxon occurring in isolated populations. To this end, a distance of 50 km has been set as a general isolation threshold. However, for plants showing relevant limitation to dispersal (e.g. due to a high level of ecological specialization versus rare habitat types) such a general threshold has been tuned according to the indication of expert botanists. For estimating continuing decline, historical habitat or population trends have been considered when available; in the absence of such data the evaluation has been founded on indications provided by local experts. Following the precautionary approach suggested by Butchart et al. (2006), taxa that were not recorded during the previous three decades, but for which uncertainty regarding extinction remained, were categorized as "Critically Endangered (Possibly Extinct)". A taxon was considered extinct (EX) if it was not recorded in the last 50 years, and when recent field surveys focused on finding the species in its historical area of occurrence were unsuccessful.

2.3. Endemic species richness, range-rarity index and protection level

In order to detect areas with high endemism richness (López-Pujol et al., 2011; Cañadas et al., 2014), all geographic data were upscaled to a 10 km × 10 km cell grid. This spatial resolution is the more appropriate to reveal a pattern of endemism at the national scale and to minimize sampling bias (Carta et al., 2018).

Endemic species richness was measured as the total number of endemic species occurring in each 10 km × 10 km grid cell irrespective to their range size. We arbitrary considered endemic-rich areas (ERAs, hereafter) as cells with > 20 taxa (n > 20). Then we analysed the spatial pattern of species endemism using the Corrected Weighted Endemism index (CWE) in order to take into account range-rarity richness issues. Weighted Endemism (WE) index was calculated as the sum of the weights of each endemic species measured as the inverse of their grid-cell range. CWE index was calculated by dividing the WE index by the total number of endemic species in a grid cell (Laffan et al., 2013), with endemism unweighted by the number of neighbours, using Biodiverse software (Laffan et al., 2010). We arbitrary considered narrow endemic-rich areas (NERAs hereafter) cells with range rarity CWE index ≥ 0.4444. For the taxa included in the Data Deficient (DD), Extinct (EX), Extinct in the Wild (EW) and Critically Endangered (Possibly Extinct) (CR[PE]) IUCN Categories, the distribution was

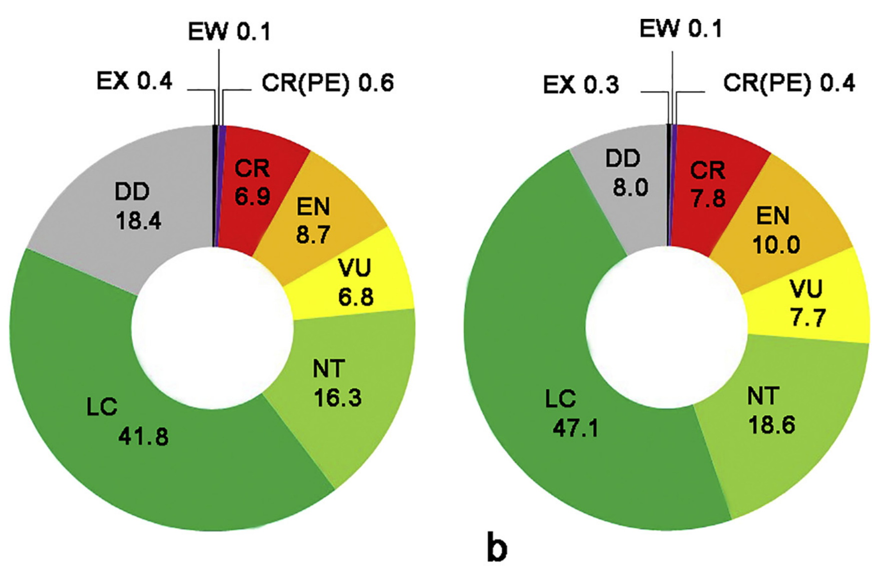

Fig. 1. a. Red list status of vascular plants endemic to Italy. b. Red list status of vascular plants endemic to Italy, excluding taxonomically critical genera (see the text).

omitted, since only few or no data were available. Therefore, the distribution data of 1077 (80.4%) taxa were used to generate endemic richness and range-rarity CWE index maps.

A gap analysis (e.g., Carta et al., 2018; Fois et al., 2018) was then applied to evaluate the current level of protection of ERAs, NERAs and single endemic taxa. For this purpose, the official map of Italian terrestrial protected areas (including: protected natural areas - EUAP, and sites of the Natura 2000 Network) was superimposed on the distribution of Italian ERAs, NERAs (10 km × 10 km cell grid) and on the AOO of each taxon. Protected area system was superimposed on the same 10 km × 10 km cell grid layer. The protection level of ERAs and NERAs was considered as 'effective' (highly protected areas) when ≥50% of the cell surface was included in a protected area, and as 'ineffective' (lowly protected areas) when < 50% of the cell surface was included in protected areas (Araújo, 2004). Moreover, we considered endemic taxa as 'fully protected' when all the AOO was included in protected areas and 'unprotected' when all the AOO was outside protected areas.

