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ORIGINAL ARTICLE

Assessment of the conservation status of the mat-forming lichens *Cladonia* subgenus *Cladina* in Italy

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Abstract
Cladina species are likely to suffer the impact of human pressure, resulting in a potential, as well as currently unknown, extinction risk for some of them. In this study, we used herbarium specimen data and literature data combined with geographic information system (GIS)-based analyses to assess the threatened status of Italian *Cladina* species according to IUCN criteria. A total of 485 records, reported during the period 1833–2013, were evaluated. Biological traits, habitat requirements and distribution patterns were used to infer species extinction risk. Extent of occurrence and area of occupancy have been calculated at the national scale, based on a 2 km × 2 km cell grid. The potential threats for the taxa were assessed using a decision-support protocol in order to set conservation targets for taxa lacking population viability analyses and habitat modelling data. The species were assigned to the IUCN categories mainly using the geographical criterion B, related to species with restricted and fragmented distribution and continuous declining trend, but the species have been tested against the maximum number of criteria for which data were available and/or appropriate. This has provided an opportunity to discuss some basic aspects of the process of lichen red-listing, suggesting some methodological improvements for the mat-forming ones.

Keywords: *Extinction risk, fragmentation, habitat directive, habitat loss, lichen conservation*

Introduction

European nature conservation policy is mainly based on a network of protected sites and on a set of habitats and species worth of protection (Policy Species), the Bern Convention and the "Habitat Directive" (92/43/EEC) being the keystone tools to prevent biodiversity loss in Europe. In this directive, lichens are under-represented, reflecting their scarce presence in the European (Sérusiaux 1989) and global (Scheidegger 2003; Yahr 2003) red lists (Martín-López et al. 2011). This situation is mainly related to the difficulties in applying IUCN criteria (2001) for lichen red-listing (Scheidegger & Goward 2002). Although IUCN criteria were developed to be applicable to almost all species, they were mainly used for mammals, vascular plants and for species which are easily sampled. However, research aiming to fill this gap by providing plausible adaptations of IUCN criteria to the case of overlooked organisms is rapidly increasing (e.g. Hallingbäck et al. 1998; Dietrich et al. 2000; Keller et al. 2005; Cardoso et al. 2011; Dahlberg & Mueller 2011), giving new perspectives for a wider inclusion of lichens in conservation plans.

The only lichens included in the Habitat Directive are those belonging to *Cladonia* L. subgenus *Cladina* (Nyl.) Vain. that are listed in the annex V, among species whose collection taking in the wild and exploitation may be subjected to management measures.

These species play important ecological roles, e.g. reducing soil moisture evaporation (Rouse & Kershaw

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1971), improving the net N mineralization and net nitrification in forest habitats (Lamontagne & Schiff 2000), and providing food for wildlife by foraging during winter (Kumpula 2001). Intensive grazing and overexploitation have historically threatened *Cladina* species in Northern Europe (Suominen & Olfosson 2000) where their commercial harvest started at the beginning of the twentieth century (Lynge 1921; Llano 1948; Kauppi 1979, 1993; Sveinbjörnsson 1987, 1990; Helle et al. 1990; Kumpula 2001). Further sources of threat for *Cladina* species arise from forest management, gravel quarrying, trampling (Kauppi 1979; Berg et al. 2008), pollution (Moser et al. 1980), dunal habitat perturbation (Gallego Fernández & Díaz Barradas 1997), burning (Webb 1998), soil scarification (Eriksson & Raunistola 1990) and overbrowsing (Suominen & Olfosson 2000).

Most of the Italian *Cladina* species have a broad circumpolar distribution throughout the northern hemisphere, and some taxa (e.g. *Cladonia arbuscula* and *C. mitis*) also have a "bipolar" distribution pattern (Myllys et al. 2003). Species related to both Alpine and Mediterranean environments are included in the national checklist (Nimis & Martellos 2008). In both environments, *Cladina* species are likely to suffer human pressure that may be related with the effects of climate change at higher elevation and touristic exploitation in coastal ranges, resulting in habitat loss and fragmentation. However, except for some general comments on their rarity/commonness provided by Nimis and Martellos (2008), the threatened status of these species is currently unknown, hindering an evaluation of the effectiveness of European policies for their protection and the development of appropriate conservation measures.

This study aims at providing support for the possible inclusion of the Italian lichens of the *Cladina* group in a national red list (Rossi et al. 2014), in conservation plans and at giving a science-based contribution to the implementation of the Habitat Directive in Italy. In particular, we used herbarium specimen data and literature data combined with GIS-based analyses of the geographic distribution of collections (Rivers et al. 2010) to assess the conservation status of the Italian *Cladina* species according to IUCN criteria. To achieve this task, several key parameters of the red-listing process have been addressed for the assessment of the conservation status of mat-forming lichens.

Materials and methods

Target species and data survey

The taxonomic position of lichens of the *Cladina* group is still under investigation (Ahti & DePriest 2001; Carbonero et al. 2002; Stenroos et al. 2002) and in this paper we consider species with a *Cladina* morpho-type, also known as "forage lichens", "mat-forming lichens" or "reindeer lichens" (Table I). Taxa were evaluated at the species level. Nomenclature followed Index Fungorum (http://www.indexfungorum.org/), while information on the global distribution pattern of the species was retrieved from Wirth (1995).

For each species, we accessed (a) herbarium specimens stored in the main Italian herbaria FI, GE, RO, TO and TSB (herbarium acronyms according to Holmgren et al. 1990), (b) herbarium specimens stored in our private herbaria, (c) the online checklist of Italian lichens (Nimis & Martellos 2008) and (d) all the available literature, including grey literature and occasional field data in order to establish:

(1) The number and the geographic position of the localities where the species are reported from 1833 to 2013. We have considered all the records for which it was possible to retrieve coordinates. Two records belonging to the same

Table I. Prevalent distribution and habitat of the *Cladina* spp.

