



Conference Abstract

Expansion of nutrient-demanding plant species in high mountains as a consequence of Climate Change: recent evidence in the N-Apennines, Italy (SENTINEL PRIN-MUR project).

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Received: 24 Apr 2025 | Published: 02 Jun 2025

Citation: Lodetti S, Petraglia A, Tomaselli M, Freppaz M, Stanchi S, Agaba S, White F, Porro F, Gentili R, Benech A, Rossi G (2025) Expansion of nutrient-demanding plant species in high mountains as a consequence of Climate Change: recent evidence in the N-Apennines, Italy (SENTINEL PRIN-MUR project). ARPHA Conference Abstracts 8: e156864. <https://doi.org/10.3897/aca.8.e156864>

Abstract

Background

Climate change (CC) is regarded as the main factor behind changes in alpine vascular plant assemblages (Gottfried et al. 2012, Pauli et al. 2012). In the alpine life zone, a shift in the floristic composition is often a consequence of upward species migration and local loss (Pauli et al. 2012). Moreover, local changes in abundance have led to species' distribution ranges expanding or retracting (Staude et al. 2022), resulting in a shift towards more nutrient- and warm-demanding plant assemblages as well as drought-adapted vegetation types (Liberati et al. 2019, Gottfried et al. 2012). Here, we

investigated the vascular plant assemblages and soil properties in a GLORIA (GLobal Observation and Research Initiative in Alpine environments) target region in the N-Apennines (Italy). The site was established in 2001 and has been monitored at seven year intervals. The study area is included in a LTER site and is part of the SENTINEL (The reSPonsEs of italian mouNTaIN Ecosystems to cLimate change) project, initiated in 2023 with funding from the Italian Ministry of University and Scientific Research (MUR). The aims of this study consist of assessing temporal shifts in the ecology of plant assemblage requirements as well as to unravel possible environmental drivers such as warming temperature and soil inorganic N availability.

Methods

Across four summits in the study site (1722-1978 m a.s.l., https://www.lteritalia.it/wordpress/?page_id=264), we investigated directional changes of plant assemblages to assess eutrophication, thermophilization and xerophilization processes as well as to assess ecological requirements of “winner” (increasing in abundance) and “loser” (decreasing in abundance) plant species. Environmental conditions were indirectly assessed based on Pignatti’s ecologic indicators for the Italian flora (Pignatti 2005). Moreover, we assessed changes in species richness to assess the expected biodiversity loss. Soil properties were evaluated through 10 cm deep soil temperature trend since 2001 and by measuring inorganic N soil concentration in the summer of 2023.

Results and discussion

We found a net increase in species richness in the lowest summits at the treeline ecotone (+12) and lower alpine (+4) belts. The two highest summits, up to the alpine belt, had a net species loss (-2 each). Noteworthy losses were the low stature (sub)alpine perennial species *Myosotis alpestris*, *Soldanella alpina* and *Aster alpinus*, while the most successful colonizers were the graminoids *Festuca paniculata* and *Poa pratensis*, and the Fabaceae *Anthyllis vulneraria* and *Trifolium repens*. A shift towards more nutrient-demanding species was the most pronounced pattern we observed (Fig. 1), being more intense in the treeline ecotone and the lower alpine belt (Fig. 1). This finding is in line with a previous European study, highlighting signs of increased nutrient demands in 52 GLORIA summits up until 2015, although the trend not significant (Staude et al. 2022). We also detected low level of local thermophilization and adaption to drought, but both supported by a few obvious thermophilous and drought-adapted winners and losers. Changes in species abundance of winning (3-9% of the species) and losing (2-8% of the species) species supported significant shifts in the ecologic indicators, especially related to increased nutrient requirements (Fig. 2). Eutrophication appeared to lead to both the expansion of more acquisitive species such as *Genista tinctoria*, *F. paniculata* and *Brachypodium genuense*, and the retraction of species growing on more oligotrophic substrates like *Agrostis rupestris* and *Viola calcarata* subsp. *cavillieri*. In our study area, the soil N-NH₄⁺ concentration at the end of the growing season was comparable to the values recorded in the alpine tundra at the LTER site Istituto Mosso (NW Italian Alps, 2525-2840 m asl) (Magnani et al. 2017), ranging between 3 - 8 mgkg⁻¹. The N-NO₃-concentration was high, especially at one site (Mommio), ranging between 0.5 - 2.7

mgkg⁻¹. This high soil inorganic N content could be related not only to the increase in temperature but also to the high N wet deposition. At the LTER site Istituto Mosso, the N critical threshold was greatly exceeded, revealing that the area is exposed to excessive N input through atmospheric deposition (Balestrini et al. 2024). In the N-Apennines, an increased level of N deposition, affecting beech growth, has been already estimated for the period 1850-2014 (Gentilesca et al. 2018). Moreover, recent studies found the increase in plant nitrogen availability and use significantly controlled by increasing mean annual temperature (Hu et al. 2024, Salazar et al. 2020). The M. Cimone Meteorological Observatory, located in the study area, has recorded a large increase in the mean, minimum and maximum annual air temperature between 1951-2018 (Costanzini et al. 2024). The increase of *in situ* soil mean temperature (+0.46°C per decades) as well as increased in duration of the vegetative period in the Eastern slope of the GLORIA site ‘Pian Cavallaro’ (M. Cimone) reflects trends in air temperature during the last two decades. Thus, plant species’ productivity may also have been stimulated by the well-established trends of higher temperatures and longer growing seasons, promoting the growth of nitrophilous species compared to others.

