



# Spatial and Height Distribution of Harvested Rupestrian Field Species in Preserved and Cultivated Communities

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## ABSTRACT

This study aimed to compare the spatial and the height distribution of three plant species between two rupestrian field communities, one preserved (A) and the other cultivated (B). One 50 × 100 m plot was delimited in each community and the populations of *Eremanthus incanus*, *Lychnophora pinaster* and *Vellozia caruncularis* were assessed for height and spatial distribution (using the Ripley's L-function). In community A, 4,098 individuals were counted, mostly *L. pinaster*, against 220 individuals in community B, prevailing *E. incanus*. An inverted-J pattern was observed for height distribution in both communities, however, with lower frequencies in B. Regular spatial distribution was found for *E. incanus* and *V. caruncularis* in community A, whereas the pattern for *L. pinaster* depended on the scale of analysis. The spatial distribution of all species differed between communities. The Ecological Park Quedas do Rio Bonito contributes to the conservation of these rupestrian field species.

**Keywords:** arnica, candeia, forest management, Conservation Unities, Ripley's function.

## 1. INTRODUCTION

The rupestrian field is a highly specialized phytophysognomy which occurs mainly on the mountains of the Southeastern, Central and Northeastern Brazil, between 21°10' and 10° S, usually above 900 m.a.s.l. (Giulietti et al., 1997; Vasconcelos, 2011). It shows discontinuous distribution, determined by shallow soils and rock outcrops (Brasil, 1983). The rupestrian

field vegetation contains many endemic species, which are adapted to high variations of temperature and water availability, acidic and oligotrophic soils, and fire occurrence (Joly, 1970; Oliveira-Filho & Fluminhan-Filho, 1999; Romero & Nakajima, 1999; Salimena et al., 2013).

Currently, conservation of rupestrian field sites is menaced by pasture, allotment and the exploitation of wood, medical and ornamental plants without proper

management, which increases the need for studies to aid their conservation (Mann, 2013). Among the rupestrian field species which are commonly exploited and deserves attention are *Eremanthus incanus* (Less.) Less., *Lychnophora pinaster* Mart. and *Vellozia caruncularis* Mart. ex Seub.

*Eremanthus incanus* is an arboreal Asteraceae popularly known as “candeia” which may reach 10 m tall, with reddish-brown lanate-tomentose or gray lepidote-tomentulose stems, frequently darkened basally by fire (Macleish, 1987). As *Eremanthus erythropappus* (DC.) MacLeish, the most common candeia species, *E. incanus* timber is economically valuable, being exploited to produce firewood, tool grips and fence posts (Scolforo et al., 2003; Oliveira et al., 2009; Silva et al., 2012).

*Lychnophora pinaster* is a shrubby Asteraceae commonly known as “arnica”. According to Coile & Jones (1981), *Lychnophora* plants are usually much branched and pachycladous; have tomentum stems and prominent leaf scars; leaves are usually crowded on the current season’s growth; and may reach 4 m tall. *Lychnophora pinaster* is widely applied to the treating of inflammatory and Chagas diseases (Chiari et al., 1991; Abreu et al., 2013), but its reckless exploitation is menacing the species conservation (Biodiversitas, 2007).

*Vellozia caruncularis*, popularly known as “canela-de-ema”, is a Velloziaceae shrub with showy lily-like lilac flowers, highly endemic to mountainous habitats, such as rupestrian fields and cangas (Menezes et al., 1993; Jacobi et al., 2007). The loss of habitat and the predatory exploiting are the main hazards for *V. caruncularis* and Velloziaceae in general (Ayensu, 1973; Lousada et al., 2011).

The analysis of the spatial and the height distribution of plants in native environments is a valuable tool to the conservation of threatened species (Niklas et al., 2003; Almeida & Cortines, 2008; Carvalho et al., 2009; Santos et al., 2011; Amaral et al., 2013; Bruzina et al., 2013). Such studies aid the identification of disturbances on the plant population structure and subsidize the construction of sustainable management plans and policies (Kanieski et al., 2012; Samaniego & Marquet, 2013; Garzon-Lopez et al., 2014; Zhang et al., 2014).

Nevertheless, studies on this issue are still scarce for plants of rupestrian fields. Therefore, this study aimed to compare the spatial and height distribution

of three plant species between two rupestrian field communities: one legally protected and the other subjected to anthropogenic disturbances.