Species	Distribution	Habitat
Cladonia arbuscula (Wallr.) Flot.	Boreal-temperate	Lichen-tundra vegetation
Cladonia mitis Sandst.	Arctic-Mediterranean, continental	Lichen-tundra vegetation, in rather dry, exposed situations
Cladonia rangiferina (L.) Weber ex F.H. Wigg.	Boreal-temperate	Lichen-tundra vegetation
Cladonia ciliata Stirt.	Boreal atlantic-temperate subatlantic-Mediterranean atlantic	On mosses in shrublands and in undisturbed maquis vegetation
Cladonia mediterranea P.A. Duvign. & Abbayes	Mediterranean-Macaronesian	On basic soils forming low clumps amongst shrub vegetation
Cladonia portentosa (Dufour) Coem	Temperate-Submediterranean, subatlantic	On heaths and moors and surfaces of peat bogs
Cladonia stellaris (Opiz) Pouzar & Vězda	Boreal-temperate Alpine, subcontinental	On poor soils and gravel. In the Alps, it is mainly restricted to shrubby vegetation with *Rhododendron* and *Pinus mugo*
Cladonia stygia (Fr.) Ruos	Arctic-temperate Alpine	In wet, boggy habitats. In the Italian Alps, it is known from a single site

locality and collected in the same year (e.g. a collection that was testified by both literature and herbarium data) have been counted as one. In the case of two records related to the same locality in different years, the most recent was considered a confirmation of the taxon in that place;

(2) The association of each species with a habitat of conservation concern that in Italy is declining due to reduction, destruction and fragmentation according to Petrella et al. (2005) and the Italian Ministry of Environment (MATTM) (2008). This information was only applied when the classification of the habitat was deducible from the MATTM's database (2012) of the Italian Special Areas of Conservation (SACs);

(3) Threats and pressures affecting *Cladina* species and their habitats. Factors of threats and pressures have been codified in accordance to threats taxonomy elaborated by IUCN and Conservation Measures Partnership (IUCN – CMP version 3.2, 2012).

Application of IUCN criteria

According to IUCN methodology, each taxon should be evaluated against all the five criteria (A–E) in order to define the most appropriate degree of risk of extinction. The assessment is properly carried out according to the criterion, or criteria, for which the risk of extinction is higher. The key points are summarized further in the text. For a more detailed description of the criteria, see IUCN (2001, 2014).

Criterion A. This criterion is based on the rate of population decline. To include a species in the category of lower threat (Vulnerable), its decline must be higher than 30% and lower than 49% (or must be included between 50% and 69% if the causes of the reduction are reversible and understood and have ceased) in a period of 10 years or three generations. For the inclusion of the species in the categories of highest threat (Endangered or Critically Endangered), the decline must be greater, progressively increasing to 90% when the causes of the reduction are reversible and understood and have ceased. In order to proceed with red list assessment by means of this criterion, we used the growth stages of *Cladina* spp. as reference to determinate the generation period.

Reindeer lichens have a growth accumulation period which lasts an average of 10 years, but can vary from 6 to 25 years (Fink 1917). The following growth stages (renovation and withering periods) may reach 120 years, and average ages of over 100 years have been reported (Ahti 1959). Using these data and the formula (IUCN 2014): age of maturity + 0.5 (length of reproductive period in life cycle), generation period of *Cladina* spp. can be estimated at 60 years [10 + (0.5 (110−10)]. This may provide a rough proxy for the generation period for *Cladina* spp.

Criterion B. This criterion is based on the size of the distribution range of the species and its ongoing or expected decline. In general, a species is considered more sensitive when its range is small. According to criterion B, a species is threatened if it has a restricted distribution (e.g. less than 20,000 km^2 for the inclusion of a species in the Vulnerable category) and meets almost two among three other requirements: (i) the populations are severely fragmented or comprised in a small number of locations, (ii) the distribution area, or the number of sites, or number of mature individuals are in decline, or the quality of the habitat of the species is deteriorating, (iii) the distribution area, or the number of sites or the number of mature individuals have temporal fluctuations.

For each species, the extent of occurrence (EOO) and the area of occupancy (AOO), being the main parameters related with criterion B, have been calculated in a GIS environment, based on georeferenced data of species occurrences.

EOO has been estimated through the calculation of the minimum convex polygon (convex hull) encompassing all the sites of occurrence of a given species (IUCN 2014). Discontinuities and disjunctions have been included in the computation to reflect the extent to which a large range size reduces the chance that the entire population of the species will be affected by a single threatening process (IUCN 2014).

AOO has been calculated as the sum of 2 km × 2 km cells occupied by the species in a fixed, standardized grid covering all Italy (Gargano 2011; IUCN 2014). We consider that a distance among sites greater than 50 km indicates severe fragmentation.

Criterion C. Criterion C is suited to small declining populations and it is based on the number of mature individuals. Criterion C1 requires the rate of decline to be quantified. If the decline cannot be measured or it is not sufficiently severe to comply with C1, criterion C2 may be used. The criterion C2 allows the use of an unquantified continuous decline, but each subpopulation of the species should consist of a few mature individuals (≤1000 mature individuals in each subpopulation to be considered Vulnerable; ≤50 to be considered Critically endangered) or 90–100% of mature individuals with respect to the total number of individuals in one subpopulation, depending on the level of risk.

Criterion D. Criterion D is exclusively applied to species whose populations, or area of distribution is extremely small: less than 1000 mature individuals, or occupied area of less than 20 km^2 for the inclusion of a species in the Vulnerable category, even lower thresholds of number of mature individuals for higher categories of threat.

Criterion E. It differs from all previous criteria, being based on the estimated probability of extinction of a species in a given time span. These probability estimates are based on models that simulate the demographic trend of the species (population viability analysis) and require data on population size across time series.

Results

General overview

A total of 485 records reported between 1833 and 2013 were included in the assessment. The time period was selected in order to compare the current range (period 1953–2013 relating to the last generation of species) with the historical distribution (1833–1952) namely the range relative to a time corresponding to the previous two generations. For each species, number of records and localities, distribution range and range reduction (loss ratio of AOO and EOO expressed as a percentage), and pressures and threats have been provided (Table II).

With some limitations related to both the nature of the lichen symbiosis and the lack of detailed information about the *Cladina* group, we evaluated the conservation status of Italian *Cladina* species using criteria A, B and D for Vulnerable category (Table III). Distribution range analysis and loss of sites of occurrence support the classification of *Cladonia ciliata*, *C. mediterranea*, *C. portentosa* and *C. stellaris* as Endangered (EN), while *Cladonia arbuscula*, *C. mitis* and *C. rangiferina* are currently classified as species of Least Concern (LC).

Detailed evaluation of the species

Cladonia ciliata and *C. portentosa* meet the criterion B2ab(i,ii,iii), as they have a small fragmented occupied range (AOO less than 500 km^2 meeting criterion B2a) and have a declining trend (b) in EOO (i), AOO (ii), area, extent and quality of preferred habitat (iii). *Cladonia ciliata* can be classified as Endangered with criterion A as well, given the severe decline (>50%) of its distribution range (EOO; Table III). Currently, the threatening factors responsible for past reduction of habitat still persist, preventing re-colonization and confirming its EN status also according to criterion A2c. *Cladonia ciliata* is known from a few localities mainly distributed

Table II. Summary of the elements of criteria A, B and D used to evaluate the threat category of *Cladina* spp.

