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ECOLOGICAL BASIS OF LIVESTOCK GRAZING IN MEDITERRANEAN ECOSYSTEMS

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Effects of herbivory on growth and survival of seedlings and saplings of *Pinus sylvestris nevadensis* in SE Spain

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Summary

We have studied the effect of herbivory by domestic (sheep and goats) and wild (Spanish ibex) ungulates in the autochthonous populations of the Scots pine Pinus sylvestris nevadensis in high mountains of south-eastern Spain, to determine whether ungulate herbivory is a limiting factor in forest regeneration. During 1995 and 1996, two study sites were established in the Sierra Nevada and in Sierra de Baza. We have evaluated all kinds of damage suffered by seedlings and saplings. The impact of ungulates was scant on seedlings, whereas in saplings damage was considerable, especially in the dry year of 1995, though less severe in the wet year 1996. The effect of ungulate herbivory was strongly negative even though the number of meristems removed was low, because herbivory preferentially occurs in the apical part of the tree. This delays the normal vertical growth, resulting in prostrated, stunted pines. Our conclusion is that herbivory may be hindering the juvenile pines from becoming adults, thus impeding the natural regeneration of these woodlands.

Keywords: forest regeneration, herbivory, *Pinus sylvestris nevadensis*, SE Spain, ungulates

Introduction

The biomass of herbivores supported per unit of primary productivity is about one order of magnitude greater in human-controlled landscapes than in natural ecosystems (Oesterheld et al. 1992). At the community level, high herbivore pressure can dramatically alter the plant species composition. At the population level, herbivores can severely constrain population regeneration of woody plants. In both senses, Mediterranean and arid habitats, grazed by domestic livestock over thousands of years, provide vivid examples (Le Houerou, 1981; Noy-Meir et al., 1989).

In this context, the Scots pine (Pinus sylvestris nevadensis) growing in Mediterranean mountains of SE Spain is a good case study. This pine inhabits southern Spain in calcareous areas of the Sierra Nevada and Sierra de Baza, occupying a strip between 1500 and 2100 m a.s.l. Both populations grow in mountains traditionally used as summer pasturelands (mainly for sheep and domestic goats). In recent times, two factors have exacerbated the overgrazing problem: the rising population of the Spanish ibex in the Sierra Nevada, and the European Community grants to encourage the raising traditional mountain livestock. Here, we examine ungulate browsing by sheep, domestic goats and the Spanish ibex in relation to sapling growth, and the subsequent impact on the natural regeneration of the woodland.

Study area and methods

We selected two study zones, one in the Sierra Nevada and the other in Sierra de Baza, and in each zone, we fixed two sites, one at the treeline and one in the middle of the woodland. We studied these sites during 1995 (a very dry year) and 1996 (a very wet one), except at the Sierra de Baza treeline in 1995, for which data are lacking. The zone in Sierra Nevada is a mixed stand of *P. sylvestris, Taxus baccata, Acer granatense*, and abundant shrubs. Here, the ungulates are domestic goats and Spanish ibex. In the Sierra de Baza, the zone is a mixed stand of *P. sylvestris and P. nigra*, with understory of *Juniperus communis* and *J. sabina*. Ungulates here are almost exclusively domestic sheep.

To evaluate the livestock pressure, we established six 50 x 2 m fixed transects at each site, collecting dung on a monthly basis. The quantity of excrement by unit surface allows comparisons of the livestock pressure in our two study zones. Dung was collected during summer, the period in which pines were subjected to herbivory of livestock and wild ungulates.

To examine the effect of ungulate activity in seedlings, we marked every seedling we found at the beginning of summer, monitored its progress, and, when possible, registered the causes of death over the summer. For saplings, we marked all that we found below 200 cm height in the plots, determining height, age (number of whorls), and herbivore damage (either by ungulates or insects), registered a the end of the summer. Because damage is usually concentrated in the apical part of the sapling, herbivory was determined as the proportion of lost meristems with respect to the total number of meristems in the apical whorls of the tree (beginning with the whorl corresponding to 1993), except for Sierra de Baza in 1995, for which data were collected from the whole plant. We also characterised the microhabitat in which pine was found (bare soil, among shrubs, under tree canopy).

Results

Seedlings suffered roughly 72% mortality during summer, of which just over 82% was by drought, 3% by insects and slightly more than 12% by ungulate trampling (n = 204). In saplings, 59.1% of trees in 1995 and 28.5% in 1996 suffered some type of herbivory in the apical meristems, and ungulates were the main herbivores (97.7% of meristems lost in 1995 and 98.5% in 1996), losses to insects and freezing being minimal.

Herbivory pressure was lower in Sierra Nevada than in Sierra de Baza. Furthermore, there was scant variation between years. However, the herbivory effects on pines were widely variable. Herbivory was much higher in Sierra de Baza than in Sierra Nevada in 1995, both as percentage of pine saplings attacked, and as percentage of twigs consumed by ungulates. Furthermore, herbivore damage in Sierra Nevada was higher at the treeline than within the woodland. In 1996, herbivory was higher at treeline than in the woodland in both sierras and in Sierra Nevada than in Sierra de Baza.