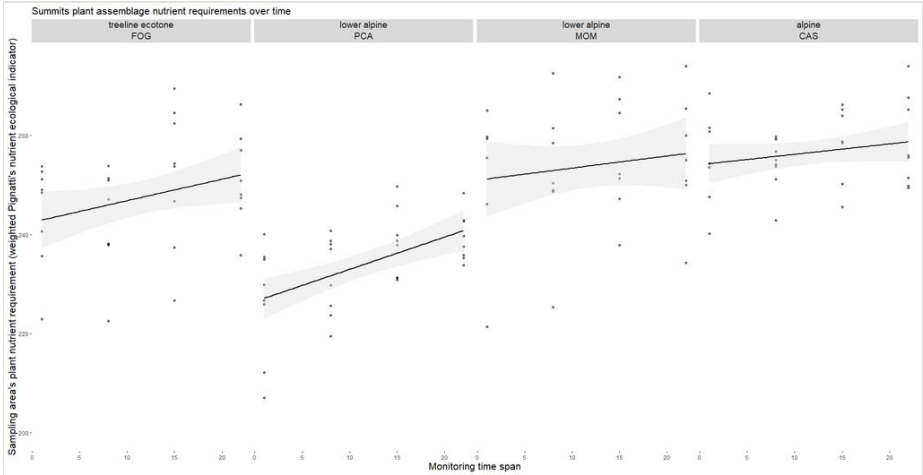
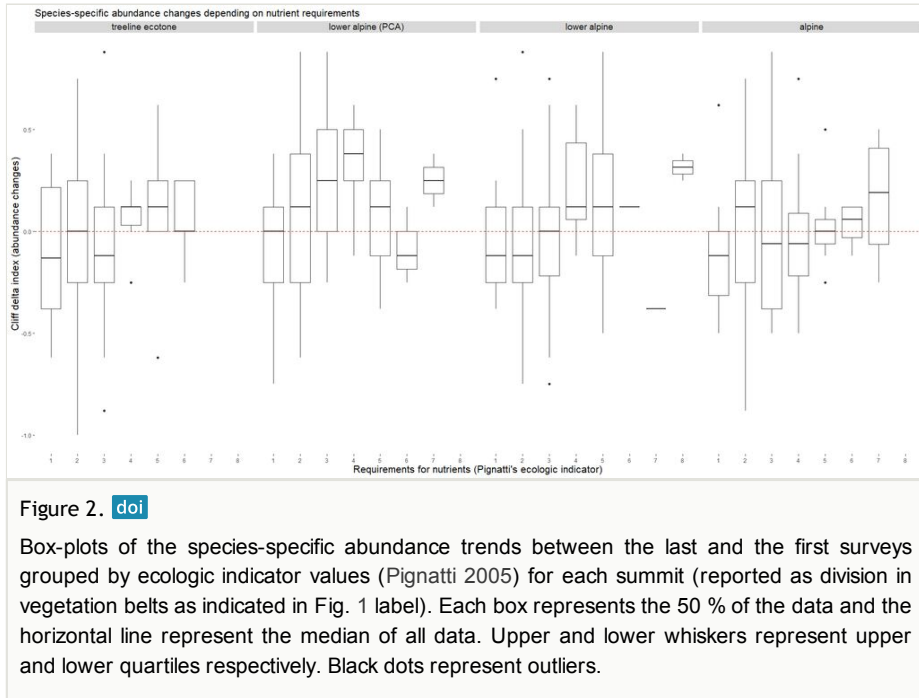


Figure 1. [doi](#)
Temporal trend of community weighted ecologic indicator for nutrient requirements (Pignatti 2005) in Northern Apennines. Temporal trend is reported for each summit: FOG (Foce al Giovo at the treeline ecotone); PCA (Pian Cavallaro at the lower alpine); MOM (Mommio at the lower alpine); CAS (Casarola at the alpine). Monitoring time span from 0 to 22 included the four surveys carry out between 2000 and 2022.

Conclusions

This initial investigation has revealed a complex and multifaceted picture of the ongoing dynamics in alpine vascular plant assemblages, highlighting an alarming biodiversity loss. The stronger influence of eutrophication over thermophilization highlights multiple, complex responses to warming, likely acting beyond the simple increase of species demands for higher temperatures. The SENTINEL project will continue to investigate the

relationships between vegetation, atmosphere, soil, and plant-insect multi-trophic interactions to disentangle CC impacts on plant species and ecosystem functioning.



Keywords

Climate change, alpine plant species, monitoring, eutrophication

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Presented at

ORAL

Acknowledgements

Italian Ministry for University and Research (MUR)

Funding program

PRIN MUR

Grant title

SENTINEL

Hosting institution

Yliopistonkatu 55, 33100 Tampere, Finland

Conflicts of interest

The authors have declared that no competing interests exist.

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