Criterion	Category		
	CR	EN	VU
A. Declines measured over one generation			
A1. Population reduction (%) observed, estimated, inferred, or suspected in the past where the causes of the reduction are clearly reversible and understood and ceased based on and specifying any of the following: (a) direct observation, (b) an index of abundance (c) a decline in AOO, EOO and/or habitat quality, (d) actual or potential levels of exploitation and (e) effects of introduced taxa, hybridization, pathogens, pollutants, competitors or parasites	>90	>70	>50
A2. Population reduction (%) observed, estimated, inferred, or suspected in the past where the causes of reduction may not have ceased or may not be understood or may not be reversible, based on any of (a) to (e) under A1			
A3. Population reduction (%) projected or suspected to be met in the future (up to a maximum of 100 years) based on any of (b) to (e) under A1	>80	>50	>30
A4. An observed, estimated, inferred, projected or suspected population reduction (%) (up to a maximum of 100 years) where the time period must include both the past and the future, and where the causes of reduction may not have ceased or may not be understood or may not be reversible, based on any of (a) to (e) under A1			
B. Geographic range in the form of either B1 (EOO) OR B2 (AOO)			
B1. Either EOO (km^2)	<100	<5000	<20,000
B2. or AOO (km^2) and	<10	<500	<2000
(a) severely fragmented or n. locations	=1	≤5	≤10
(b) continuing decline in (i) EOO, (ii) AOO, (iii) area, extent and/or quality of habitat and (iv) number of locations or subpopulations			
D. Very small or restricted population			
Restricted AOO (km^2)	–	–	AOO < 20 Location ≤ 5

Notes: CR, critically endangered; EN, endangered; VU, vulnerable. According to IUCN criteria.

Table III. Assessment of the *Cladina* spp.

Species	Records (1833–2013)	Locations in the last 50 years	Past AOO (km^2)	Past EOO (km^2)	Current AOO (km^2)	Current EOO (km^2)	Information lost in the last 50 years (%) AOO	Information lost in the last 50 years (%) EOO	Pressures (P)/Threats (T)	Assessment
Cladonia arbuscula	137	57	320	192,600	296	192,600	7.5	0	1.1 Housing and urban areas (P), 5.2.1 Intentional use (T), 9.5 Air-borne pollutants (P)	LC
Cladonia mitis	73	47	0	0	180	93,810	0	0	5.2.1 Intentional use (T), 9.5 Air-borne pollutants (P), 11.1 Habitat shifting and alteration (P, T)	LC
Cladonia rangiferina	136	78	384	401,800	360	401,800	6.25	0	5.2.1 Intentional use (T), 9.5 Air-borne pollutants (P), 11.1 Habitat shifting and alteration (P, T)	LC
Cladonia ciliata	34	7	60	320,300	24	154,600	40	52	1.3 Tourism and recreation areas (P, T), 6.1 Recreational activities (P, T), 7.1.1 Increase in fire frequency/intensity (P, T), 8.1 Invasive non-native/ alien species/diseases (P), 9.5 Air-borne pollutants (P)	EN A2c + B2ab(i,ii,iii,iv)
Cladonia mediterranea	28	20	80	269,200	72	254,900	9	6	1.3 Tourism and recreation areas (P,T), 6.1 Recreational activities (P, T), 7.1.1 Increase in fire frequency/intensity (P, T), 8.1 Invasive non-native/alien species/diseases (P), 9.5 Air-borne pollutants (P)	EN B2a(iii)
Cladonia portentosa	37	8	64	56,210	36	47,790	43.75	14.9	7.3 Natural system modifications (P, T)	EN B2ab(i,ii,iii,iv)
Cladonia stellaris	33	17	108	73,880	96	25,090	11	66	5.2.1 Intentional use (T), 9.5 Air-borne pollutants (P), 11.1 Habitat shifting and alteration (P, T)	EN A2c + B2ab(i,ii,iii)
Cladonia stygia	1	?	–	–	–	–	–	–	5.2.1 Intentional use (T), 9.5 Air-borne pollutants (P), 11.1 Habitat shifting and alteration (P, T)	DD

Notes: Number of records and locations, EOO and AOO, the loss ratio (%) of distribution in the period 1963–2013, pressure and threats are reported for each Italian species. In the second column, the term "record" refers to each documentation of the presence of the species from literature and herbaria data, unless they relate to the same site in the same year; in the third column, the term "location" refers to each site for which at least one record in the period 1963–2013 was found. "?" used for *C. stygia* means lack of details. Pressure and threats are reported according to IUCN Threats Classification Scheme (Version 3.2).

