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Alpine dragon- and damselfly communities of anthropogenic habitats. An interplay between habitat requirements and temperature.

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Keywords: Alpine environments, artificial habitats, Bergman's rule, freshwater biodiversity, elevational gradient, habitat filtering.

Introduction

Alpine environments harbor a large diversity of natural habitats and thus are hotspots of global biological diversity (Steinbauer et al. 2016; Antonelli et al. 2018; Pinkert et al. 2024). Concerningly, while natural habitats are on the decline worldwide (Sala et al. 2000) human habitat modification has extended up to alpine elevations spurred on by demands of tourism, energy production and recently conservation (Fait et al. 2020; Brosse et al. 2022; Gerfand et al. 2024). Peatlands and freshwater habitats harbor a large part of the Alpine threatened biodiversity, but remain underrepresented in conservation efforts (Bragazza 2009). Artificial ponds have been proposed as stepping-stone or substitute habitats, that could boost population sizes of alpine freshwater species and assist them in shifting their ranges and better track climate change (Ilg & Oertli 2014; Oertli et al. 2014; Fait et al. 2020; Gerfand et al. 2024) and hundreds of pond creation and restoration projects have been carried out across several countries to establish habitats for biodiversity, with costs amounting to millions of Euros (Bartrons et al. 2024). However, little is known about the interactive effect of temperature and anthropogenic disturbance on invertebrate communities, with alpine species often being particularly vulnerable to human impacts (Negro et al. 2010; Kašák et al. 2013; Assandri & Bazzi 2022). Thus, the conservation value of alpine artificial water bodies remains therefore unclear.

Methods

Focusing on dragonflies and damselflies, whose semi-aquatic life cycle and ectothermic nature make them particularly sensitive to temperature (Hassall 2015) and habitat conditions (Bílková et al. 2025), we examined the taxonomic and functional composition on 28 natural and 13 anthropogenically altered sites spanning a 2000-meter elevational gradient in the European Alps. This altitudinal gradient comprises a wide heterogeneity of habitats (Assandri 2019), which range from natural alpine wetlands harbouring boreo-alpine specialists like *Aeshna subarctica* and *A. caerulea* (Assandri et al. 2022) to large and warm lakes, harbouring thermophilous species like *Trithemis annulata* (Puff et al. 2023). Our aim was to assess how diversity, abundance and functional traits change along elevation and if natural and anthropogenic habitats follow similar trends.

submitted: 20.03.2025
accepted: 20.09.2025

DOI: 10.5281/zenodo.17207703

Results & Discussion

Our results demonstrate that, similar to continental scales (Pinkert et al. 2017; Zeuss et al. 2017; Acquah-Lamptey et al. 2020; Mähn et al. 2023), dragonflies follow trends in morphology and life history at a regional scale, along an elevational gradient, as expected by Bergmann's rule (Shelomi 2012) and thermal melanism hypothesis (Clusella Trullas et al. 2007). In damselflies however, functional responses to temperature, especially morphology, are different and their abundances strongly declined below moderate temperatures, while those of dragonflies were unaffected by temperature (Figure 1). This suggests that dragonflies are better adapted to the cold temperatures of higher elevations, while damselflies seem far less able to adapt their morphology to cold environments. Additionally, both dragon- and damselfly communities at anthropogenic alpine sites were composed of more thermophile species than at natural alpine sites, indicating poor support of the natural and unique faunal elements via artificial water bodies (Figure 1). This must be considered for conservation aimed at maintaining and improving the status of alpine specialists (Ilg & Oertli 2014; Oertli et al. 2014), which not only constitute certain odonate lineages but also distinct parts of the functional diversity, as we show. The ecological dynamics of alpine artificial water bodies stem from the additive constrains of temperature and anthropogenic disturbance. This dual constraint appears to hinder typical alpine species from colonising these man-made environments, posing a challenge for their role in biodiversity conservation amid global warming and biodiversity decline. See Puff et al. (2025) for more details.

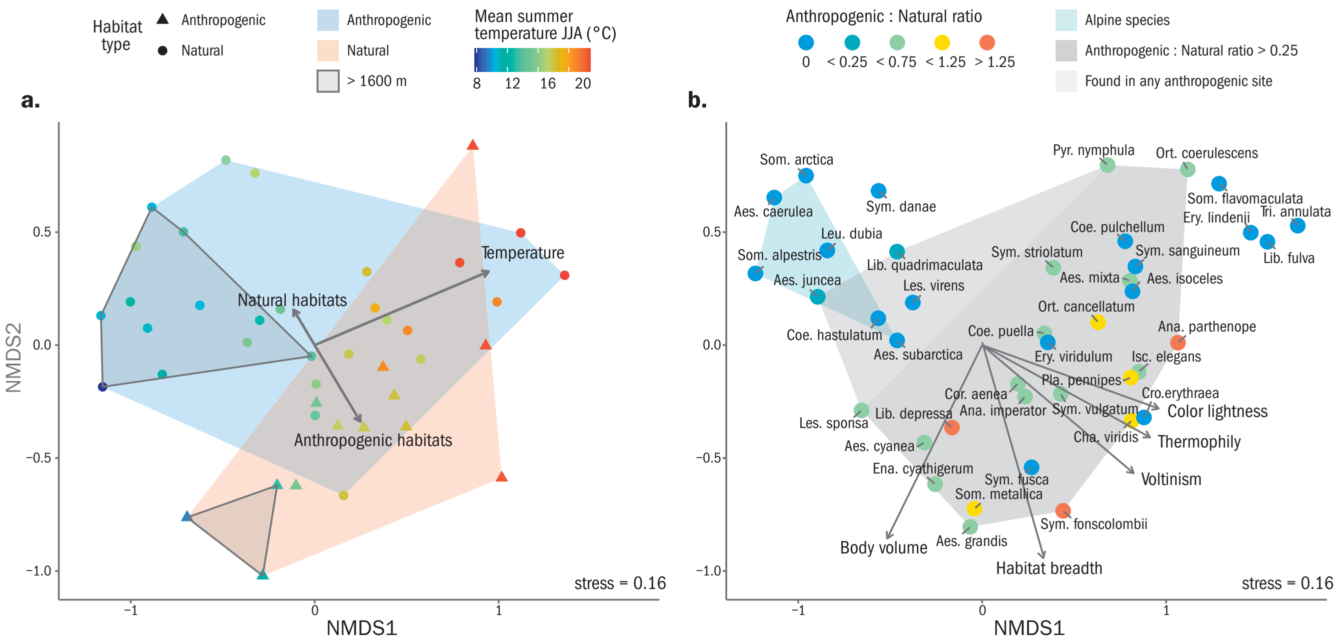

Figure 1: NMDS ordination of species communities. Panel (a) shows site scores with arrows indicating site variable loadings; panel (b) shows scaled species scores with trait loadings. The ratio of anthropogenic to natural sites was calculated from study data. Alpine species are defined as those with a Temperature Index < 6 (Termaat et al. 2019). Genus names in (b) are abbreviated to the first three letters. Modified from Puff et al. (2025).

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