3. Results

3.1. Red list assessment

The list of Italian endemic vascular plants includes 1340 species and subspecies (see Table A1). Six taxa have been categorized as Extinct (EX): *Anthyllis hermanniae* L. subsp. *sicula* Brullo & Giusso, *Herniaria fontanesii* Gay subsp. *empedocleana* (Lojac.) Brullo, *Limonium catanense* (Tineo ex Lojac.) Brullo, *Ranunculus hostiliensis* Pignatti, *R. mutinensis* Pignatti, and *Suaeda kocheri* Guss. ex C.Brullo, Brullo & Giusso. One taxon, namely *Limonium intermedium* (Guss.) Brullo, has been recognized as Extinct in the Wild (EW) and eight taxa have not been recorded in recent years and qualified as Critically Endangered (Possibly Extinct) [CR(PE)] (Fig. 1a and b).

A total of 300 taxa (22.4%) have been assigned to a risk category (Critically Endangered, Endangered, Vulnerable; CR, EN, VU, Fig. 1). Additional 218 taxa (16.3%) have been categorized as Near Threatened (NT), and 560 (41.8%) as Least Concern (LC). Because the available data did not allow a reliable assessment, 247 taxa (18.4%) are considered as Data Deficient (DD). At the family level, the percentage of threatened taxa is quite variable (Fig. 2), ranging from 34.3% in Apiaceae to 7.9% in Rosaceae. The percentage of Data Deficient species is also highly variable, ranging from 2.8% in Fabaceae to 55.3% in Rosaceae. At the genus level, the percentage of threatened species varies from 35.7% in *Dianthus* to zero in *Taraxacum*.

3.2. Major threats

Most of the evaluated taxa are affected by multiple threats (Table A2). The major threats to Italian endemic vascular plants are those related to natural system modifications, agriculture, residential development and human disturbance, which affect respectively 33.6%, 24.1%, 23.6%, and 20.5% of taxa (Fig. 3 and Table A2). More specifically, threats concerning natural system modifications are related to the increase in fire frequency (186 taxa) and abandonment of managed lands (208 taxa). Threats from residential and commercial development encompass new human settlements in urban areas and suburbs (104 taxa) and the tourism (193 taxa). Agriculture represents a major threat, especially due to livestock farming and ranching (210 taxa) and, to a lesser extent, to non-timber crops (59 taxa). Finally, human disturbance, mainly related to recreational activities (e.g., hikers, off-road vehicles, rock-climbers), affects 249 taxa.

Currently, transportation corridors (road and railroads), climate change (drought), plants collection for commercial or cultural purposes, and non-native invasive species represent minor threats.

