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Trampling Impacts on Coastal Sand Dune Vegetation in Southeastern Brazil

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Abstract: Experimental trampling was conducted in a coastal sand dune community located in a State Park in Southeastern, Brazil. To evaluate the effects it was used 5 permanent plots. The trampling intensities were 25, 75, 200, 500 and 1,000 passes and each plot had a control area. Response to trampling was assessed by determining species composition, vegetation cover and height evaluation, right after trampling, 2 weeks, 3 months, 6 months, 9 months and 1 year after trampling. The same parameters were evaluated just before trampling. Although there was a substantial loss of vegetation cover on 500 and 1,000 treatment plots, the study area was recovered in a few months. Reductions in height occurred with less impact: 200 passes. The 500 and 1,000 pass interference didn't show statistical difference for cover and 200, 500 or 1,000 passes were statistically similar for the community, suggesting weak linearity between impact and amount of use. The results show that this community has a good resilience; probably in response to the natural stress the vegetation suffers continuously. The vegetation's changes in species composition seem to be more accurate; especially the extinction of rare species and the introduction of alien ones.

Introduction

Large numbers of experiments on vegetation trampling have been conducted since Bates (1935) has published the first research on this subject in the United Kingdom. We could say that the 70s and 80s have produced most papers including different vegetation communities. These works, therefore, were developed in areas that had already been changed for agricultural or pastoral purposes. Then, the correlation between impact and amount of use were difficult to achieve. Experimental trampling research was rare and there was a lack of continuity to really understand the effects of the increasing recreational pressure over natural areas. In order to standardize the experiments around the world, Cole and Bayfield (1993) presented a protocol where they indicate a proposal on the way researchers should evaluate trampling experiments by using parameters that were comparable with other sites. According to Cole and Monz (2002) research based on this kind of methodology have been contributing to the general knowledge of recreation ecology and to the efficiency of visitor management in protected areas.

Considering the growing knowledge on recreation ecology, we are now wondering what we have learned from all those experiments and if the managers have been using those experiences to control visitor impacts on natural areas. More than 10 years after Cole's and Bayfield's proposal, many rules are being used to control impacts of recreation in Latin America, but in many cases the decisions are still based on the concept of recreational carrying capacity. One can ask why this concept is still used, taking to account that we already know that the number of visitors in a certain area is not the main cause of impacts as we have to consider the type and distribution of use and the visitors' behaviour. One possible answer is the lack of experiments that indicate the relationship between use and their effects on vegetation in Brazilian ecosystems.

What is considered in the present work is that we still need to raise answers to highlight the effects of trampling on Brazilian vegetation communities in order to make better decisions for the conservation of natural areas.

Study Area

Considering the lack of information on impacts over Brazilian vegetation, this work will analyse the effects of experimental trampling on coastal sand dune vegetation at "Parque Estadual da Serra do Mar – Núcleo Picinguaba", located in Ubatuba, São Paulo State, Brazil.

The total area of Picinguaba is 47,000 hectares, including five beaches. The study area (Fazenda Beach) was chosen because it has the reminiscence of original vegetation in better conditions, has fewer houses and also has low visitation. All these factors contribute to keep the experimental variables under control. The beach is 4 km long, and receives visitor flows on weekends, holidays and school vacations. Most visitors take a one-day visit, because there are no hotels there. It has a camping area for at about 40 tents, which is only open on holidays and vacation times (in general with no more than a hundred people). The beach receives school and university groups all year long and the park has simple accommodations for them.

The coastal sand dune vegetation is very threatened in Brazil, especially at São Paulo State where the big cities are concentrated. Urban people frequently go to smaller cities and natural areas to escape from the crowds. As our country doesn't have a cold winter, the beaches receive tourists all around the year, and the pressure on coastal ecosystems is always increasing as a consequence of the need to increase the number of tourist infrastructures. The climate in the area can be classified as tropical wet, with no dry period. The mean precipitation is 2,600 mm per year, and the mean temperature 21°C. The coldest period, from May to September, is also the driest one.

