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Fire affects the functional diversity of epilithic lichen communities

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A B S T R A C T

Epilithic lichen communities in dry grasslands on calcareous substrata play important functional roles, which may be compromised by the impact of fire. Lichens are involved in both rock weathering and rock stabilization, these processes being directly related to soil formation. In this paper, we examined the hypothesis that the functional and the taxonomic diversity of epilithic lichen communities in Mediterranean dry grassland is influenced by both time since fire and fire frequency. These disturbances produced different effects on the functional richness and on the taxonomic diversity of the communities. Our findings revealed that: (1) a drastic reduction of biodiversity was caused by frequent fires in the same area; (2) that resulting lichen communities in burned sites were merely an impoverishment of unburned areas; and (3) that in the case of infrequent fires, lichen communities can recover functional diversity even if a reduction of taxonomic diversity occurs.

1. Introduction

Since the inter-glacial period, fire has played an important role in shaping plant communities and landscapes in the Mediterranean basin (Trabaud, 1994). Fires have a relevant impact on the structure, biodiversity and functioning of ecosystems, through major effects on their physical, chemical and biological properties (Buscardo et al., 2015). Despite the fact that Mediterranean ecosystems are able to recover readily after fire (Trabaud, 1994), changes in the intensity and frequency of fires can have major influences on the recovery of plant communities (Lloret et al., 2003; Pausas and Verdú, 2008).

Calcareous grasslands are one of the most species-rich habitats and a central issue in nature conservation management in Europe (WallisDeVries et al., 2002). Mediterranean dry grasslands on calcareous substrata are more diverse and prone to more frequent wildfires than are many other grassland habitats (Blasi et al., 2012). Aboveground plant cover in these calcareous grasslands is often discontinuous, with rock surfaces colonized by organisms such as cyanobacteria, chlorophyceae, fungi and lichens (Pohl and Schneider, 2002; Hoppert et al., 2004; Grube and Berg, 2009; Spitale and Nascimbene, 2012). Due to their poikilohydric nature, these latter organisms occupy a small but unique ecological niche, and represent one of the few life forms able to survive in such an extreme environment prone to high desiccation rates (Kranner et al., 2008; Giordani et al., 2014b).

Despite the huge amount of studies dealing with the ecological effects of fires on the diversity of ecosystems components, the impact of this disturbance on lichens has been rarely investigated (Mistry, 1998a, b; Johansen, 2001; Bowker et al., 2004; Ketner-Oostra et al., 2006; Nelson et al., 2015). Lichens lack protective tissues, such as cork, and are particularly disposed to fire-induced direct damage (Yahr, 2000). As an immediate effect, lichen thalli are expected to be completely destroyed by the fire (Johansen, 2001). Other indirect disturbances include damage to the photosynthetic apparatus and the reproductive structures, as a consequence of high air temperature during the fire. Despite this low resistance, certain lichens showed relative resilience to fire events (Yahr, 2000; Ketner-Oostra et al., 2006), being able to re-colonize newly available surfaces and playing a decisive role as pioneer organisms in primary stages of community succession (Garty and Binyamini, 1990; Lawrey, 1991; Favero-Longo et al., 2012).

The response of ecosystems to fire is expected to be modulated

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by species' biological traits (Díaz and Cabido, 2001; Pausas and Verdú, 2008). It has been demonstrated that combinations of functional traits control a range of ecosystem processes and services, leading in some cases to trait-service clusters where multiple associations are seen between traits and ecosystem services across different trophic levels (de Bello et al., 2010). Functional trait effects on ecosystem processes were usually investigated for dominant traits in a community, such as those regarding vascular plants, whereas much less is known for other organisms, including lichens (Cornelissen et al., 2007). However, the degree of trait-service associations depend on the spatial scale at which the effect traits operate and that at which the services are provided (de Bello et al., 2010). Consequently, although higher plants usually account for a large majority of biomass in most terrestrial ecosystems, the relevance of epilithic and endolithic organisms at the level of rock outcrops is not negligible. Lichens have been associated with several ecosystem services such as soil fertility, nutrient cycling, biocontrol, mineral production and soil formation (de Bello et al., 2010). Lichen contribution to this latter ecosystem service is particularly evident on calcium carbonate surfaces, where epilithic and endolithic organisms regulate the processes of both biophysical and biochemical weathering of rocks, which is a preliminary step in soil formation (Jie and Blume, 2002; McIlroy de la Rosa et al., 2014). The former effects include physical weakening of the rocks as a consequence of desiccation and re-hydration processes, whereas the biochemical action is due to the production of metabolites which can enhance the weathering (Ascaso et al., 1998). Moreover, despite the primary deteriorative effect on their substratum, endolithic lichens can also stabilize and preserve the rock surface morphology (Hoppert et al., 2004; Favero-Longo et al., 2009). That means that the equilibrium between biodeterioration versus bioprotection may be altered by changes in the diversity and composition of lithic lichen communities. As a consequence of massive alteration of communities, e.g. due to a fire event, the decay of lichen hyphae may expose weakened rocks to dissolution, triggering relatively rapid surface lowering due to weathering processes (McIlroy de la Rosa et al., 2013, 2014).