## 2. MATERIAL AND METHODS

The study was carried out in two rupestrian field communities, approximately 1.1 km apart from each other: one within a protected area (Quedas do Rio Bonito Ecological Park) and the other prone to anthropogenic disturbances, outside the Park. The Ecological Park Quedas do Rio Bonito is a 235 ha private reserve established in 1976 which protects a valuable fragment of native forest with well-represented and well-preserved plant population (Oliveira-Filho & Fluminhan-Filho, 1999), whereas its surroundings are visibly cultivated. It is located within the coordinates 21° 19’ 45” – 21° 20’ 48” S and 44° 58’ 18” – 44° 59’ 24” W, between 1,000 and 1,300 m of altitude. The local climate is a transition between Cwb and Cwa, according to the Köppen classification: temperate, with dry winter, mean annual precipitation of 1,529 mm and mean annual temperature of 19.4 °C. The predominant soils in the area are Leptosols and Cambisols, with frequent rock outcrops (Curi et al., 1990).

The area’s original vegetation comprises a mosaic of forest, savannah (cerrado) and rupestrian field fragments, with relatively frequent fire occurrence (Eiten, 1982; Oliveira-Filho & Fluminhan-Filho, 1999; Vasconcelos, 2011). In general, the rupestrian fields are associated with shallow and young soils on the mountains; whereas the savannah and forest fragments occur at lower altitudes and on the older and deeper soils (Oliveira-Filho & Fluminhan-Filho, 1999).

Each rupestrian field community, had one 50 × 100 m plot delimited (Figure 1). Both plots faced west and were within 1,000 and 1,200 m of altitude. The plots were set with the length uphill. They also showed rock outcrops, indicating shallow soils. The plot inside the Park (Figure 2a) is far from the entrance or roads, and can only be assessed through a hilly trail; whereas the plot outside (Figure 2b) is close to the road and has an easier access.

Within the plots, all live *Eremanthus incanus*, *Lychnophora pinaster* and *Vellozia caruncularis* individuals with height above 0.30 m had their height and position (X and Y coordinates) assessed. The position was

assessed with a measuring tape considering the plot length (100 m) as the X axis and plot width (50 m) as the Y axis. The (0.0) coordinate was assigned to the northeastern corner of the plots. The height was measured with a graduated rod. Data were collected in April, 2007.

Density distributions for height classes were prepared for each species and community using five classes with 1 m of amplitude each. To offset the strong decrease in the density of individuals in the larger classes and linearize the distribution, data were transformed to  $\ln(n+1)$  (Espírito-Santo et al., 2005). This transformation allows a better representation of the greater and low-density classes, facilitating graphical comparison (Oliveira-Filho et al., 2001).

The spatial distribution of the species was analyzed with the Ripley's K (h) function (Ripley, 2004), recommended for the study of spatial patterns. The Ripley's K (h) function (Equation 1) is a probability density function which considers the variance of the distances among all pairs of events (Moeur, 1993; Haase, 1995):

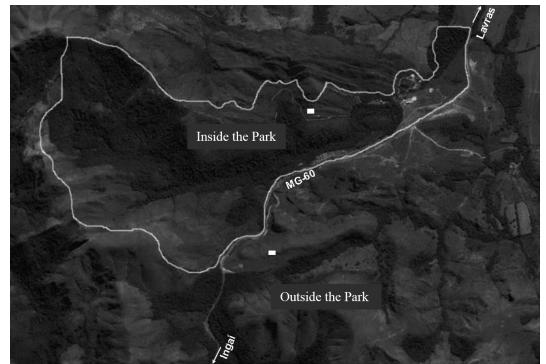
$$\hat{K}(h) = \frac{R}{n^2} \sum_{i=1}^n \sum_{j=1, i \neq j}^n \frac{I_h(d_{ij})}{w_{ij}} \quad (1)$$

Where  $\hat{K}(h)$  is the expected number of events (plants);  $h$  is the radius of the circle centered in each event;  $R$  is the area of the studied region (plot);  $n$  is the number of observed events;  $d_{ij}$  is the distance between the  $i^{th}$  and  $j^{th}$  cases;  $I_h(d_{ij})$  is an indicator function which is 1 if  $d_{ij} \leq h$  and 0 otherwise; and  $w_{ij}$  is an edge correction factor, corresponding to the proportion of the circumference of the circle centered at the  $i^{th}$  event that is within the region  $R$ .