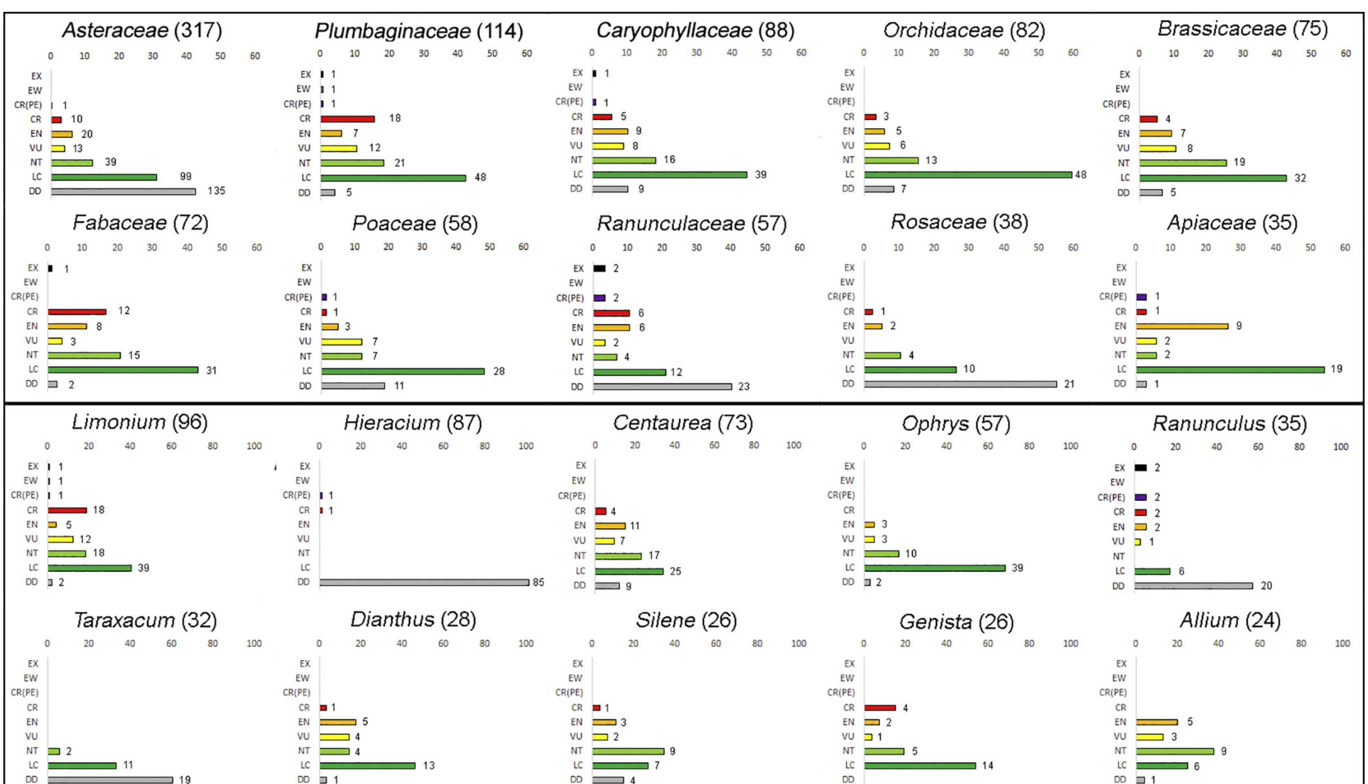

Fig. 2. Major families and genera of the Italian endemic vascular flora (the corresponding number of taxa is in brackets). For each family and genus, the percentage of endemic species assigned to each category and the number of species is reported.

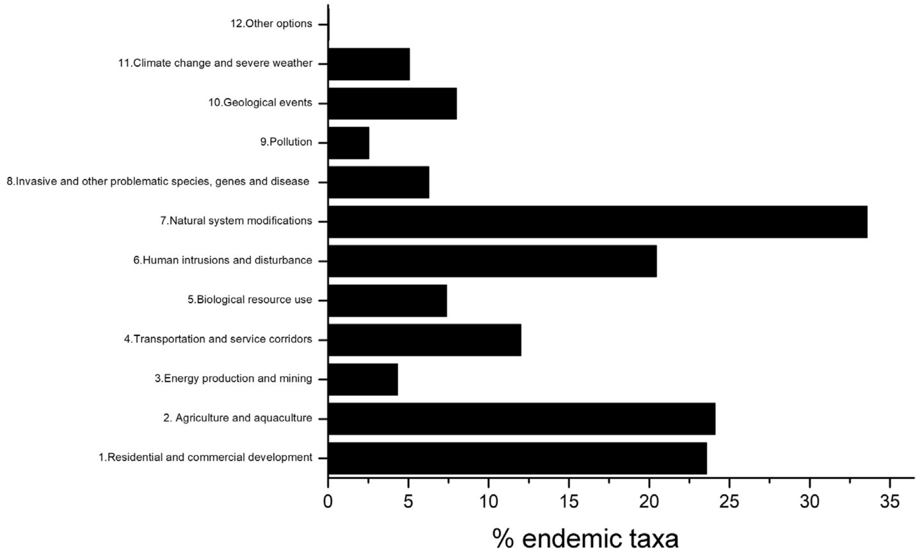

Fig. 3. The percentage of Italian endemics affected by each major threat category according to the IUCN Threats Classification Scheme (version 3.2; IUCN, 2012b).

3.3. ERAs and NERAs distribution

The endemic species richness is highly variable across cells, ranging from zero to 86 taxa per cell (in the Madonie mountains, Sicily). The most important areas for endemic species (ERAs; Fig. 4) occur in Sardinia, Sicily, Southern Apennines (Aspromonte, Sila, and Pollino massif), Gargano promontory, Central Apennines (Majella and Gran Sasso mountains), Northern Apennines and Apuan Alps. Because of the selection criteria (i.e. taxa occurring only in the Italian administrative territory), the Alps are instead less represented, since several Alpine endemics are shared with neighbouring countries. Nevertheless, some areas of Southern Alps (e.g., Orobian Alps and surroundings of Garda Lake) show high levels of Italian endemics richness (up to 19 species).

The analysis of patterns of endemism using range weighting reveals that some ERAs remain of key importance (Sardinia, Sicily, Apuan Alps), but single cells with highest CWE index are dispersed throughout the territory, with higher concentration in coastal and subalpine areas. The most important areas for narrow endemic species (NERAs; Fig. 5) besides Sardinia, Sicily and the Apuan Alps are the Tuscan Archipelago, the small Sicilian Islands (Aeolian Islands, Pelagie Islands and Pantelleria), Southern Apulia and southern-alpine slope.