We have chosen the left side of the beach to install the samples, at the 800 final meters, where a very small number of visitors just walk around and rarely stay. In general people don't stop by this area because it is far from the entrance, where there are parking spaces, restrooms, showers and the Visitor Center.

Vegetation

The dunes at the study area are near the shoreline, being susceptible to invasion by waves, which bring and remove sand and other substrates. When sea level is very high (frequently in winter time) the vegetation can be partially destroyed or removed, but the rhizomes and roots are generally kept in soil, which contributes to a quick regeneration.

The sand dunes' vegetation is composed mainly by herbs like *Hydrocotyle bonariensis*, *Blutaparon protulacoides* and *Ipomea pes-capre*, and grasses like *Panicum racemosum* and *Stenotaphrum secundatum*. In the transition to the fixed dunes, where there are more bushes than herbs, we can find some vines like *Mikania cordifolia*. The most frequent bush species in the area are *Dalbergia ecastophylum* and *Sophora tomentosa*, which form a continuous cover on the ground. Among these herbs we can find some characteristic treelets like *Schinus terebentifolius*, *Rapanea umbellate* and *Rapanea ferruginea*. There is also an alien tree species on the beach (*Terminalia catapa*).

Methods

To evaluate the effects of trampling on coastal sand dune vegetation, permanent plots were used. Five replications of 1,5 m x 5 m were located on the sand dunes, on areas with no evidence of human impacts, as suggested on the protocols of Cole and Bayfield (1993). The sample design was systematic, sorting the first sample and locating the plots in regular intervals. Each replication consists of six lanes delineated at the corners by stakes. The lanes were 0,5 wide, separated by a buffer of 0,4 m, both 1,5 m long (the entire extension of the replication). The treatments were randomly located (control, 25 passes, 75 passes, 250 passes, 500 passes and 1,000 passes) on each sample, in the 0,5 m x 1,5 m lanes (Cole & Bayfield 1993). We have standardized the weight and the type of shoes (tennis) of the tramplers (Cole & Bayfield 1993), as most experimental studies do. The trampling impact was done at once as suggested by Cole and Bayfield (1993). Trampling treatments were applied at the end of the growing season, on March, the end of summer season, the most visited period on this park. Trampling in this season simulates vegetation changes due to more intensive use in this period of the year. The period with more visitors starts on late December and generally finishes on early March, period of summer vacation ending with Carnival holydays. This is considered the better period for beach tourism, not only because it's vacation time, but also considering it's the hottest period of the year and the warmest water temperature.

Measurements were taken on two 30 x 50 cm sub-plots, located adjacent to each other, on each treatment (Cole & Bayfield 1993). The parameters measured were:

1. Visual estimates of the vegetation cover of each species
2. Visual estimates of bare ground;
3. Measures of vegetation height.
4. Species composition;
5. Species frequency.

The data were collected before trampling, immediately after, 15 days after, 3, 6 and 9 months after and 1 year after trampling. Most papers on trampling effects assess the measures just 15 days and one year after trampling. It was decided to take intermediate measures because the community appeared to have a quick recovery.

Data Analysis

As suggested by Cole and Bayfield (1993), the evaluated variables were the community relative cover and relative height.

1. Relative cover (RC): based on the sum of the coverage of all species after trampling, over the initial cover, corrected by a factor that takes the variation of the control plots into account. It is calculated for each treatment as follows:

$$RC = \frac{\text{surviving cover on trampled subplots}}{\text{initial cover on trampled subplots}} \times cf \times 100\%$$

Where:

$$cf = \frac{\text{inital cover on control subplots}}{\text{surviving cover on control subplots}}$$

2. Relative Height (RH): similarly to relative cover, it is based on the mean of height measures after trampling and for each treatment. The relative height is calculated in a similar way as relative cover:

$$RH = \frac{\text{mean height of each treatment}}{\text{initial height on the same treatment}} \times cf \times 100\%$$

Where:

$$cf = \frac{\text{initial height on control subplots}}{\text{height of survivors on control subplots}}$$

A Friedman test was used to assess if there were significative differences among the treatments. When any significative difference (p-value= 0,05) was detected, comparison tests were employed between control and each treatment and between each pair of treatments.