To compare  $\hat{K}(h)$  against the random pattern, the transformed  $\hat{L}(h)$  function was used (Equation 2):

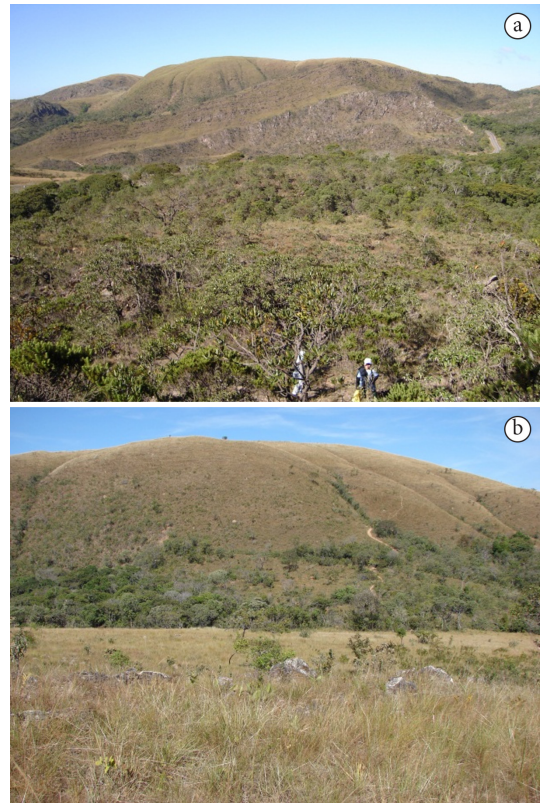
$$\hat{L}(h) = \sqrt{\frac{\hat{K}(h)}{\pi}} - h \quad (2)$$

The significance of the  $\hat{L}(h)$  function deviations was determined by the construction of an envelope of complete spatial independence among events, based on 500 independent simulations of  $n$  events in the study area. The plotting of  $\hat{L}(h)$  as a function of the distance  $h$  indicates clustered distribution at positive values, regular distribution at negative values and random distribution at values within the constructed



**Figure 1.** Location of the plots (white rectangles) inside and outside the Ecological Park Quedas do Rio Bonito. Each plot has 50 x 100 m (0.5 ha). The Park's boundary is shown in white.

**Figura 1.** Localização das parcelas (retângulos brancos) dentro e fora do Parque Ecológico Quedas do Rio Bonito. Cada parcela possui 50 x 100 m (0,5 ha). Os limites do Parque estão representados pela linha branca.



**Figure 2.** General view of the plots within (a) and outside (b) Ecological Park Quedas do Rio Bonito.

**Figura 2.** Vista geral das parcelas dentro (a) e fora (b) do Parque Ecológico Quedas do Rio Bonito.

envelope (Bailey & Gatrell, 1995). Data were analyzed with the aid of the Splan package for the R software (Rowlingson & Diggle, 1993; Bivand & Gebhardt, 2000).

### 3. RESULTS AND DISCUSSION

A total of 4,318 individuals of the three species were surveyed in both communities, with a predominance of *L. pinaster*, with 47.8% of the total frequency, summing 2,065 individuals. The second most abundant was *E. incanus*, with 1,156 (26.8%) individuals, followed by *V. caruncularis*, with 1,097 (26.4%) plants.

