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RESEARCH ARTICLE

Beyond the green: assessing quarry restoration success through plant and beetle communities

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In assessing the effectiveness of ecological restoration actions, outcomes evaluation using a multi-taxa approach can greatly contribute to a clearer understanding of their success/failure. Since comprehensive biodiversity assessments are rarely possible, choosing taxa groups that are indicative of the ecosystem's structural and functional recovery is of major importance. Our goal was to evaluate the success of revegetation actions performed in a Mediterranean limestone quarry, using plants and epigean beetles as indicators. We compared their abundance, diversity, and community composition between revegetated sites aged 5, 13, and 19 years and a natural reference. Total plant cover significantly increased with restoration age and quickly reached reference values. However, native woody species cover dropped in the oldest site, while non-native species became dominant. The abundance of beetles was always lower in restoration sites when compared to the reference, increasing with age, although not significantly. The richness of both plant species and beetle families was lower in restoration sites and did not show any trend towards the reference values. Finally, using nonmetric multidimensional scaling, the composition of plant and beetle communities from restoration sites showed a clear separation from the reference. Restoration efforts have successfully modified post-quarry sites, but considerable differences remain, probably largely related to the use of the non-native species *Pinus halepensis* in restoration plans. *P. halepensis* high cover in restoration sites greatly affects the structure of the ecosystem, and most likely its functioning too, as well as related ecosystem services, causing divergence from the reference values and compromising restoration success.

Key words: chronosequence, Coleoptera, limestone quarry, Mediterranean, multi-taxa

Implications for Practice

- Practitioners may be misled by high plant cover in restoration sites, which reduces the visual impact of disturbed areas but also conceals planted exotic species (e.g. *Pinus halepensis*) prevalence. Thinning and cutting of *P. halepensis* could create better conditions for native plant species to thrive.
- Different responses of beetle and plant communities to restoration actions stressed how evaluating different taxa may provide a complementary and more enlightening indication about ecosystem's structural and functional recovery.
- An identification of beetles to family level was sufficient to compare and detect differences between restoration and reference sites. This allowed a rapid assessment of community characteristics and a broader implementation of multi-taxa approaches.

Introduction

The Mediterranean landscape has a long tradition of mining, especially in karst regions, where there are many in operational and abandoned quarries that require restoration actions (Gams et al. 1993). Open quarries are one of the most problematic areas to restore, since their exploration requires removing all topsoil and associated biota, drastically modifying the original topography and causing a major visual impact (Correia et al. 2001; Clemente et al. 2004; Lima et al. 2016; Mavrommatis & Menegaki 2017). Spontaneous colonization ("passive restoration") has been reported to efficiently create early successional stages, many times with important conservation status (e.g. Baasch et al. 2012; Tropek et al. 2012; Prach & del Moral 2015). However, total recovery of these highly degraded areas may take hundreds of years (e.g. Cullen et al. 1998; Correia et al. 2001)

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