The approach for measuring functional diversity is basically the same as for taxonomic diversity, and information can be retrieved both within (i.e. α-diversity) and among communities (i.e. β-diversity). Consequently, functional diversity is often quantified as the functional richness of the traits present in the community and the dissimilarity of functional composition between communities (Villéger et al., 2011). In the case of lichens, functional diversity has been used for assessing the effects of several natural and anthropogenic disturbances, such as short- and long-range nitrogen depositions (Pinho et al., 2012; Giordani et al., 2014a, c) or aridity (Concostrina-Zubiri et al., 2014; Matos et al., 2015). However, these works mainly focused on functional α-diversity (Spitale and Nascimbene, 2012), whereas the connection between various components of lichen diversity in terms of functionality is still poorly investigated (Giordani et al., 2014c). In this paper, we used a set of diversity descriptors for assessing the effects of fires on epilithic lichen communities of calcareous outcrops in Mediterranean dry grasslands. We hypothesized that both time since fire and fire frequency can significantly affect the functional diversity of epilithic lichen communities in a Mediterranean area.

2. Materials and methods

2.1. Study area

The study area is located in Liguria (NW-Italy) in the Natura 2000 site IT1331718 - Monte Fasce (9.045278 E; 44.406111 N). The study area includes 1165 ha of a calcareous mountainous relief laying close to the coast of the Ligurian sea and ranging from 100 to 832 m a.s.l. The site protects 46 species and 11 habitats included in the European Nature Directives and it is mainly characterized by vast semi-natural dry grasslands and scrubland facies on calcareous substrates (*Festuco-Brometalia*) (European Habitats Directive Annex I habitat type code 6210).

2.2. Sampling design

We planned two parallel experimental designs for identifying the effects of fire frequency and time since fire on epilithic lichen communities. Based on an updated map of fire occurrence in the Liguria Region during the period 1996–2010, we identified landscape patches in the survey area belonging to several categories of fire frequency and age. Patches included in the ‘Time since fire’ dataset were affected by a single fire event. Prior to selection, we defined patches belonging to the following strata: ‘Three years’, ‘Five years’ and ‘Twelve years’ (affected by fire 3 years, 5 years and 12 years before the lichen sampling, respectively). To control the possible interaction between time age and frequency, as for the ‘Fire frequency’ dataset we only considered patches which were affected by fires between 3 and 6 years before the lichen sampling. We defined the following strata: ‘One fire’, ‘Two fires’, ‘Three fires’, depending on the number of fire events which occurred in a given patch. A ‘Control’ category was considered for both ‘Time since fire’ and ‘Fire frequency’ datasets, including patches that never burnt in the considered period of 15 years. For each category of fire frequency and age, we randomly selected 4 landscape patches. In each landscape patch, 3 rock outcrops were randomly selected and sampled in the field. On each outcrop, the occurrence of lichens was recorded by means of a 50 × 50 cm grid (subplot) divided into 25 10 × 10 cm quadrats. Overall, 96 subplots were sampled. Most species of lichenised and lichenicolous fungi were identified in the field, whereas critical specimens were collected and identified at the laboratory, using standard stereo- and light-microscopy techniques used in lichen identification. Data on lichen occurrence were organized in two datasets: ‘Time since fire’ and ‘Fire frequency’ (Appendix 1), which were subsequently used for testing the effects of fire age and fire frequency on the functional diversity of epilithic lichen communities.

2.3. Functional traits

For each lichen species we defined a set of functional traits, defined as a component of their phenotype that determines its effect on processes and its response to environmental factors (Violle et al., 2007). Selected traits are mainly associated with both reproduction and light-related processes in lichens. The former include those describing the characteristics of the ascomata and of the ascospores. In particular, the shape, the number, the dimension and the color of the ascospores may play a decisive role in the phases of dispersal and establishment of new thalli (Armstrong, 1981). As light-related traits, together with the photobiont type, we also included some features involved in the protection from possible negative effects of light (e.g. UV radiation), such as thallus and epithecium colors or the presence of pruina (Giordani et al., 2003). Other traits were also included, which are expected to play simultaneous roles in lichen eco-physiology. For example, growth form can regulate several major functions in lichens, such as substrate colonization, evapo-transpiration or photons absorption (Palmqvist, 2000).

For each trait, we assigned functional attributes, i.e. a particular value or modality taken by the trait which varies both along environmental gradients and through time. In particular, we considered the following functional traits retrieved from Nimis and Martellos