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A multi-taxon approach reveals the effect of management intensity on biodiversity in Alpine larch grasslands

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HIGHLIGHTS

- In the Alps larch grasslands form one of the most pleasing aspects of the landscape.
- A multi-taxon approach was used to evaluate the effects of management intensity.
- Management intensity influences the biodiversity of autotrophic organisms.
- Higher biodiversity was found in extensively managed larch grasslands.

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ABSTRACT

In the Alps, larch grasslands form one of the most pleasing aspects of the landscape. However, their effectiveness in contributing to biodiversity conservation may depend on the intensity of their management. We used a multi-taxon approach to evaluate the effects of the intensification of management practices and those of abandonment on the biodiversity of the main autotrophic organisms hosted in this habitat, including vascular plants, bryophytes, and lichens. The study was carried out in the eastern part of South Tyrol, in the Italian Alps, where the diversity patterns of these three organismal groups were compared among intensively managed, extensively managed, and abandoned stands. The management intensity was found to strongly influence the biodiversity of the organisms, with a general pattern indicating the best conditions in extensively managed stands. Both abandonment and management intensification were detrimental to biodiversity through different mechanisms that led to species loss or to major shifts in species composition. However, the most negative effects were related to management intensification, mainly due to the high nitrogen supply, providing evidence for the increasing impact of eutrophication on Alpine environments.

1. Introduction

In the European Alps, agriculture and forestry played an important role in shaping the economy and the human population structure up to the beginning of the 20th century (Tasser et al., 2013). Several traditional management types, such as coppice forests, orchards, mountain-pasturing and double-use systems, developed over time in rural areas. In the 1950s, technical progress in the machinery and equipment used for agriculture and the growth of tourism and industry strongly influenced the agriculture and forestry in mountain areas (Krausmann et al., 2003; Streifeneder et al., 2007) through two contrasting processes: the intensification of land-use in more favorable sites, and complete abandonment of less favorable sites (Zimmermann et al., 2010). Traditional farming practices, which require significant effort and manual labor, declined throughout Europe (MacDonald et al., 2000; Bergmeier et al., 2010).

In the Alps, larch grasslands are one of the traditional management types that are still locally maintained across the montane and subalpine belts, forming one of the most pleasing aspects of the landscape (Fontana et al., 2014). Larch grasslands consist of meadows or pastures with scattered larch (*Larix decidua* Mill.) individuals. This anthropogenic landscape was found to provide several ecosystem services benefiting human well-being, for example, offering opportunities for recreation, providing cultural and historical value and providing diverse habitats that harbor several species of conservation concern (Fontana et al., 2013; Nascimbene et al., 2006).

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The effectiveness of larch grasslands in contributing to biodiversity conservation in Alpine landscapes may, however, depend on the intensity of their management (Tasser and Tappeiner, 2002). In particular, stands managed using traditional methods based on non-intensive practices are expected to benefit several organism groups (MacDonald et al., 2000), hosting a community that is richer in species than either intensively managed or abandoned stands (the intermediate disturbance hypothesis; Grime, 1973; Hilbert et al., 1981; Molino and Sabatier, 2001; Svensson et al., 2007). However, this pattern may differ among organisms exploiting different resources and substrates and may also lead to severe shifts in assemblage composition (Poschlod et al., 2005; Paillet et al., 2009). For example, plant communities are expected to be negatively affected by mowing frequency (Nascimbene et al., 2013a), and many terricolous and epiphytic bryophytes may benefit from abandonment, preferring closed, canopied forests (Fenton and Frego, 2005). However, Paltto et al. (2008) noted that excessive canopy closure related to the development of secondary woodlands could place many epiphytic lichens at a disadvantage (Paltto et al., 2011). Moreover, the augmentation of nitrogen input related to management intensification could lead to a decrease in species richness and to a change in the composition of autotrophic species, as eutrophication is recognized as one of the main threats to vegetation in natural and semi-natural ecosystems (Kleijn et al., 2009). In particular, epiphytic lichens and forest floor bryophytes are extremely sensitive to nitrogen loads, which cause the rarefaction of many forest species and the establishment of nitrogen-tolerant species across Europe (Dirkse and Martakis, 1992; Giordani et al., 2014).

This work aimed to evaluate the effects of both intensification of management practices and of abandonment on the biodiversity of Alpine larch grasslands. In particular, our study is based on a multi-taxon approach in which we tested the effect of (i) intensively managed stands that are mown and fertilized, (ii) extensively managed stands that are either mown and fertilized or used for grazing, and (iii) abandoned stands, in which forest succession is occurring on larch grasslands that were abandoned 20–50 years ago, on vascular plant and cryptogam (bryophyte and lichen) diversity. These organisms are best suited to encompass the composite habitat structure of Alpine larch grasslands, which provide establishment opportunities for both soil-dwelling and epiphytic species. According to the intermediate disturbance hypothesis (Svensson et al., 2007), we expected greater diversity in extensively managed stands than in the other stand types. However, we hypothesized that the response to management intensity may differ among organisms with different traits and ecological requirements and, due to their strong sensitivity to environmental conditions (*e.g.*, Giordani et al., 2014), we expected that epiphytic lichens would be the most responsive organisms.