3.4. Protection of Italian ERAs, NERAs and endemic taxa

Regarding the in situ potential conservation, 69.4% of ERAs are effectively protected (with 16% of cells fully included in a protected area), while 29.5% are ineffectively protected. Only 1.1% of the ERAs are totally unprotected (i.e.: Catena Costiera area in Calabria). Conversely, only 20.9% of NERAs are effectively protected, while 70.5% are ineffectively protected and 8.6% are totally unprotected (Fig. 6).

The current system of protected areas ensures the total protection of 135 Italian endemic taxa (10%), while 28 taxa are totally unprotected (2.1%), 13 of these, are threatened with extinction (Table 1).

4. Discussion

Endemic taxa are the most valuable component of a flora and deserve high regional and global conservation priorities (Schmeller et al., 2008; Brundu et al., 2017). However, the high number of endemic species hosted in countries within biodiversity hotspots, like Italy, may prevent effective conservation efforts, without an exhaustive, accurate and updated priority list. Assessments of species conservation status are considered effective tools to aid conservation planning and to evaluate conservation options (Hoffmann et al., 2010). Narrow endemic taxa confined to Italy represent 16.4% of the whole Italian flora according to the most recent checklist (Bartolucci et al., 2018). Moreover, about 5.0% of the Italian endemics are of high potential economic interest, being crop wild relatives (Domina et al., 2012). The assessment of their extinction risk, as well as their protection level, is therefore crucial to reach the targets of Global Strategy for Plant Conservation (GSPC) and Convention on Biological Diversity (CBD).

In this study, all the 1340 vascular plants endemic to Italy were assessed under the IUCN categories and criteria. This is one of the largest and most complete conservation assessment of the vascular flora endemic to a country (for other examples see MEP-CAS, 2013; SANBI, 2017), and could provide a powerful tool for the conservation of plant diversity in Europe and in the Mediterranean basin, allowing the accomplishment of the GSPC Target 2 at least for species under full Italian responsibility.

Looking at global trends, the proportion of threatened Italian endemic taxa (22.4%) is perfectly consistent with the global estimations (22.0%; Brummitt et al., 2015) and also comparable with another Mediterranean country, i.e. Spain (22.1%; Muñoz-Rodríguez et al., 2016), albeit in the latter taxa have been evaluated through a quick assessment process (see Muñoz-Rodríguez et al., 2016 for details). Our results show that six taxa are already extinct, and eight taxa are possibly extinct. This extinction rate is similar to that reported for Spain, where five endemic taxa are considered extinct (Aedo et al., 2015) and lower than observed, for instance, in other global biodiversity hotspots with Mediterranean-type climate as California, where 17 endemic taxa have been recently declared extinct (Rejmánek, 2018), or South Africa, where extinct species, not considering only endemic taxa, are 29 (0.2% of whole South Africa flora; SANBI, 2017). Comparing the assessment of endemic plants with some major groups of animals in Italy, vascular plants represent one of the most threatened taxonomic groups in Italy together with vertebrates (28.0%; Rondinini et al., 2013) and saproxylic beetles (21.0%; Audisio et al., 2014), while dragonflies and butterflies reach lower percentages (10.9% and 6.3% respectively, according to Riservato et al., 2014 and to Balletto et al., 2015).

Concerning Italian endemic plants, some genera show a marked extinction risk. The highest percentage of threatened species is reached by several of the most representative genera of the Italian endemic flora, such as *Limonium*, *Dianthus*, *Allium*, and *Centaurea* (collectively representing > 30% of taxa included in a threatened category). Most of the taxa belonging to these genera grow in coastal areas, where

