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Short Communication

Unsustainable cattle load in alpine pastures alters the diversity and the composition of lichen functional groups for nitrogen requirement

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ABSTRACT

Despite their considerable relevance as biodiversity hotspots, alpine ecosystems are presently threatened by several anthropogenic disturbances. Among these, pasture-derived nitrogen deposition is expected to significantly alter community composition and diversity of many sensitive organisms, such as lichens. We analysed patterns of γ-diversity components in epilithic lichen communities of pasturelands in the Maritime Alps (north-west Italy). Our aims were: (1) to estimate the shift in functional groups for nitrogen tolerance along a gradient of increasing cattle load; (2) to establish the cattle critical load. High cattle load reduced the species replacement and significantly increased the similarity in the oligotrophic component of the lichen communities. The oligotrophic component was the most sensitive functional group to nitrogen. Based on the relative abundance of oligotrophs we set the cattle critical load of the area at 0.12 grazing animals per hectare.

Alpine regions represent one of the largest biodiversity hotspots in Europe, based on favourable climatic conditions, habitat heterogeneity, dynamic processes and historical land use (Casazza et al., 2008). However, many alpine ecosystems are threatened by human activity, resulting in the potential loss of distribution range and habitat suitability for many species over the near future (Casazza et al., 2008). This loss is a consequence of climate change, increasing urbanisation and atmospheric nitrogen deposition (Giordani et al., 2014). In threatened ecosystems, changes in land use affects the biodiversity, with vegetation communities largely controlled by pastoral practices and other agricultural activities. In combination with fire, grazing is the main disturbance of vegetation and biomass loss with domestic cattle grazing as major driver of global vegetation dynamics (Diaz et al., 2007). In addition to grazing damage, intensive browsing and trampling, pasture is

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a significant source of nitrogen deposition in alpine environments. Pastoral activities often occur in protected areas, even though their negative effect on biodiversity is known.

In alpine pasturelands, lichens represent a relevant component of the ecosystem where lichens colonize bare soil and rock outcrops. In alpine regions, characterised by highly stressful environmental conditions for many organisms, lichens are among the dominate organisms. Lichens have a high freezing tolerance including the ability to be photosynthetically activated by water vapour uptake from snow at temperatures ca. −20 °C (Kappen, 2000). Field studies have demonstrated that alpine lichens are metabolically active at air temperatures between −0.7 and 12.8 °C (Reiter et al., 2008). Conversely, lichen communities are sensitive to several disturbances, including nitrogen depositions from cattle. Nitrogen deposition is thought to cause shifts in species composition in lichen communities, altering the relative abundance of several functional groups with different nitrogen requirements, i.e. nitrophic vs. oligotrophic species (Pinho et al., 2011). Based on these properties, epiphytic lichen functional groups related to nitrogen supply have been used to set critical loads and levels for nitrogen compounds in forest or agricultural ecosystems (Giordani et al., 2014). Even though in saxicolous vs. epiphytic communities the distribution of lichens is more associated with incident solar radiation and geochemistry, mineralogy and the physical properties of substrata (e.g. Spitale and Nascimbene, 2012), possible common driving factors, such as eutrophication can be hypothesized.

This study investigated the novel idea of evaluating the effects of pastoral grazing on the composition and diversity of epilithic lichen communities in alpine areas. In particular, we estimated the shift in lichen communities along a gradient of increased cattle load, with particular reference to the relative abundance of functional groups for nitrogen tolerance. To achieve this aim, we analysed patterns of γ-diversity components (species replacement, *R*; richness difference, *D*; and similarity, *S*) using the conceptual and methodological framework provided by Podani and Schmera (2011). We aimed to establish the cattle critical load in the study area, based on the variation of the relative frequency of functional groups.

Lichen sampling was conducted in seasonally grazed pastures at high altitude (1 400–2 000 m a.s.l.) in the Alpi Marittime Regional Park (south-western Italian Alps). To highlight possible critical thresholds in the ecosystem, twenty-one sampling plots were randomly selected in seven non-adjacent pasture patches along a gradient of impact based on the declared number of grazing animals per pasture (i.e., Adult Cattle Unit, ACU), which is considered a proxy variable for the nitrogen load affecting a pastoral area. In the studied pastures the ACU ranged from 90 to 250. The overall pasture area was 4 565 ha, the patches ranging from 90 ha to 981 ha.

The surveys were carried out during the summer of 2011, on acid migmatitic gneiss rocks with a max inclination of 30°. Under undisturbed conditions, this substratum mainly hosts oligotrophic lichen communities. The surveys used a North oriented square grid (50 × 50 cm) divided into 25 quadrats. The frequency of each species was calculated as the sum of each lichen species per quadrat within the grid. To calculate the diversity of functional groups, species were grouped according to nitrogen tolerance using an *a priori* classification (Nimis and Martellos, 2008). This classification used a 5-class ordinal scale, where the value 1 was given to strictly oligotrophic species, while a 5 corresponded to species tolerating a very high eutrophication. Specifically, species classified as 1 and 2 were considered oligotrophic, species with a maximum value equal to 4 or 5 were N-tolerant and species with a minimum value equal to 4 or 5 were considered as strictly nitrophylic (see Supplementary Material).

We analysed the presence–absence data matrix with SDR Simplex software (Podani, 2001), using The Simplex method (SDR Simplex – Podani and Schmera, 2011). We evaluated the relative importance of components of γ diversity, i.e., *S*, *D* and *R* for all pairs of plots.

Table 1 – Percentage contributions from the SDR Simplex analyses of epilithic lichen communities in the study area. Results are presented for the entire dataset including all sampled species and for subsets of functional groups for nitrogen tolerance. Bold numbers emphasize the maximum for each column in each dataset. Arrows indicate monotone trends along gradients of cattle load.

Dataset	Cattle load	Similarity(S)	Relativized species replacement (R)	Relativized richness difference (D)	Relativized beta diversity (R+D)	Relativized richness agreement (R+S)	Relativized nestedness (S+D)
All species	Low	34.4	**49.4**	16.2 ↑	65.6 ↑	**83.8**	50.6
	Intermediate	40.1	**44.8**	15.1	59.9	**84.9**	55.1
	High	44.2 ↓	**50.1**	5.8	55.8	**94.2** ↓	49.9
Oligotrophic	Low	30.4	**54.6** ↑	14.9	69.6 ↑	**85.1**	45.3
	Intermediate	33.6	**48.3**	18.1	66.4	**81.9**	51.7
	High	37.9 ↓	**46.9**	15.1	62.1	**84.9**	53.1 ↓
N-tolerant	Low	**72.0**	15.3	12.7	28.0	**87.3**	84.7
	Intermediate	**72.0**	0.0	28.3	28.3	71.7	**100.0**
	High	**81.0** ↓	10.7	8.3	19.0	**91.7**	89.3
Strictly nitrophytic	Low	19.2	**50.5**	30.3	**80.8**	69.7	46.1
	Intermediate	21.1	**57.8**	21.1	**78.9**	78.9	31.1
	High	16.7	**47.7**	35.7	**83.3**	64.3	35.0