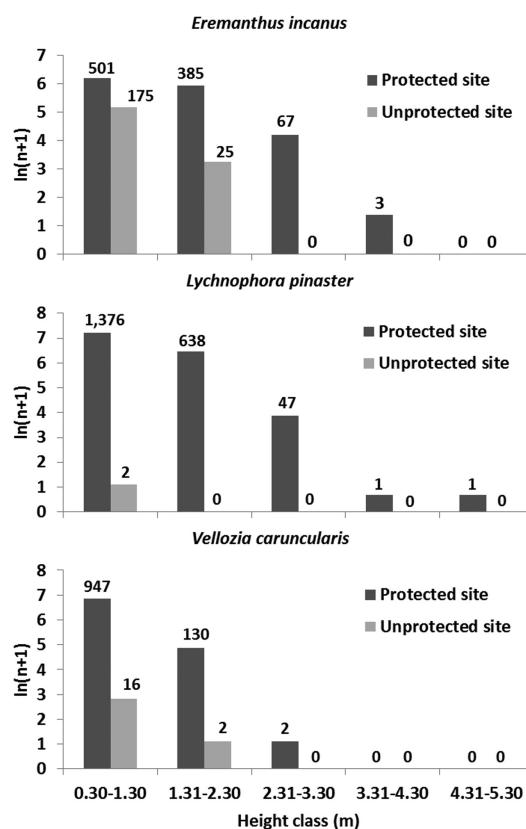
All species were more frequent in the protected community, which contained 4,098 individuals, 94.9% of the surveyed plants. The most noticeable difference between communities occurred for *L. pinaster*, with only 2 individuals in the unprotected community, 0.1% of the total *L. pinaster* plants. *Eremanthus incanus* was the most abundant species in the unprotected community, with 200 individuals, 17.3% of the total *E. incanus* plants. Eighteen *V. caruncularis* individuals were observed in the unprotected community, 1.6% of the total *V. caruncularis* plants.

With exception of the *L. pinaster* population in the unprotected community, whose height distribution pattern could not be identified due to the low number of plants, the height distribution for the three species populations showed an inverted-J (negative exponential) pattern (Figure 3), the usual pattern for native tree populations (Oliveira-Filho et al., 1994; Almeida & Cortines, 2008; Sühs & Budke, 2011; Zhang et al., 2010, 2014). The higher frequency of individuals with lower height is a sign of structural stability, since mortality in the superior classes is compensated by recruitment from the inferior classes.

The species with the highest difference between plots was *L. pinaster*, with only two individuals found in the unprotected community, both of the lowest height class. Since all parts of *L. pinaster* plants are used for medical purposes, its harvesting is not selective. Therefore, there is no preference for larger individuals and all visible plants might be harvested, reducing density severely in all height classes. Similarly, *V. caruncularis* plants are used mainly as ornaments and might also be collected indistinctly, but with less intensity than *L. pinaster*.

On the other hand, *Eremanthus incanus* wood is commonly used in the region as tool cables and fence posts; therefore, larger individuals are preferred by the logger. This might be the reason why the frequency of individuals in the superior height classes was so low in the unprotected community. This form of exploitation is harmful to the *E. incanus* native population and to the exploitation activity itself, since the spatial distribution, the regenerative potential and the maintenance of superior seed-trees in the population are neglected (Pérez et al., 2004; Silva et al., 2008).

The spatial distribution of the *L. pinaster* population in the protected community was regular at very short (up to 10 m) and large (more than 70 m) distances, and aggregated at 10-70 m distances (Figure 4). In the



**Figure 3.** Height density distribution for the three species in the two rupestrian field communities. The numbers above bars indicate the observed frequency without logarithmic transformation.

**Figura 3.** Distribuição de densidade de altura para as três espécies nas duas comunidades de campo rupestre. Os números acima das barras mostram a frequência observada, sem transformação logarítmica.