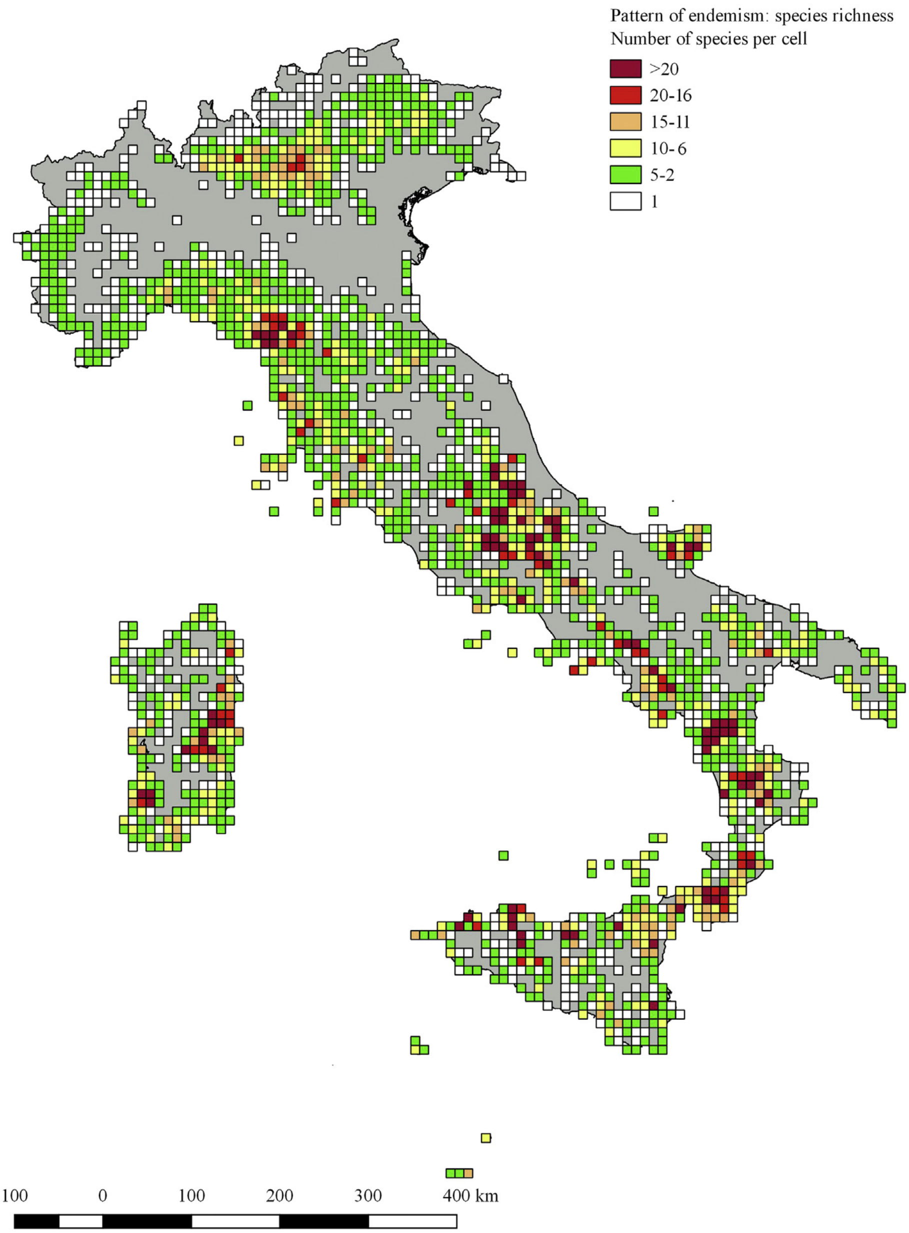

Fig. 4. Distribution map showing the number of the Italian endemic vascular plants recorded in 10 km × 10 km quadrats. ERAs are in dark red (n > 20 taxa). In grey cells, no endemic taxa have been reported. Taxa assigned to EX, EW, CR(PE) and DD categories were not considered in the analysis. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

increased tourism impact and residential development have caused dramatic habitat changes, with consequent loss of suitable habitat (e.g., Fenu et al., 2013; Lhotte et al., 2014).

It is noteworthy that 18.4% (247) of taxa were assessed as Data Deficient. The high percentage of DD species highlights the importance of accurate taxonomic knowledge in conservation assessment (Callmander et al., 2005). This seems particularly relevant for some apomicts like *Alchemilla*, *Hieracium*, *Pilosella* and *Taraxacum*, which were assigned mostly to DD category due to difficulties in the identification of (micro)species by field botanists. The high percentage of Data Deficient cases points towards the need for further taxonomical, biological, ecological and biogeographical analyses of endemic species, to update their distribution and to facilitate their conservation.

The analysis of endemic species richness highlighted areas where endemic species cluster together (Fig. 4) or where the highest diversity of narrow endemic species can be found (Fig. 5). Implications of these analyses are important because they allow the identification of areas of potential conservation importance and the focusing of direct conservation management actions in geographical areas with the highest levels of plant diversity (Crain et al., 2011) or with high concentration of narrow endemic species (Wulff et al., 2013). Our choice to restrict endemic taxa to national boundaries, has unavoidably caused the underrepresentation of taxa endemic to the alpine biogeographic region in our dataset, despite it being a well-known European biodiversity hotspot (Aeschimann et al., 2011 and reference therein). For alpine taxa, the extinction risk should be assessed using a biogeographical approach involving all the countries hosting their ranges, and a unique threat category should be adopted by each country to facilitate the convergence of action plans in different administrative areas and to avoid unnecessary conservation efforts (Gentili et al., 2011). Alternatively, at least for taxa growing close to national borders, risk assessments should be done twice, once by a country basis and once by a biogeographic region basis. Nevertheless, the analysis of patterns of endemism using range weighting reveals that the Alps host also many narrow endemic