Results and discussion

1. Vegetation cover

After the data analysis, it was possible to figure out that the relative cover was mostly affected for the two first measurements (right after trampling and 15 days after it - Figure 1)

The treatment of 1,000 passes showed less cover reduction than the 500 one, considering the measurement right after trampling, but there were no statistical differences between them. After 15 days, there were no differences at all. We consider that the initial differences between these treatments may be a reflex of the species composition, because some species are less resistant than others. These results contribute to the presupposition that there is a weak o linearity between impact and use. After 500-passes, we can double the interference and the vegetation behaviour is still the same.

After one year, the cover differences in the treatments were not visible anymore. The same vegetation response was found by Cole (1995), for 18 vegetation types in the USA.

Some species were more vulnerable than others. Grasses like *Panicum racemosum* were more resistant, and the vegetation area where this specie dominates appears to absorb more impact. Liddle (1988) suggests that the grasses' morphology is really more consistent than the dicotyledonous. The author points out that some of the most important features that give resistance to grasses are the rhizomatous or stoloniferous main stems with growing points near the surface of the ground, its frequent branching and the persistent meristems at the base of the leaves, what was observed in this species. The vegetation cover regeneration has occurred in no more than 3 months, what shows the high resilience of this vegetation type (figure 1). Some treatments have even increased the cover after trampling. Liddle (1988) reports that some research has found this pattern, a little increase on vegetation cover and biomass in areas with low trampling intensities. For the author drifts in species composition may explain this increase.