The main negative effect of herbivory on Scots pine was a pronounced retardation of in pine growth. As commented above, ungulate herbivory mainly attacked the apical part of the pine. Due to the monopodial architecture of the pine, herbivore damage in the apical parts usually forces the plant to generate a new growing axis from a lateral twig,--that is, a loss of primary apical dominance. The regressions performed between the number of pine whorls and height indicate that pines with higher proportions of losses in apical dominance reached less height at a similar age (number of whorls, W), as reflected by the slope of the regression equations (Table 1). Consequently, pines had stunted forms with retarded passage of herbivorized juvenile pines to reproductive ones.

Discussion

During the dry year 1995, sheep, the only ungulate in Sierra de Baza, browsed on pine due to the low pasture production. However, in 1996, with the end of the drought, sheep preferentially grazed on pasture, hence the damage to pines was much lower although the quantity of livestock did not change. In Sierra Nevada, where ungulates were domestic goat and Spanish ibex (two species much more pruned to browsing), pine damage was lower in the wet year, because of alternative resources such as pasture or other more palatable woody species. However, the reduction in herbivore damage from 1995 to 1996 was less notable than in Baza (Table 2).

Table 1. Ungulate pressure (g of dry dung/m2), percentage of Scots pines herbivorized (sample size in parenthesis), and herbivory intensity (percentage of meristems removed in the apical part of labelled pines), in the study areas in Sierra Nevada and Sierra de Baza, SE Spain. All data expressed as mean±standard error, except % of plants herbivorized.

		Sierra Nevada		Sierra de Baza	
	Year	Treeline	Woodland	Treeline	Woodland
Dung counts	1995	0.28±0.04	0.29±0.05	---	0.69±0.14
	1996	0.24±0.07	0.39±0.07	0.10±0.03	0.60±0.24
% of plants herbivorized	1995	65.04 (123)	38.93 (124)	---	87.50 (81)
	1996	45.16 (149)	20.99 (181)	31.11 (45)	20.91 (110)
% of meristems removed	1995	21.72±2.27	14.15±1.84	---	27.40±2.39
	1996	18.50±2.50	7.45±1.36	5.71±1.64	4.29±1.05

Table 2. Regression equations performed confronting number of pine whorls against height. The pines are grouped depending of the percentage of apical losses suffered (from 0 to 25%, from 26 to 50%, and more than 50%). W is the number of whorls. Only pines with more than five whorls are used.

Group	Equation	R^2	n
0-25%	Pine height = -29.4 + 8.5 x W	0.57	124
26-50%	Pine height = -11.3 + 5.2 x W	0.44	173
> 50%	Pine height = 2.4 + 4.1 x W	0.44	99

Regardless of the year, damage was heavier for pines growing in clearer zones of the woodland (treeline) than in the closer zones. That is, the sparse woody areas suffered the heaviest herbivore pressure at the borders, a situation that hampers woodland expansion. Furthermore, the spiny shrubs surrounding the saplings offered protection from ungulates in both treeline and forest (Zamora et al. in press). The advantage of shrub facilitation to saplings increased parallel to herbivore pressure, to the point that in some situations the only seedlings and juvenile trees which survived remained within the islands formed by spiny shrubbery. Beyond these areas of protection, natural regeneration could be completely arrested by strong herbivore pressure.

Wild and domestic ungulates may constitute a major factor hindering this woodland natural regeneration. This is a common situation in livestock areas, but also in protected areas like Sierra Nevada, where wild ungulates are overabundant, causing harmful effects similar to those of livestock. The results of these conclusions for management planning in protected areas are of special importance. Firstly, despite the similarities and geographic proximity of the studied zones, the impact of livestock and wildlife strongly differ, given that the ungulate species in the two areas are different. Consequently, management should be planned on a local basis. Secondly, herbivore damage varies widely depending of the climatic conditions, and therefore management cannot be fixed for several years without taking into account the variations in climate, and hence productivity available to herbivores. Thirdly, the understory of shrubs provided refuge against ungulates for seedlings and saplings of *P. sylvestris*, and the other canopy species such as *A. granatense, Quercus spp.* and *Sorbus spp.*, thus favouring the natural regeneration of the forest (Zamora et al. in press). Under strong ungulate pressure, a good management strategy to encourage forest regeneration would be to preserve shrubbery within forest, especially in the forest border, where ungulate pressure is higher.

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References

Le Houerou, H. N., 1981. Impact of man and his animals on Mediterranean vegetation. Ages 479-521. In: F. di Castri, D. W. Goodall and R. L. Spetch, editors. Ecosystems of the world 11: Mediterranean-type shrublands. Elsevier, Amsterdam, The Netherlands.

Noy-Meir, I., N. Gutman & Y. Kaplan, 1989. Responses of Mediterranean grassland plants to grazing and protection. Journal of Ecology 77:290-310.

Oesterheld, M., O. E. Sala, & S. J. McNaughton, 1992. Effect of animal husbandry on herbivore-carrying capacity at a regional scale. Nature 356:234-236.

Zamora, R., J.A. Hodar & J.M. Gomez (in press). Plant herbivore interaction: beyond a binary vision. In: F.I. Pugnaire & F. Valladares (editors). Handbook of Functional Plant Ecology. Marcel Dekker Inc., New York, USA.