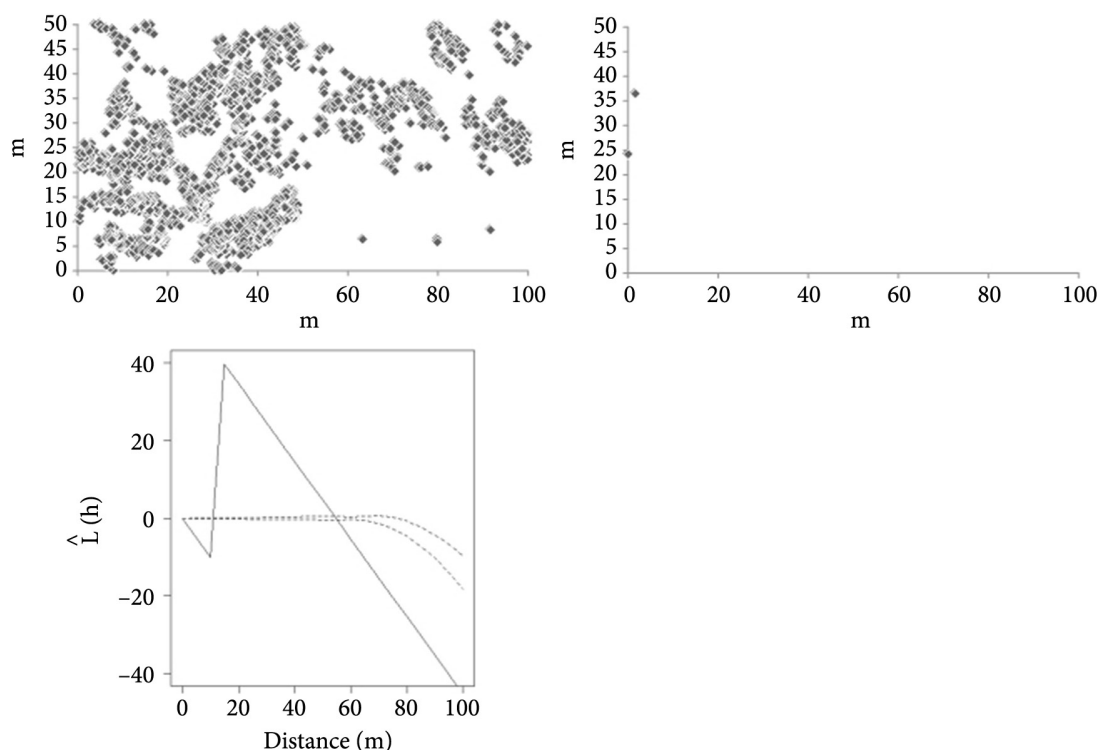
protected community the *E. incanus* and *V. caruncularis* populations showed regular distribution, with linear decrease in  $\hat{L}(h)$  as  $h$  (search radius) increases (Figures 5 and 6).

The spatial distribution of plants is influenced by biotic and abiotic factors, and their relative contribution varies with the analysis scale, i.e., the search radius (Dale, 2000; Garzon-Lopez et al., 2014). Rupestrian field areas might have microsites of more fertile and deep soils or rock cracks, promoting the occurrence of plant clusters or “isles” of vegetation. In this study, aggregated distribution in the protected community was observed only for *L. pinaster*, suggesting that this species is more influenced by the presence of microsites than *E. incanus* and *V. caruncularis*. Gianotti et al. (2013) found that the *L. pohlii* density in a rupestrian field fragment was higher in the plots with higher pH, P-rem and base saturation. Diniz et al. (2010) also observed aggregated distribution for *L.*

*pinaster* in a rupestrian field reserve and suggested that vegetative propagation might also contribute to this pattern.