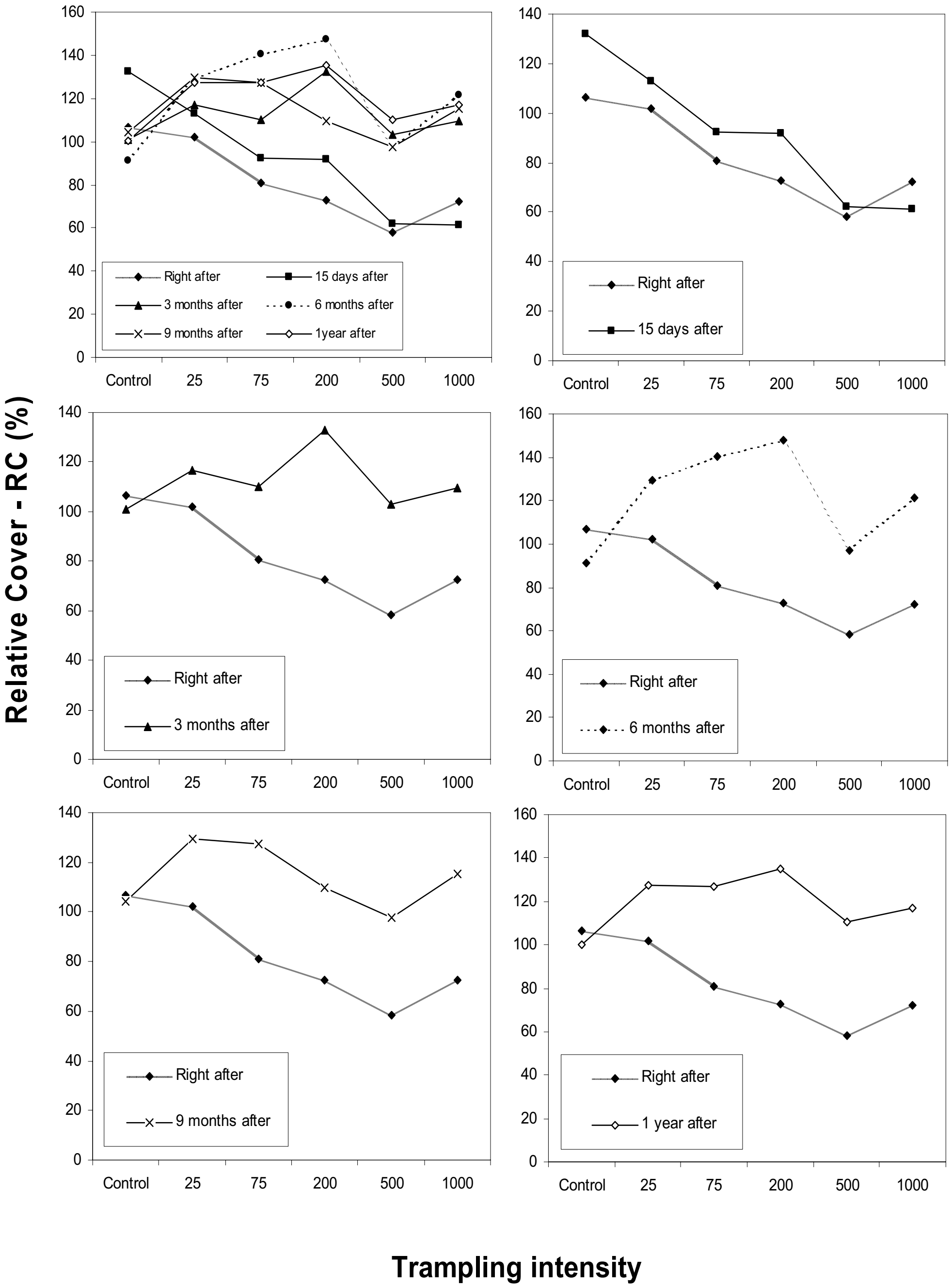

Figure 1: Relative vegetation cover of the coastal sand-dune, right after, 15 days, 3 months, 6 months, 9 months and 1 year after trampling application.

2. Vegetation Height

The 200-pass treatment showed a similar effect with 500 and 1,000 passes, considering relative height (figure 2). In fact, the 200, 500 and 1,000 trampling treatments showed no statistical differences between them, but all were different from control. This suggests that 200 passes is critical to height reduction on this vegetation, and that after this limit low extra interference is added. Cole and Monz (2002) indicate that in communities that show more resistance to the effects of use, the height reduction is more pronounced. The findings on this experiment show the same tendency.

After 15 days the 200 passes treatment showed less recovery than the others. It is probably an effect of the vegetation composition, which gives specific resistance patterns to different samples in the same plant community. So, the relative height shows a reduction tendency with less impact. The recovery of it occurred in a slower way if compared with the relative cover recuperation. The

