The effect of rock climbing on Mediterranean cliff vegetation: first steps for the implementation of an innovative and comprehensive methodology in a wide geographical range

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Introduction

In recent years, rock climbing has grown tremendously in popularity, and this activity is projected to rise at least 50% more in the next 30 years (Cordell 2012). Human pressures are thus promoting a great impact on the organisms that inhabit these previously-undisturbed ecosystems (Farris 1995), especially plants as sessile organisms. Despite their roughness, these ecosystems can support a great diversity of species, harboring a high level of endemic and endangered species (Lavergne *et al.* 2003). Therefore, we are at a critical moment at which we need to increase our knowledge of the current and potential impact on these habitats, in order to prevent the loss of biodiversity. However, few studies have assessed the effects of climbing activity on the vegetation of these habitats, and all of these studies were conducted as isolated case studies, lacking an accurate and unified methodology (Holzschuh 2016). Therefore, studies with coordinated sampling across large geographic scales are needed. This project proposed to evaluate the effects of rock climbing on plant biodiversity in different locations with Mediterranean environmental conditions, one of the most widely distributed biomes around the world (Di Castri & Mooney 2012), including California (USA), central Chile, Western Cape (South Africa), south of Australia, and the Mediterranean Basin (Llorens et al. 2007; Fig. 1). With the support of the American Alpine Club (AAC), we conducted field-samplings in different regions along Spain, south of France and California (USA). This project supported by AAC (1) provided a starting point for the study of the long-term effects of rock climbing on plant communities, and (2) it was a first step for evaluate, for the first time, the effects of rock climbing in a wide geographic range. This study is urgently needed to fully understand the potential impacts of this activity, allowing to implement adequate management and conservation measures in these ecosystems.

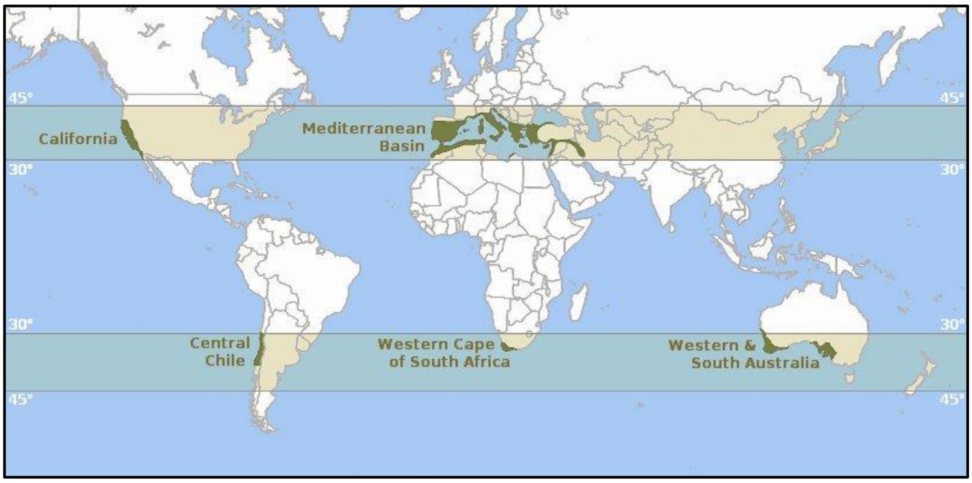

Figure 1: Map showing the different regions of the world classified as Mediterranean.

Purpose

The funding and support of AAC was fundamental to reach the following objectives: first, we aimed to establish a consistent, unified and robust methodology in the sampling of climbing effects on cliff habitats, since it is a discipline with lacks but urgently demands in this respect. Second, we aimed to evaluate the climbing impact on different cliffs of California and Mediterranean basin. Third, we aimed to lay the foundation stone for the development of a framework for environmental impact assessment on cliff areas of the Mediterranean environment across a wide geographical range. Fourth, we aimed to start up long-term research monitoring stations (LTER), intended to evaluate whether the effects of the climbing activity is increasing with higher intensity use over time. Ultimately, with these objectives, we pretend to conduct the first large scale study in this timely topic, involving Managers, Scientifics and Climbers in the decisions for managements and conservation plans of these habitats.

Methods

Mediterranean climbing routes were surveyed for differences in the plant species richness, composition, abundance and cover between transects frequented and not frequented by climbers. A 'case-control' study methodology will be implemented by establishing quadrats of 3 m × 3 m at three different heights of the cliff face: in the bottom, middle and top section (Fig. 2). Each quadrat was divided into five transects: a central climbed transect (C) where the intensity of rock climbing is maximal, two immediately adjacent transects where surveys will not be conducted (‘no survey’), and two other lateral unclimbed transects on each side (U), that represent the areas no frequented by climbers (Fig. 2). The proximity of the control points to the climbed transect precludes the possibility that differences in other physical features could act as drivers of differences between climbed and unclimbed transects. The consideration of the ‘no survey’ transects calls for a higher separation between the unclimbed and climbed transects. That could prevent any noise in the data acquisition from casual ascent deviations, as ‘no survey’ transects cannot be considered completely undisturbed.