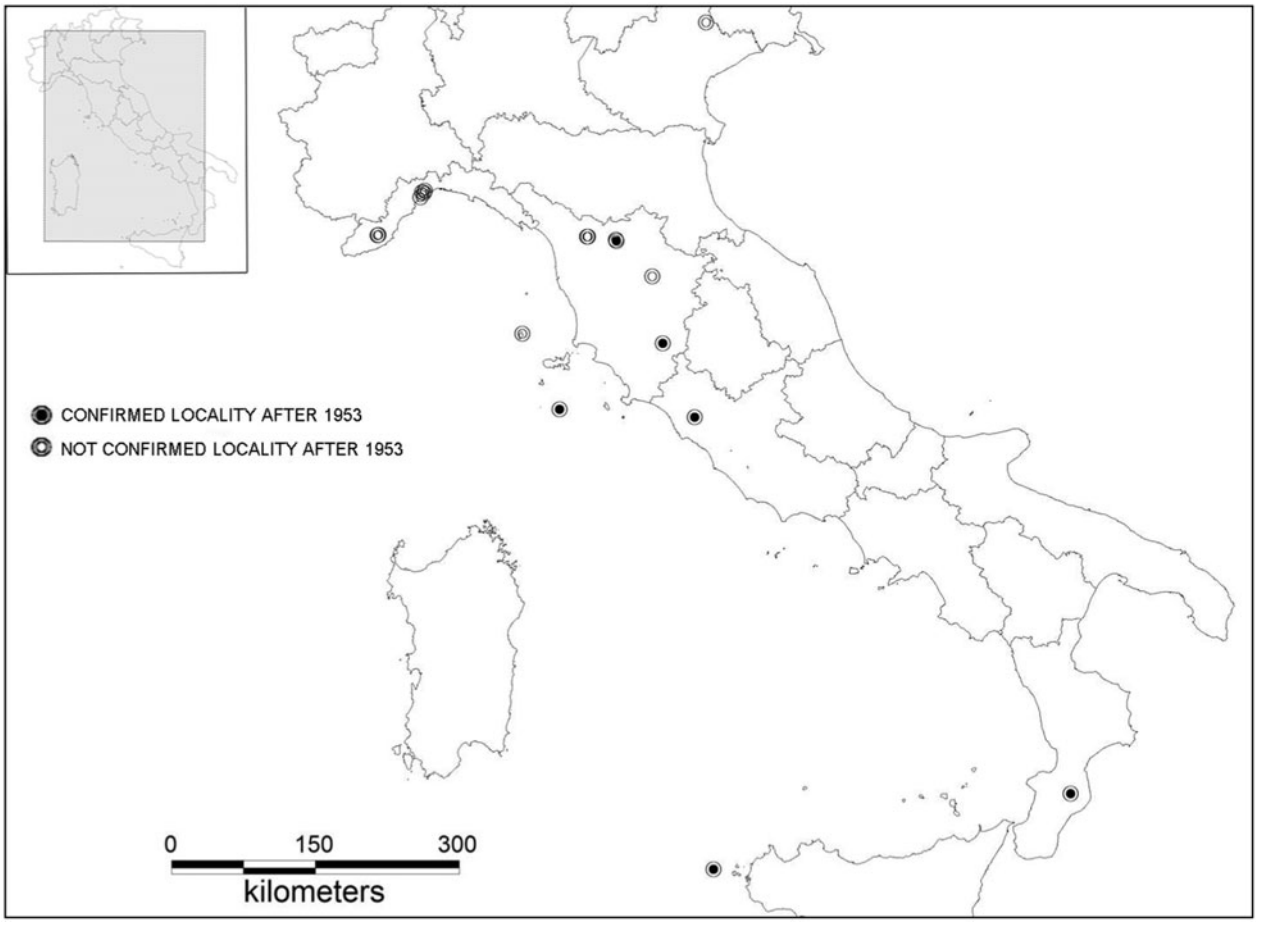

Figure 1. Records of *Cladonia ciliata* in Italy.

along Tyrrhenian Italy (Figure 1), most of old records being currently located in urbanized areas. *Cladonia portentosa* is characteristic of moorland vegetation in upland areas, colonizing scattered patches of soil on outcrops and boulders. The Italian records of this species indicate a highly fragmented distribution (Figure 2).

Subpopulations of *Cladonia mediterranea* are small sized and severely fragmented (Figure 3). Some subpopulations are included in protected areas, but most of them are subjected to strong anthropic pressures due to coastal management. This lichen is classified as Endangered because of restricted range (B2), fragmentation of the populations (a) and continuing decline in (iii) habitat quality.

Cladonia stellaris is classified as Endangered according to criterion A2c. Italian subpopulations are currently small sized, relatively isolated and restricted to the Alps (Figure 4). The Endangered status is due to the loss of occurrence in the most Southern stands along the Northern Apennine and a continuing decline in extent of the specific habitat.

Cladonia arbuscula and *C. mitis* are widely distributed over the entire Alpine area. *C. arbuscula* also grows in the high mountains of Sardinia, but it is likely to be declining along the Northern Apennine (Figure 5), where this species was not found during recent surveys in that area (Benesperi, unpublished data) and *C. mitis* has been confirmed (Figure 6). *Cladonia rangiferina* is the most widespread among Italian *Cladina* species (Figure 7). Since these three species are relatively common in their specific habitats and do not suffer imminent threats determining decline in the immediate future, they are currently considered of LC.

Cladonia stygia is listed in the Italian checklist (Nimis & Martellos 2008) as collected in Valle d'Aosta where it is strictly protected (Regional law n. 45, 7th December 2009). However, there is no detailed information about sites of occurrence and collected samples were lost (Nimis, pers. comm.). For this reason, the species is currently assigned to the category Data Deficient (DD), being in need of further research.

Discussion

In this study, we used all available information to assess the status of *Cladina* species, recognizing that