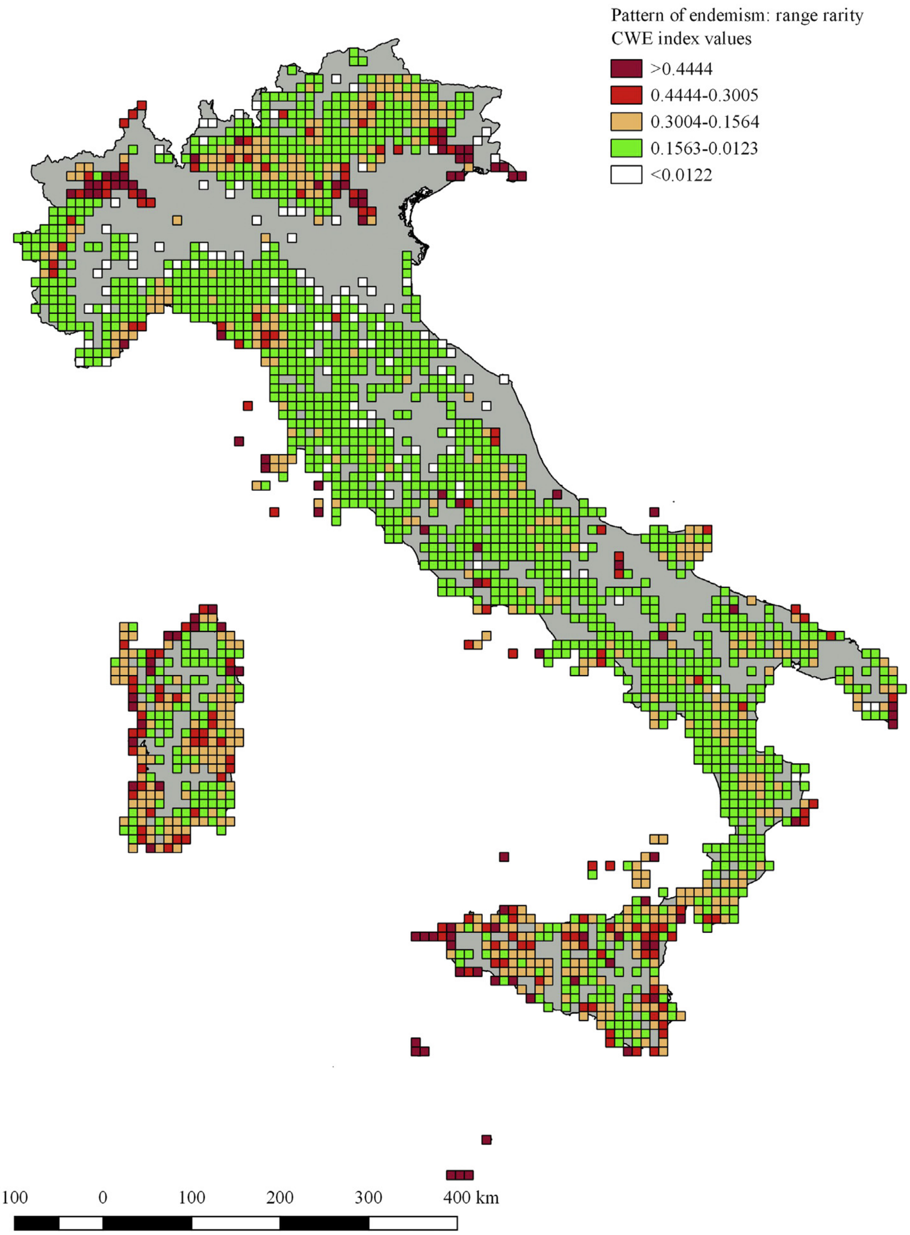

Fig. 5. Distribution map showing the spatial pattern of range-rarity richness using the CWE index in 10 km × 10 km quadrats. NERAs are in dark red (CWE index ≥ 0.4444). In grey cells, no endemic taxa have been reported. Taxa assigned to EX, EW, CR(PE), and DD categories were not considered in the analysis. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

taxa confined to Italy. This is consistent with the high level of narrow endemic species recorded in the south-western and eastern Alps (Aeschimann et al., 2011). NERAs are also concentrated in the near-coastal cells of Sardinia, Sicily, and minor islands. This is not surprising, since in small islands and in coastal areas the highest diversity of some of the most representative Italian endemic genera like *Limonium*, *Centaurea*, and *Genista* can be found. The analysis of threats affecting endemic plants suggests that the human pressure connected with agriculture, residential and commercial development or recreational activities is a key driver of extinction risk. Approximately two-thirds of the Italian endemics are threatened by anthropogenic, direct and/or indirect, disturbance. Population density and related human activities are recognized as main threats in all the Mediterranean biome (Underwood et al., 2009). Among indirect threats, we can include climate change; although it does not currently have a significant impact on species conservation (Fig. 3), it is strictly connected with natural system modifications like an increase in frequency of fires (Pausas and Fernández-Muñoz, 2012) and water management and use, both listed among the main threats to the conservation of Italian endemic plants (Table A2). Especially in coastal areas, increased tourist inflow has negative impacts on the endemic flora (e.g., Ballantyne and Pickering, 2013; Fenu et al., 2013) and can produce detrimental consequences, such as in Sicily, where the extinction of some endemic taxa and the fast decline of some species related to sandy dunes habitats or coastal areas (e.g.: *Limonium* or *Dianthus* species) have been reported (Orsenigo et al., 2017). This is particularly alarming, if we consider the high number of NERAs in near-coastal cells, especially in major and minor islands.