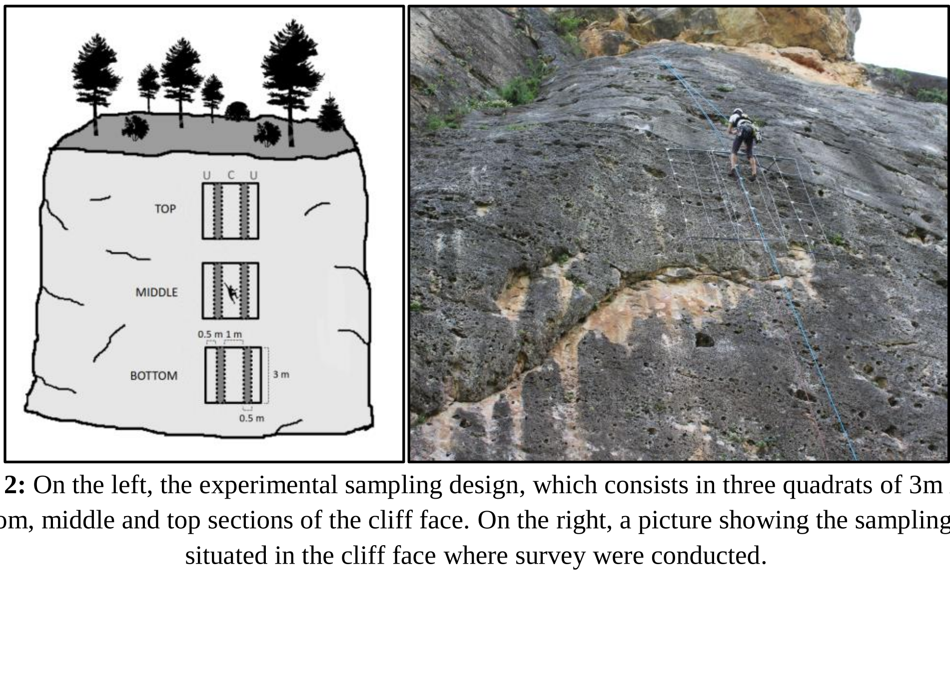

Figure 2: On the left, the experimental sampling design, which consists in three quadrats of 3m x 3m in the bottom, middle and top sections of the cliff face. On the right, a picture showing the sampling quadrat situated in the cliff face where survey were conducted.

Plant species were identified in situ, and individuals of each species were counted. A photo-plot sampling (*see* Elzinga *et al.* 2015) was also used for each 0.5 m × 0.5 m subplots to estimate the plant cover (and also the coverture of lichens and mosses; Fig. 3), and to ensure long term monitoring at the same sampling point (adapted from Farris 1995 and Lorite *et al.* 2017). Moreover, to eliminate the possible bias produced by the physical characteristics of the rock, the slope of the sampling area and the percentage of cracks/crevices (*i.e.* microtopography) present in each quadrat were measured. After sampling (*i.e.* ex situ, in the lab), identified species were categorized as specialized rock-dwelling species, referring to all species with strict association with rocky habitats, and generalist species, referring to ubiquitous species with no association to rocky habitats. In addition, the degree of difficulty of the climbing route was noted, and the intensity of climbing was calculated (through expert judgement and by the calculation of the 'CUI', potential climbing-use intensity; Clark & Hessl 2015) and accounted for.

Figure 3: Pictures of 0.5 m × 0.5 m subplots by using a photo-plot sampling procedure.

Discussion

A total of 27 sampling routes and 243 plots were sampled during springtime 2018 (Fig. 4), including different locations of Madrid (Spain), Chulilla (Spain), Pyrenees (France and Spain), and San Diego (California, USA). An innovative survey design adapted from March-Salas *et al.* (2018) was implemented, including the proposals mentioned in the critical review of Holzschuh (2016). Preliminary results show a significant decrease in plant cover, species abundance and richness, and a shift in the community composition in climbed transects compared to unclimbed transects. The effect of rock climbing was even higher in generalist species than in rock-specialist species, suggesting that different group of plant species will respond differently to this recreational activity. Moreover, the degree of use-intensity of the sampling routes seem to be of high importance, since the climbing impact increase with higher frequentation level (Lorite *et al.* 2018). Therefore, rock climbing could be an important determinant in cliff-face floral structure, since it alters the normal development of plants in such environments.

Figure 4: Picture showing the sampling of one of the transects of Patones (Madrid, Spain).

Moreover, our samplings show that cliffs harbour a great diversity of plant species, with more than 60 species sampled (for some examples, *see* Fig. 5), as well as different lichens and mosses. This is the greatest survey effort conducted in this topic so far, and shows that rock climbing can affect to a great diversity of species and organisms.

In conclusion, this was a very successful field campaign, and a fantastic first step for applying this methodology in the rest of Mediterranean regions, leading to the first large scale study in this topic. The information suministrated by this project will help to reduce the existing controversy and conflict of interests between climbers and park managers, and we expect that it will lead to the application of global conservation measures, as well as a particular action plan for a correct regularization of each locality sampled.

Figure 5: Pictures of some plant species sampled during the surveys of this project supported by AAC.

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