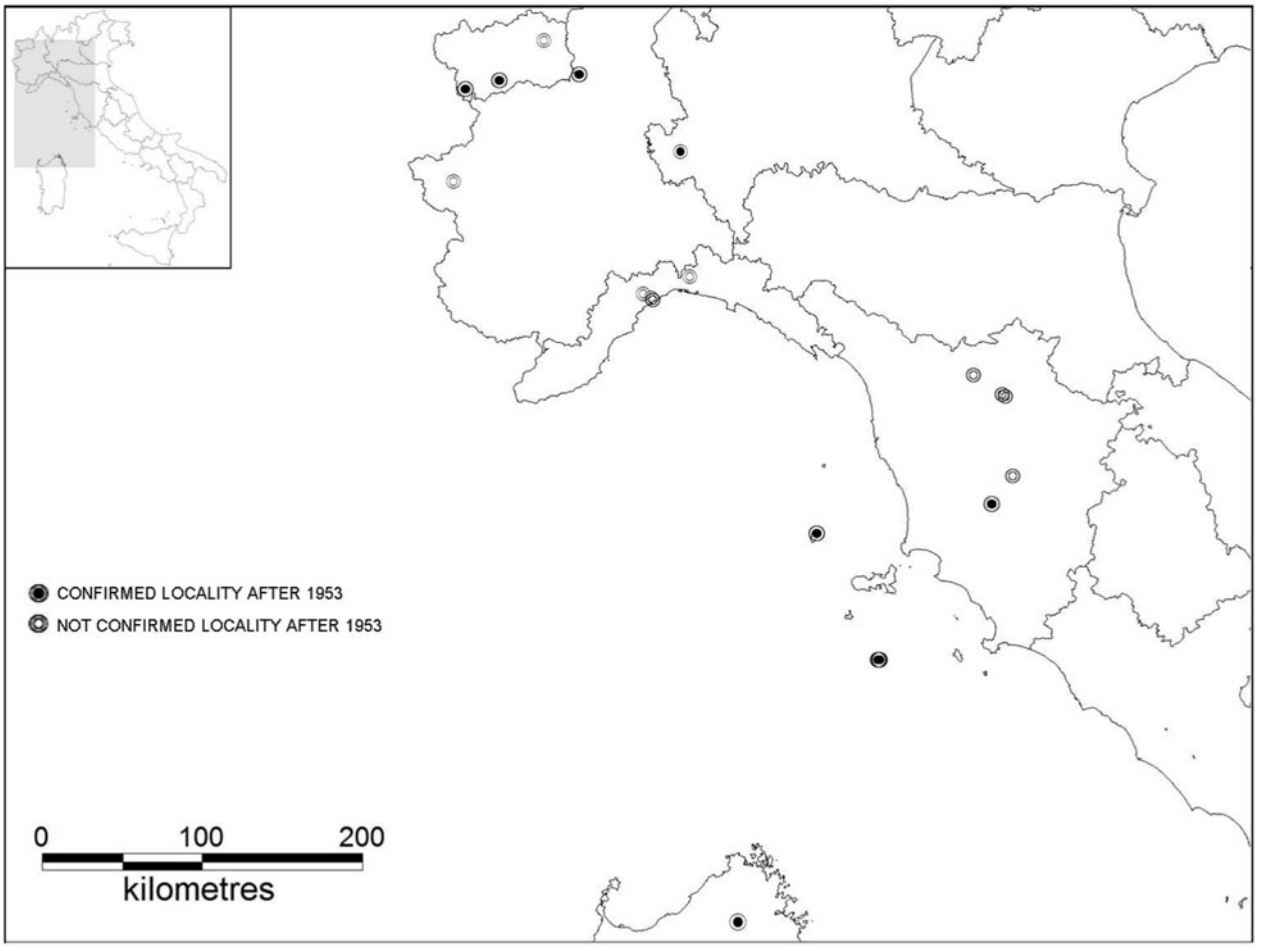

Figure 2. Records of *Cladonia portentosa* in Italy.

data recorded are often extremely patchy and this could affect the results. For historical reasons and lack of experts (Nimis & Martellos 2003), the epigeic lichen flora of central-southern Apennines was only occasionally included in floristic surveys (Nimis & Tretiach 1999, 2004; Ravera et al. 2006) and is still little known. However, although the work is not based on a systematic exploration of the territory, the latest floristic studies on the Alps (e.g. Piervittori & Isocrono 1999; Thor & Nascimbene 2006; Nascimbene 2008; Nascimbene et al. 2012; Matteucci et al. 2013) and in the dune systems (e.g. Potenza et al. 2010; Benesperi et al. 2013), which include elected habitats for *Cladina*, are considered sufficient for an overview of the current situation and a discussion on the applicability of IUCN criteria.

Our results indicate that in Italy four *Cladina* species are facing an extinction risk, while three species are still common and abundant at least in the higher mountains. The main source of threat for these species is habitat loss or change leading to a highly fragmented distribution of the sub-populations. In general, our study confirms results from Central Europe where terricolous lichens were found to have experienced a decline in area of distribution during the twentieth century (Hauck 1992, 1996) due to fertilization, overgrazing, habitat loss (Wirth 1995; Hauck 1996; Bültmann 2005), intensive forest management (Berg et al. 2008), acid precipitation (Hauck 2008) and climate change (Aptroot & van Dobben 2002).

The evaluation of the conservation status of the species on the basis of IUCN criteria is the first step to enhance conservation activities. However, our work emphasizes that even this step may be problematic for lichens, mainly due to lack of data and objective problems in the rigorous application of IUCN criteria, that require a flexible interpretation (Hodgetts 2000; Dahlberg & Mueller 2011; Nascimbene et al. 2013). Our experience indicates that the main constraints are related to the application of criteria based on mature individual counts, estimates of population size and spatial dynamics. Due to difficulties in transposing these elements of IUCN assessment to lichens, criteria C, D and E were not eligible as well as several subcriteria of criteria A and B. Basically, C and D criteria, as all subcriteria based on mature individual counts, were

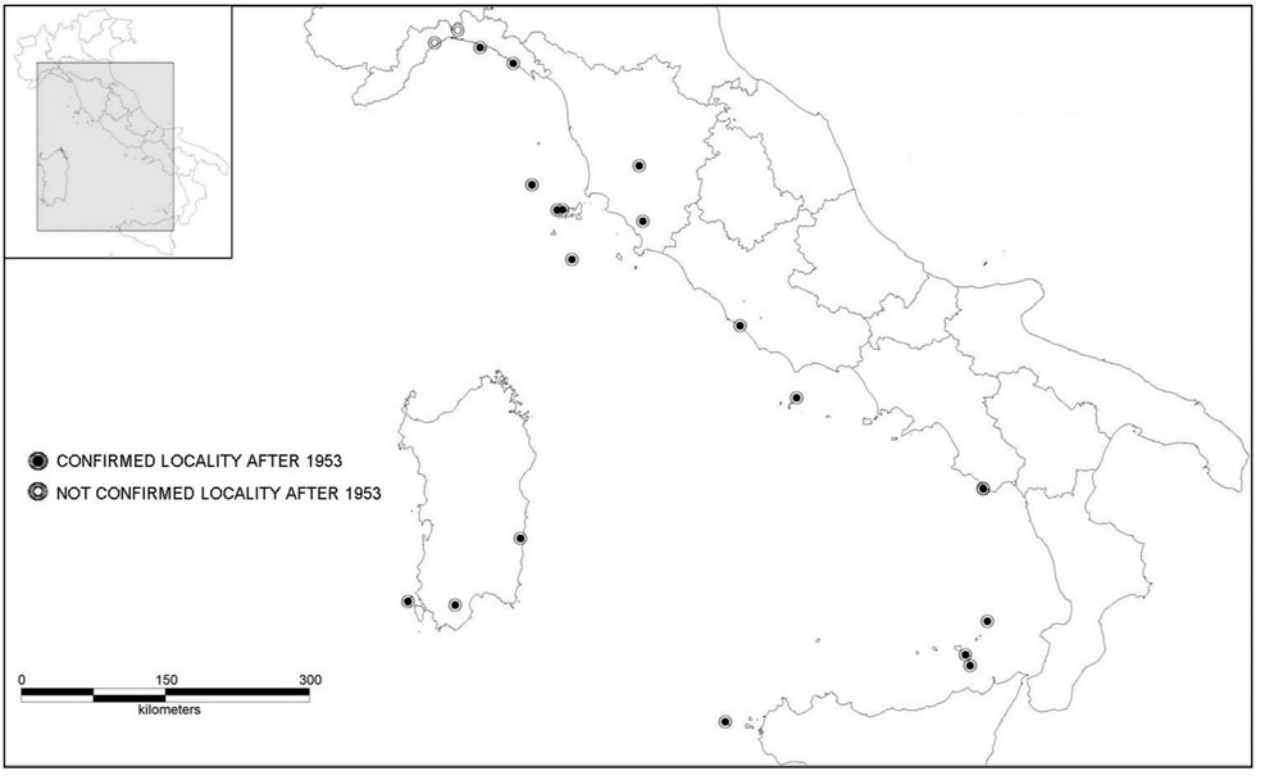

Figure 3. Records of *Cladonia mediterranea* in Italy.