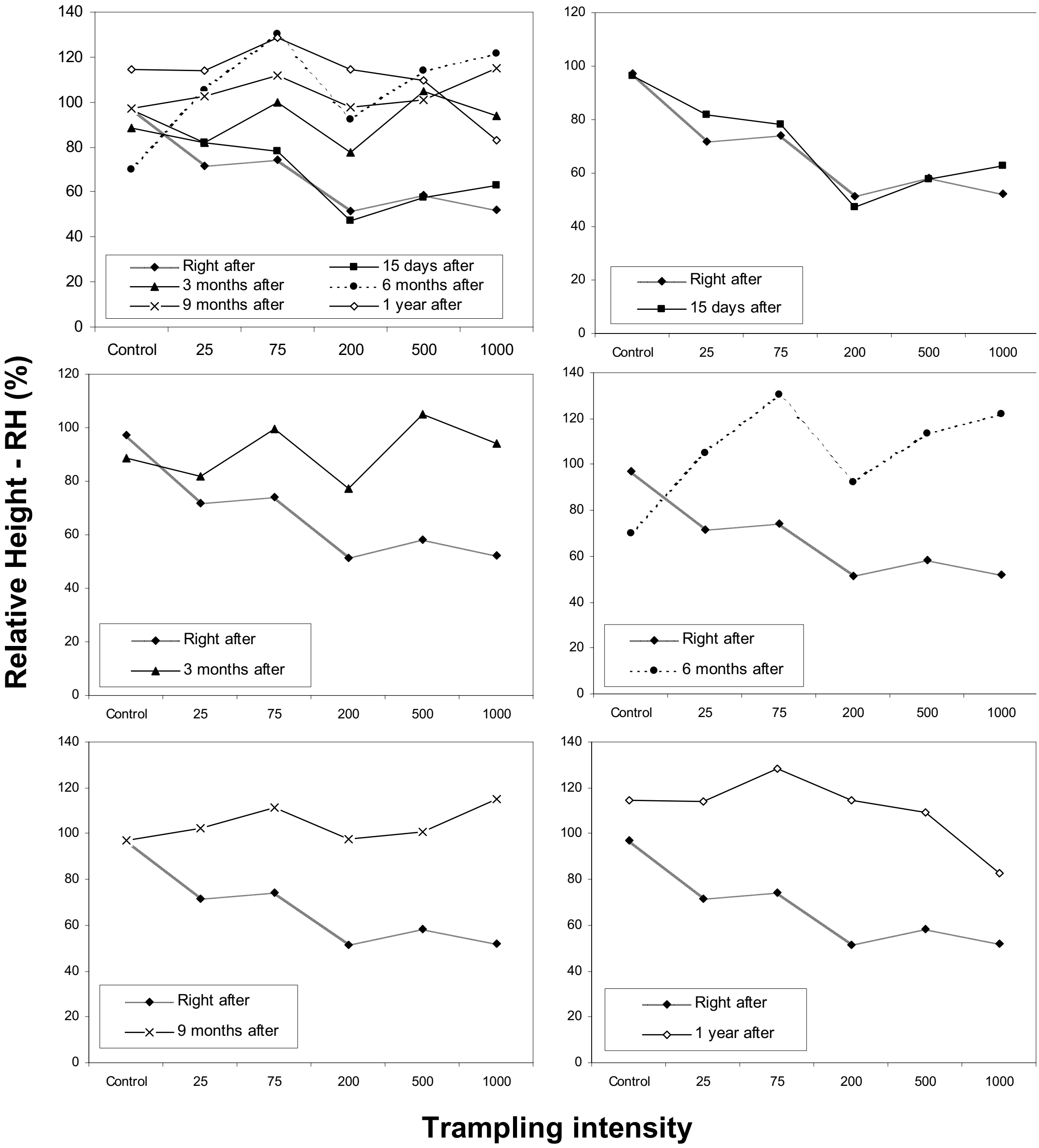

Figure 2: Relative vegetation height of the coastal sand-dune, right after, 15 days, 3 months, 6 months, 9 months and 1 year after trampling application.

same situation was observed by Cole and Bayfield (1993), in three different sub-alpine communities in the USA.

Areas where the species *Blutaparon portulacoides* dominates showed less resistance. These findings may suggest that heavy visitor use should be conducted into the areas where grasses dominate.

Conclusions

The results indicate that maybe the chosen parameters (vegetation cover and vegetation height) are not appropriate to evaluate the trampling impacts in such a vegetation type, because sand dunes already have a high level of natural disturbance and recovery every year, associated with the dynamics of the area. As the community passes through natural stress, such as high tidal variations in winter, with substrate and vegetation removal, they have strategies to survive and to recover very quickly, showing a good resilience.

Reductions in height occurred with less impact than in cover. Probably the first effect of trampling for this vegetation type is a decrease in relative height. Similar patterns were found in other researches in the US.

The statistical analysis could demonstrate that the relation between impacts and amount of use is not very linear. After these findings we truly believe that we must reconsider the recreational carrying capacity usage for protected areas in Brazil.

This way, we consider that changes in composition of species can be more accurate to determine the limits of acceptable changes for this plant community, especially the extinction of rare species and the introduction of alien ones. This thought comes from the findings on this research, because although the community recovery was quick, there was species composition drift after the impact.

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