2. Materials and methods

2.1. Study area

The study was carried out in the eastern part of South Tyrol (7400 km^2, Italian Alps) in the region of the Pusteria valley, east of the city of Bressanone (46°43′ N, 11°39′ E; see map in Appendix A in Supplementary data). Because the area is surrounded by mountain chains, *i.e.*, the main Alpine ridge in the north and the Dolomites in the south, large parts of the area lay above 1000 m a.s.l. (ASTAT, 2011). The climate is Northern Central European, with a mean annual precipitation of approximately 1000 mm in the upper montane belt and with the precipitation maxima occurring in summer. The mean annual temperature is 6 °C in the bottom of the valley, while in the alpine belt it is 3 °C (Autonome Provinz Bozen—Südtirol, 2010). In this region, larch grasslands are subject to three main management types, corresponding to a gradient of management intensity: (1) intensively managed stands that are mown and fertilized twice per year (max. 10 Mg ha^{-1} stall manure per year, corresponding to c. 230 kg ha^{-1} N per year); (2) extensively managed stands that are either mown and fertilized (max. 3 Mg ha^{-1} stall manure per year corresponding to c. 70 kg ha^{-1} N per year) once per year or used for grazing; and (3) abandoned stands, in which forest succession is allowed to proceed on larch grasslands that were abandoned 20–50 years ago.

2.2. Sampling design

The study area was divided into several forest domains corresponding to administrative units for both forestry and agriculture (Appendix A). Using GIS (Arcmap 10), we selected the four forest domains hosting the highest number of larch grasslands according to the official distribution map (Autonome Provinz Bozen — Südtirol, 2011). Information on abandoned larch grasslands was derived from historical land-use maps (land register of Emperor Francis I, 1861, vegetation map; Peer, 1980) and by interviewing the local forest rangers. The mean field size of the individual larch grasslands was approximately 2.5 ha. Subsequently, we randomly selected 7 circular plots ($r = 10$ m, area $= 314$ m^2) for each of the three stand types (intensively managed, non-intensively managed, and abandoned), in order to encompass the variability of each stand type in the study area. To reduce spatial dependence, the minimum distance between plots of the same management type was chosen to be greater than 500 m. The slope, aspect, elevation, and soil pH were comparable among the management types, while the tree density and the carbon/nitrogen ratio intrinsically differed between the abandoned and managed stands (Table 1). The carbon/nitrogen ratio of the soil was measured for each plot; using a split-tube sampler (Eijkelkamp, diameter = 4.2 cm; height = 20 cm), we collected a soil sample from the center of the plot. Roots were removed and soil samples were sorted into gravel and mineral soil using a sieve (2 mm mesh size). The dry weights of the soil samples were determined after drying at 65 °C for 24 h. The total organic carbon and nitrogen contents of the mineral soil samples were determined using an elemental analyzer (Thermo Scientific, Flash EA 2000).

2.3. Sampling of the biota

In each of the plots whose dimensions were between the required minimum area for meadows (25 m^2) and that of forests (500 m^2, Dierßen, 1990), all vascular plants were recorded, and the abundance was visually estimated for each species according to Braun-Blanquet (1932).

The occurrence (*i.e.*, presence/absence) of soil-dwelling bryophytes was recorded in 5 randomly placed 40 × 50 cm frames (total area surveyed per plot = 1 m^2). To estimate the average bryophyte biomass in the surface unit, we measured the percent cover by line intercepts (Elzinga et al., 2001) and the biomass standard area. The cover was measured along 3 line intercept transects (length = 23 m × 3) by noting the point along the tape where the cover began and the point at which it ended. The percent cover was the sum of these intercepts divided by the total length. The line transects were positioned along a triangle inset in the plot. In a random bryophyte colony along each line transect, we collected a sample of biomass using a 10 × 10 cm quadrat. Thus, the bryophyte biomass in the plot was estimated by combining the cover data (resulting from the 3 line transects) and the weight data (resulting from the biomass harvested in 3 quadrats). Preliminary surveys executed in spruce forests (Spitale, unpublished) using transects of different lengths and quadrats of different size, showed that, for the same number of replicates, the results were similar using a larger plot size (50 × 50 cm). In the laboratory, we sorted out all the extraneous materials other than bryophytes using a dissecting microscope. The samples were weighed after drying at 40 °C for 12 h. The bryophyte biomass on the forest floor was expressed as Kg/ha.

In each plot, on five larch individuals, the epiphytic bryophytes and lichens were recorded using four standard 10 × 50 cm frames as sampling grids, subdivided into five 10 × 10 cm quadrats (Asta et al.,