On the other side, the abandonment of traditional agricultural practices (i.e. mowing, nomadic grazing) or the shift to intensive farming or livestock have strongly contributed to habitat loss or modification in the Mediterranean Basin (Plieninger et al., 2014) resulting in a major threat for endemic species also in Italy (Baiamonte et al., 2015; Astuti et al., 2018).

Our analyses reveal that ERAs partially overlap with protected areas

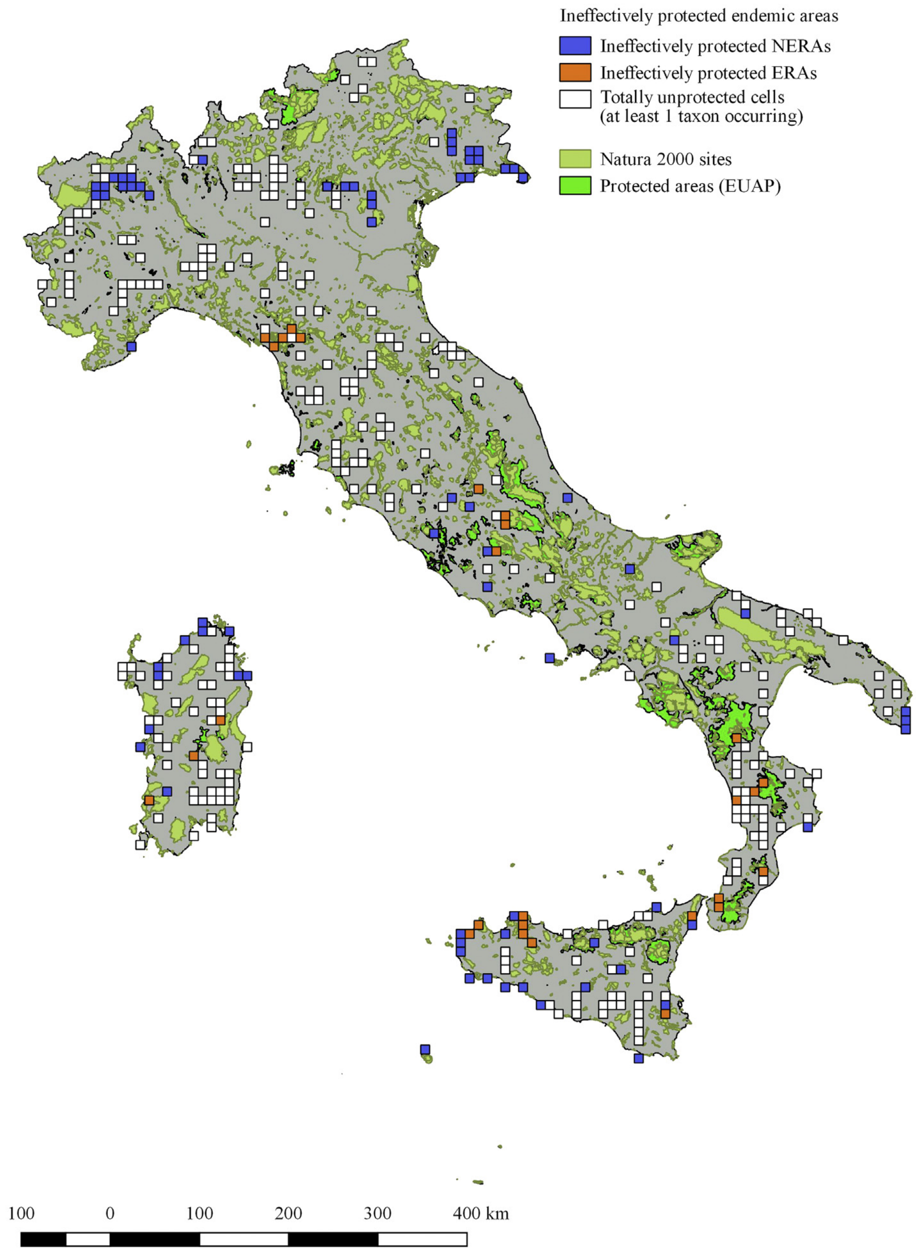

Fig. 6. Natural protected areas included in the gap analyses: EUAP protected areas (bright green); Natura 2000 sites (pale green). Blue squares represent NERAs 10 km × 10 km quadrats ineffectively protected (< 50% of cell surface included in protected areas); orange squares represent ERAs 10 km × 10 km quadrats ineffectively protected (< 50% of cell surface included in protected areas); white squares represent totally unprotected cells containing at least one endemic, not protected taxon. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