not applicable to lichens with a mat-forming habit (e.g. *Cladina*, *Stereocaulon*, *Cetraria*) since it is not possible to distinguish a single genetic individual in a lichen mat (Ahti 1961; Beard & DePriest 1996). In assessing the status of epiphytic lichens, this problem can be solved adopting the concept of "functional individual", including all conspecific thalli inhabiting a tree individual from which their survival depends (Scheidegger & Goward 2002; Scheidegger & Werth 2009). Thalli of several

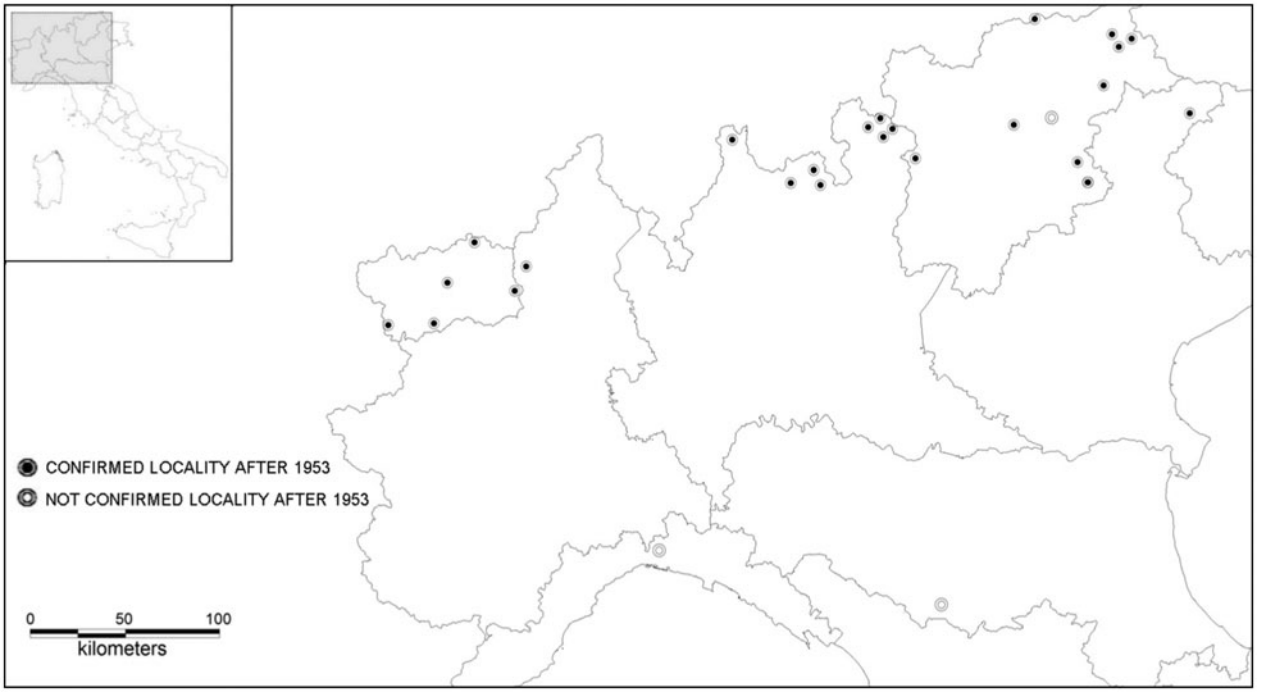

Figure 4. Records of *Cladonia stellaris* in Italy.

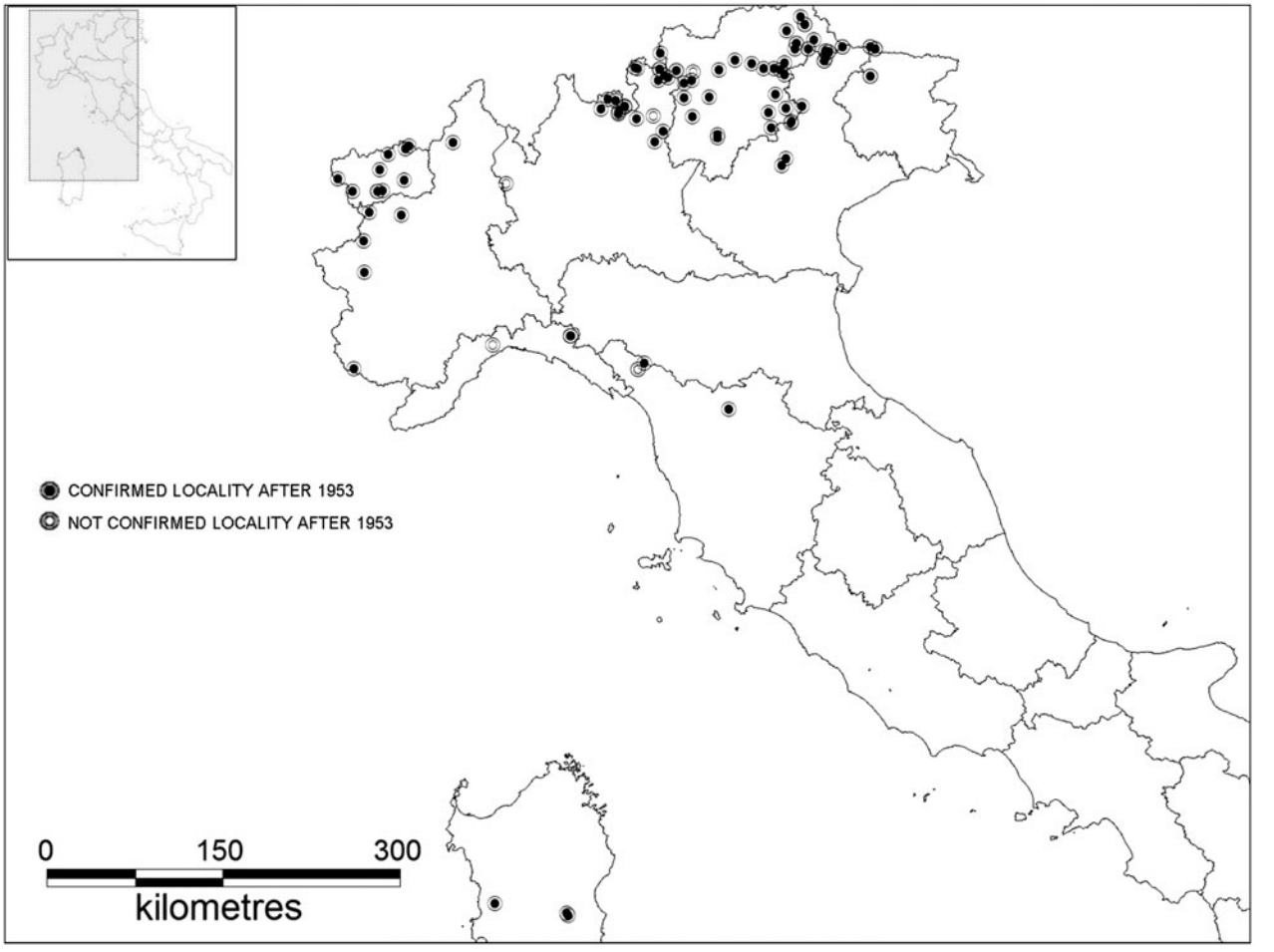

Figure 5. Records of *Cladonia arbuscula* in Italy.