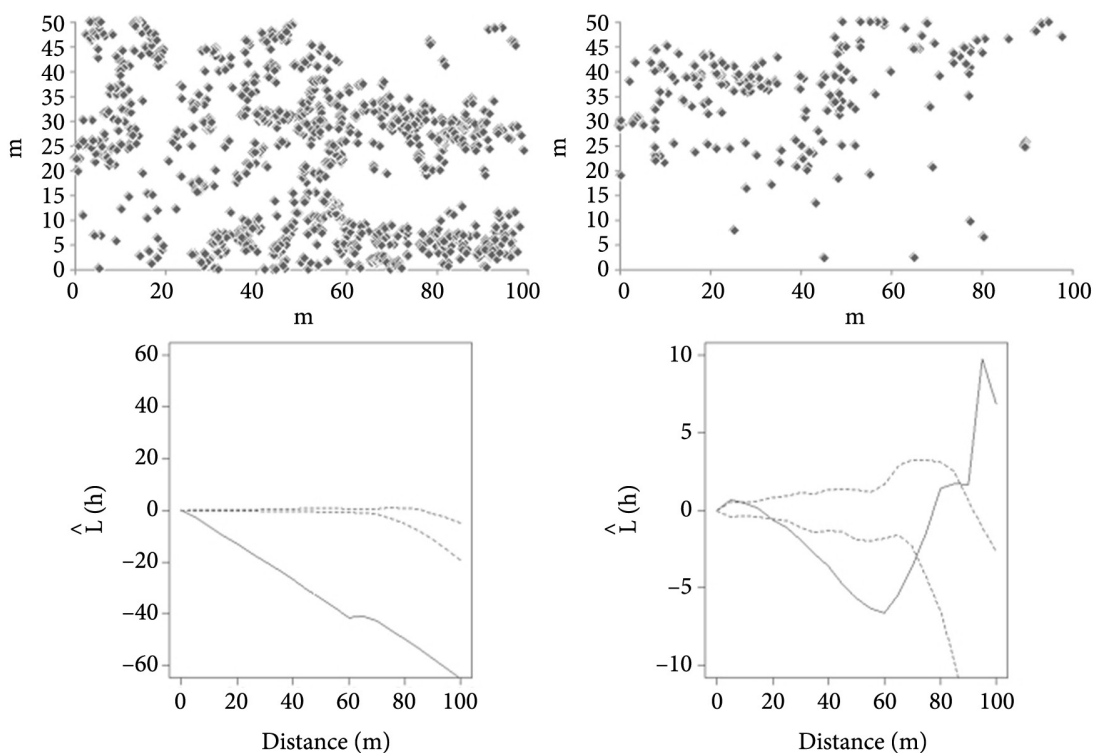
In the unprotected community, the *E. incanus* and *V. caruncularis* populations showed variable distribution patterns according to the search radius (Figures 5 and 6). At short distances (up to 20 m), the pattern for *E. incanus* was random, changing to regular at medium distances (20-70 m) and aggregated at higher distances. The *V. caruncularis* distribution pattern was aggregated at short distances (up to 35 m), random from 35 to 60 m and regular at higher distances. It was not possible to describe a pattern for *L. pinaster* in the cultivated community due to the low number of individuals found (two plants, 12 m distant from each other).

The changes in the spatial distribution pattern between the protected and the unprotected communities are probably reflects of the anthropogenic activities.



**Figure 4.** Maps of spatial distribution and Ripley's  $\hat{L}(h)$  graphic for the *Lychnophora pinaster* populations. (a) and (c): protected community. (b): unprotected community. The continuous line depicts the calculated  $\hat{L}(h)$  and the dotted lines delimit the confidence interval for random distribution.

**Figura 4.** Mapas de distribuição espacial e gráfico da função  $\hat{L}(h)$  de Ripley para as populações de *Lychnophora pinaster*. (a) e (c): comunidade protegida. (b): comunidade desprotegida. A linha contínua representa o  $\hat{L}(h)$  calculado e as linhas pontilhadas delimitam o intervalo de confiança para distribuição aleatória.



**Figure 5.** Maps of spatial distribution and Ripley's  $\hat{L}(h)$  graphics for the *Eremanthus incanus* populations. (a) and (c): protected community. (b) and (d): unprotected community. The continuous lines depict the calculated  $\hat{L}(h)$  and the dotted lines delimit the confidence interval for random distribution.