(Fenu et al., 2017b). Similar results were obtained also by Brundu et al. (2017) concerning the degree of protection of type localities of Italian endemic plants. ERAs include both high and low altitude mountains and sites with different human impacts. On the contrary, 70.5% of NERAs are mainly ineffectively protected by Italian system of protected areas, with 8.6% of areas rich in narrow endemic taxa completely uncovered by protected areas and Natura 2000 networks. The current Italian system of protected areas covers about a quarter (24.7%) of the country (percentage increased in the last decade compared to Rosati et al., 2008, who reported 20.3% of protection for the country), a percentage higher than required by international targets (Watson et al., 2014). Despite this, more efforts should be done to include further ERAs, NERAs and unprotected endemic taxa in protected areas, since from our results it emerges that GSPC Target 5 has been only partly accomplished. For example, the institution of small size protected areas (< 20 ha), defined to protect a population of a single or of a group of narrow endemic, rare or threatened plant taxa, following the Spanish experience (Laguna et al., 2004), could have positive effects on conservation of endemic species and increase the NERAs protection. Moreover, it becomes urgent to develop and put into practice specific conservation measures which are, at present, missing for most of the considered taxa. Finally, more detailed analyses are needed to understand which areas host the highest phylogenetic diversity or the higher evolutionary distinctiveness, as a further element of prioritization of conservation actions (Isaac et al., 2007; Faith, 2008; Jenkins et al., 2014).

5. Conclusions

As a priority action, in situ conservation efforts (e.g., enlargement of

Table 1
List of threatened taxa fully unprotected (i.e.: their AOO is completely outside protected areas) by protected area system.

Taxa	Category	AOO (km^2)
Centaurea corensis Vals. & Filigh.	CR	4
Epipactis zaupolensis (Barbaro & Kreutz) Bongiorni, De Vivo & Fori	CR	4
Genista bocchierii Bacch., Brullo & Feoli Chiapella	CR	4
Limonium catanzaroi Brullo	CR	4
Limonium opulentum (Lojac.) Brullo	CR	4
Limonium sibthorpianum (Guss.) Kuntze	CR	4
Limonium tauromenitanum Brullo	CR	4
Malva stenopetala (Coss. & Durieu ex Batt.) Soldano, Banfi & Galasso subsp. *plazzae* (Atzei) Iamonico, Bartolucci & Peruzzi	CR	24
Rhinanthus helenae Chabert	CR	4
Salvia ceratophylloides Ard.	CR	4
Serapias nurrica Corrias subsp. *santuingensis* (Senis, M.P. Grasso & Orrù) Senis, M.P. Grasso & Orrù	CR	4
Clinopodium raimondoi Spadaro, A.S. Faqi & Mazzola	VU	4
Dianthus vulturius Guss. & Ten. subsp. *aspromontanus* Brullo, Scelsi & Spamp.	VU	4

existing protected areas, institution of new small size protected areas) should be directed to those areas standing out as particular conservation hotspots for Italian endemic plants currently ineffectively protected. Moreover, particular attention should be addressed to NERAs in coastal areas and small islands, as well as in the Alps and in residual high-naturalistic valued hilly and plain sectors. In these areas, monitoring efforts should be strengthened, in order to prevent the erosion of the natural irreplaceable heritage. Secondly, urgent measures should be undertaken to prevent the extinction of endangered species, starting from the 93 taxa classified as Critically Endangered, but possibly extending to all the 300 threatened species, in order to halt or prevent the worsening of their status. For these taxa, conservation measures (e.g., habitat protection, ex situ conservation, population reinforcement) cannot be further postponed.

In general, a conservation-oriented management strategy of the national territory should reduce the human impact, especially in coastal areas, but also should maintain traditional agriculture activities to counteract land abandonment.

Information provided in the present study will be useful in the future to measure trends of the overall extinction risk of endemic plants through the Red List Index (Brummitt et al., 2015).

Further priorities for a successful conservation strategy of Italian endemic vascular plants are:

- Improvement of taxonomic knowledge in apomictic and poorly known genera;
- Improvement of distribution data and population trends, starting from DD species;
- Development and implementation of action plans including conservation actions, legal protection, establishment of new and targeted protected areas, ex situ conservation and translocation.

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