macrolichens can even be counted in detail (Scheidegger 2003), while whether or not inconspicuous epilithic and epigeous lichens or epigeous mat-forming lichens could be treated in this way remains an open question. Restrictions to the application of criterion E are related with the lack of data on population size across time (such as survival, fecundity, population growth rate, etc. and the correlation among them and size or density of the local population) and/or a rigorous quantitative model based on presence–absence data from a high number of localities. These data are usually gathered by large-scale and long-term monitoring programmes (Scheidegger et al. 2000) and the lack of this type of information is related with the chronically insufficient financial support to studies addressing overlooked organisms such as lichens (Heilmann-Clausen & Vesterholt 2008), as in the case of Italy. This situation is reflected by the fact that even the assessment on standardized basis of the conservation status of species addressed by European policies (e.g. Article 17 of the Habitats Directive: Conservation status of habitats and species of Community interest) is still lacking and evaluations are mostly based on expert assessment (EIONET 2013).

When starting this work, we were aware of a possible failure and we forced the only possibility that we had: to retrieve and use all the available information on our target species and then fitting it with IUCN criteria as much as possible. In some cases, few parameters included in the IUCN criteria (e.g. the evaluation of extreme fluctuations in population size) were not applicable at all to lichens or to *Cladina* spp. (e.g. the number of mature individuals), while in other cases we tried to adapt them to our dataset. For example, to use criterion A, generation period must be defined. We tried to solve this problem using available references that address growth rates of our target lichens. To estimate the 60-year generation period, we assumed that the mature stage in *Cladina* may correspond to the growth-accumulation period. However, in this process we did not consider the different contribution of vegetative and sexual reproduction (Jahns et al. 2004) because vegetative regeneration is the predominant strategy of these species compared to the poor development of apothecia and spores (Ruoss & Ahti 1989). The latter consideration has also led to the assessment of "severe fragmentation". To use

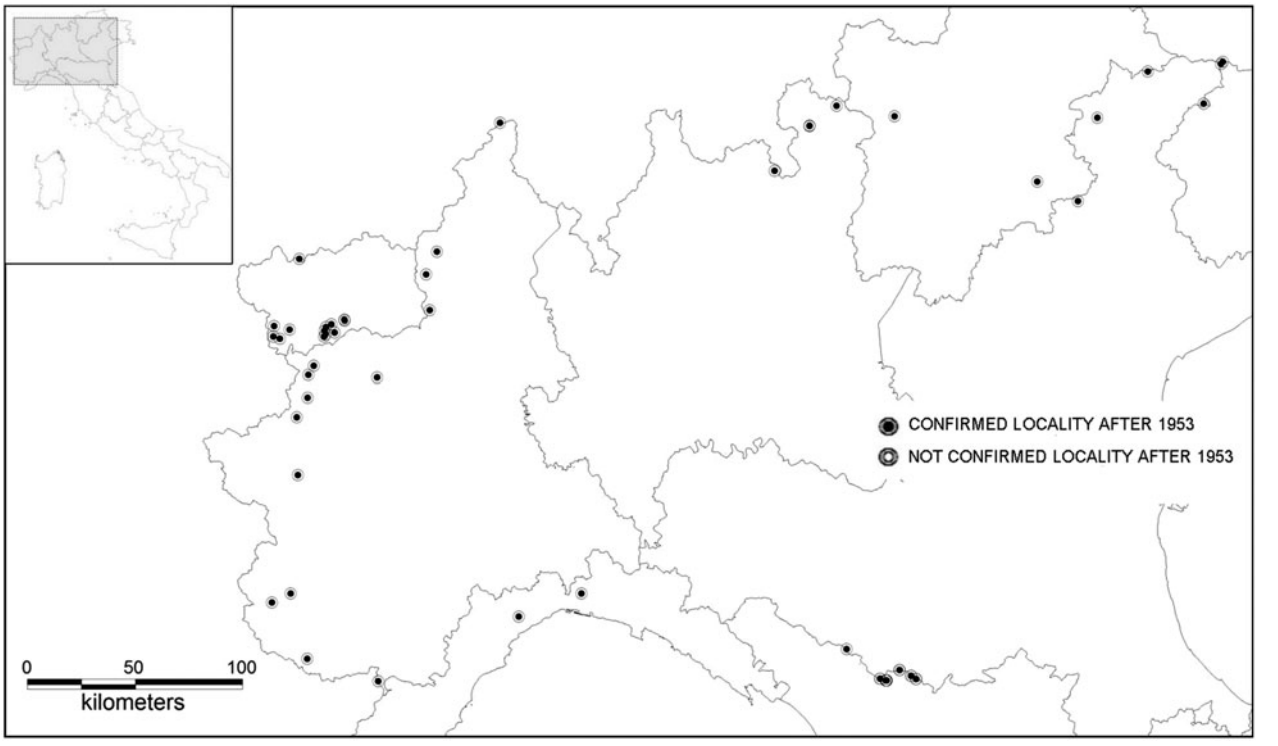

Figure 6. Records of *Cladonia mitis* in Italy.

criterion B, fragmentation must be assessed at a scale that is appropriate to biological isolation for the taxon under discussion. According IUCN guidelines (2014), to indicate severe fragmentation it is recommended a distance between 100 and 1000 km for "taxa with spores" and a minimum distance larger than 50 km between subpopulations for "taxa without spores". We opted for the latter because: (i) to our knowledge, there is no information on gene flow among subpopulations of *Cladina* spp., (ii) in a lichen symbiosis, the mycobiont which produces spores coexists with one or more algal or cyanobacterial photobionts. This additional complication prevents lichens being considered like other taxa with spores since the symbionts (fungal spore and photobiont) must come into contact and (iii) thallus fragments (vegetative reproduction) are inefficient for long-distance dispersal, not reaching a distance of 100 m (Heinken 1999).