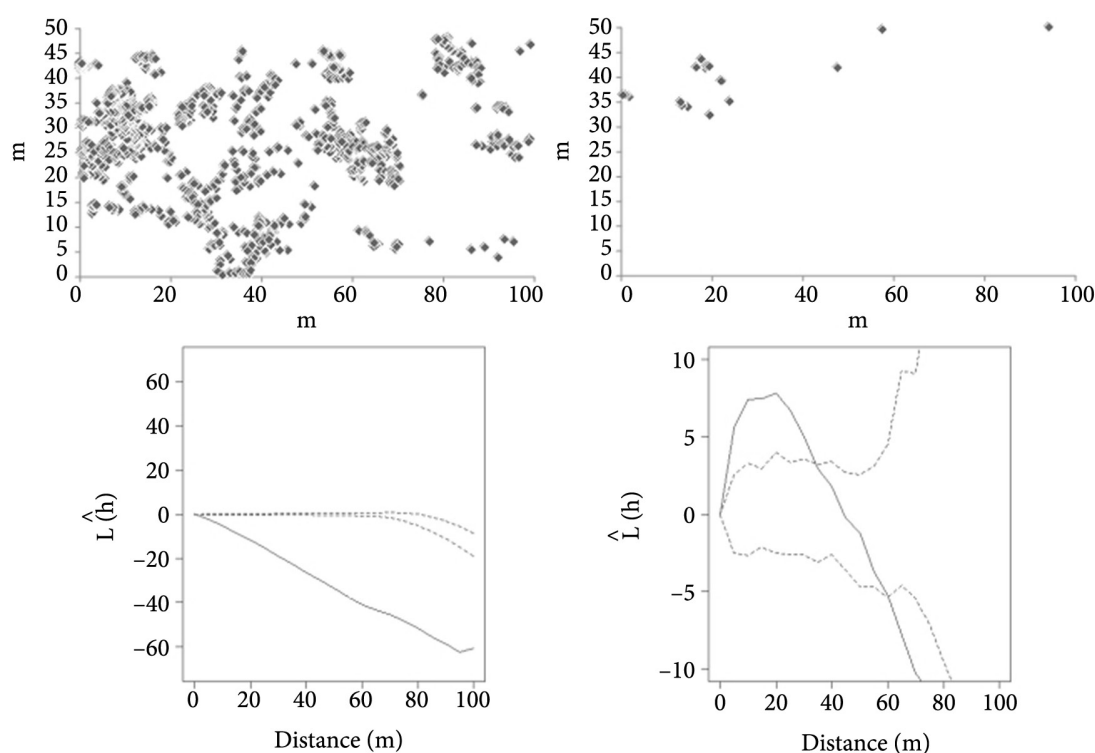
**Figura 5.** Mapas de distribuição espacial e gráficos da função  $\hat{L}(h)$  de Ripley para as populações de *Eremanthus incanus*. (a) e (c): comunidade protegida. (b) e (d): comunidade desprotegida. As linhas contínuas representam o  $\hat{L}(h)$  calculado e as linhas pontilhadas delimitam o intervalo de confiança para distribuição aleatória.

Since there is no control on the kind, intensity or frequency of those activities in the area, it is not possible to describe the relationship between the observed patterns and the disturbance factors. However, it can be inferred, from the changes in the spatial and height distributions, that such anthropogenic activities do not respect the communities' structure.

Sustainably-managed communities usually show predictable and minimum changes on the spatial and height distribution (Scolforo, 1998). Zhang et al. (2014), for instance, observed slight modifications on the spatial and diameter distribution patterns on managed forests in China. Silva et al. (2008) observed predominance of clustered distribution for *E. erythropappus* in a managed site at shorter distances ( $h$ ) and regular or random distribution at large distances, reflecting the influence of the seed-tree management system in the species' spatial distribution.

In this study, detrimental alterations in the height and spatial distribution of *L. pinaster*, *E. incanus* and *V. caruncularis* disturbances were noticed in the cultivated community. The resilience of rupestrian fields is low, given the particularities of the phytophysiology and the high endemism (Le Stradic, 2012). Therefore, the reckless exploitation of its resources menaces the conservation of biodiversity.

The creation of conservation units is probably the best strategy to preserve rupestrian fields (Ribeiro & Freitas, 2010; Mann, 2013). In fact, there are significant rupestrian field communities within conservation units, especially those of direct use, which allow sustainable harvesting (Ribeiro & Freitas, 2010). However, there is little information on the sustainable management of rupestrian field species in those areas. The better understanding of the population patterns in preserved and cultivated sites, preferably evaluating the impacts of specific activities, such as harvesting, would aid the



**Figure 6.** Maps of spatial distribution and Ripley's  $\hat{L}(h)$  graphics for the *Vellozia caruncularis* populations. (a) and (c): protected community. (b) and (d): unprotected community. The continuous lines depict the calculated  $\hat{L}(h)$  and the dotted lines delimit the confidence interval for random distribution.

**Figura 6.** Mapas de distribuição espacial e gráficos da função  $\hat{L}(h)$  de Ripley para as populações de *Vellozia caruncularis*. (a) e (c): comunidade protegida. (b) e (d): comunidade desprotegida. As linhas contínuas representam o  $\hat{L}(h)$  calculado e as linhas pontilhadas delimitam o intervalo de confiança para distribuição aleatória.

building of sustainable management strategies for rupestrian fields inside and outside conservation unities.

#### 4. CONCLUSION

- The differences on the height and spatial distribution on the cultivated community are probably due to anthropogenic activities.
- The Ecological Park Quedas do Rio Bonito contribute to the conservation of *Eremanthus incanus*, *Lychnophora pinaster* and *Vellozia caruncularis* populations.

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