Finally, also the interpretation of the term "location" (criteria B and D) may be problematic. According to IUCN criteria, this term defines a geographically or ecologically distinct area in which a single threatening event can rapidly affect all individuals of a taxon (IUCN 2014). The use of data mainly retrieved from literature and that can be roughly georeferenced with variable precision, hinders to properly consider localities of occurrence as locations. However, since most of the threats to *Cladina* spp. are attributable to the quality of the habitat (Table II), the threat to the "location" and to the localities of occurrence of each species is almost always the same. For this reason, following the same assumption of Dahlberg and Mueller (2011) for fungal species, we consider "location" and localities of occurrence as two equivalent concepts.

Conclusion

The global strategy for plant conservation and the European strategy for plant conservation require the enhancement of the knowledge on the conservation status of the flora, even at regional and national level, in order to set up an effective conservation strategy by 2020. Red-listing following the IUCN criteria is the most used assessment system all over the world (De Grammont & Cuaròn 2006; IUCN 2012). However, there is an urgent need to revise some of the parameters of the IUCN protocol in order to make it useful also for fungi, including lichen-forming species, as suggested by several recent studies (e.g. Scheidegger & Werth 2009; Dahlberg & Mueller 2011) and by our experience with mat-forming lichens. For example, the parameters related to the use of the generation period and the assessment of severe fragmentation should be calibrated differently. The generation period (criteria A, C1 and E) is not always known nor can be inferred, and the provided proxy which compares three generations to 10 years is not realistic for lichens and should be longer (at least 50–60 years). The use of criterion B to assess the fragmentation of

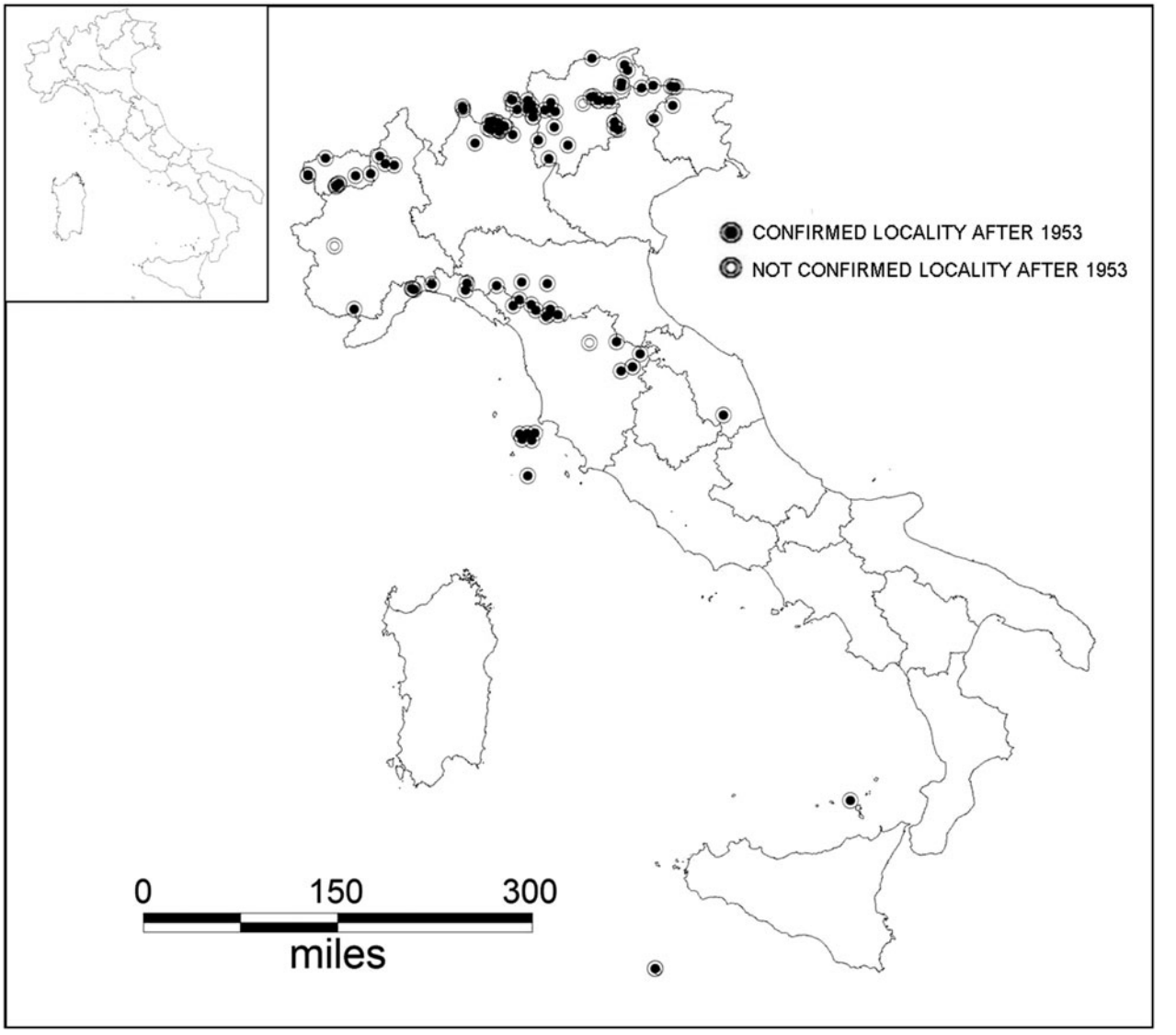

Figure 7. Records of *Cladonia rangiferina* in Italy.

subpopulations should include the possibility to consider the prevalent dispersal strategy instead of the dichotomy "with OR without spores". Moreover, even spore-dispersed lichens may have a limited propagation ability (Giordani et al. 2015) resulting clustered subpopulations both at the local and landscape scale (Benesperi et al. 2013). This suggests that the application of criterion B to lichens would benefit from the improvement of models focusing on the spatial patterns of the species at multiple spatial scales.

Our study also highlights the urgent need for appropriate conservation measures to mitigate the decline and extinction risk of several Italian *Cladina* species, according to European policies. Although in Italy the only programme for plant conservation (Important Plant Areas) which includes lichens is mainly based on a species-oriented approach (Blasi et al. 2011; Ravera et al. 2011), the habitat-oriented approach is considered the most effective practice for lichen conservation (Hallingbäck 2007; Scheidegger & Werth 2009). This fully applies to *Cladina* species whose protection may be achieved by conservation measures focused on habitat protection and on the regulation of collections. Furthermore, considering the recent success of recolonization after propagation (Roturier & Bergsten 2009), dispersal of lichen fragments could be an effective means of restoring *Cladina* stands in appropriate habitats. The improvement of *Cladina* conservation would also benefit from discussion at the European level on the applicability of IUCN criteria to assess their conservation status.

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