Restoration of Endemic Dwarf Pine (*Pinus culminicola*) Populations in North Mexico

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Abstract

Pinus culminicola (dwarf pine) was first described in 1961 by Andresen and Beaman as a new species at the top of the protected area Cerro El Potosí, Nuevo León México. Later, the distribution of this species with a total of 106 ha was described. In 1978 wildfires at Cerro El Potosí burned 34% of the dwarf pine population. During the past four decades, a reduction of the area formerly covered by dwarf pine has been observed, due to human impact. Currently only 30 ha of fragmented areas covered by dwarf pine exist at Cerro El Potosí, and these include many old trees with low seed production and they are subject to grazing by cattle. The species is now considered endemic and it is subject to special protection.

A study was established to test the effect of cattle, small mammals and elevation on the success of reforestation of an endemic dwarf pine species. *Pinus culminicola*. We planted and monitored 2-year-old seedlings at three elevations within the natural distribution range of this species at Cerro El Potosí in Nuevo Leon, Mexico. At each elevation three treatments were established: (1) seedlings protected from cattle plus small mammals, (2) seedlings protected from cattle, and (3) seedlings with free access to cattle and small mammals. Seedling survival was ca. 50% in (1) after four years, but there were no surviving seedlings with free access to cattle.

Seedling survival was poor after four years for seedlings protected from cattle and small mammals, and no seedlings survived after being exposed to grazing and trampling for three to four years. Mortality was similar at all sites in spite of differences in environments and plant communities present at different elevations. After four years, surviving seedlings were still very small and thus susceptible to trampling and grazing both by cattle and small mammals.

Introduction

Restoration of endemic species should be done with knowledge of the species biology as well as an understanding of the community organization (Teketay 1997). Endangered species recovery is always difficult, and biologists need to use the best tools, skills, and experience available. Fragmentation and habitat loss are the main threats to the survival of most endangered species; hence the inclusion of dynamic processes of plant communities in restoration plans would result in lower habitat loss and fragmentation (Tucker & Murphy 1997; Huxel & Hastings 1999; Jiménez et al. 1999). Lesica and Allendorf (1999) argue that a primary goal of restoration is the establishment of long-term viable populations that will restore ecosystem functions and processes, prevent erosion, and protect biological diversity.

The protected natural area “Cerro El Potosí“ is located in the Sierra Madre Oriental, in the southern part of the State of Nuevo Leon, Mexico; it has an elevation of 3670 m above sea level and is the highest peak in northern Mexico (García & González 1991). Due to its geographical isolation, and peculiar geological strata, it has many rare, endemic and endangered plant species (Rzedowski 1978). The vegetation types at the summit of Cerro

El Potosí are Alpine and Subalpine Prairie, *Pinus culminicola* (Pinaceae) Matorral (shrubland), mixed forest of *Pinus culminicola-P. hartwegii* (Pinaceae), mixed forest of *Pinus hartwegii-P. culminicola*, mixed forest of *Abies vejari* (Pinaceae)-*Pseudotsuga menziesii* (Pinaceae)-*Pinus hartwegii-P. ayacahuite* (Pinaceae), and forests of *Pinus hartwegii*(Guzmán 1998; García et al. 1999; Jiménez et al. 2002).

Pinus culminicola (dwarf pine) was described by Andresen and Beaman (1961) as a new species endemic to Cerro El Potosí. Later the same authors described the distribution of the species as a total of 106 ha (Beaman & Andresen 1966). In 1978 wildfires at Cerro El Potosí burned 34% of the dwarf pine population (García 1989). During the past four decades, a reduction of the area formerly covered by dwarf pine has been observed, due to human impact (Jiménez et al. 1996). Several wildfires drastically reduced the area formerly covered by dwarf pine. Currently, only 30 ha of fragmented dwarf pine area exist at Cerro El Potosí, and these include many old trees with low seed production that are subject to cattle grazing (Jiménez et al. 1999). The species is now considered endemic and is subject to special protection.

Methods

Experiment

The experiment was laid out in December 1997 at three elevations and vegetation types: (a) High elevation at 3500 m in *Pinus culminicola* matorral, (b) Intermediate elevation at 3400 m in *Pinus culminicola-Pinus hartwegii* forest, and (c) Lower elevation at 3300 m in *Pinus hartwegii-Pinus culminicola* forest. At each elevation three square plots of 625 m^2 were established for planting 2-yr-old dwarf pine seedlings that had been grown in a seedling nursery. Three treatments were made for each plot: (1) small mammal plus cattle exclusion (chicken wire), (2) cattle exclusion (barbed wire) and (3) free range. For each treatment at each elevation, 110 seedlings were planted at a density of ca. 2 seedlings in each 10 m^2. At the time of planting, seedlings were ca. 100 mm tall and 5 mm in stem diameter.

Monitoring

All planted seedlings were labeled so they could be distinguished from any naturally established seedlings. We monitored seedlings annually from November 1998 to November 2001. Plant survival was determined by checking the position of each planted seedling. Stem diameter and total height were measured for all surviving seedlings. To test whether grazing and elevation affected seedling survival, we used a two-way ANOVA. To test whether elevation affected seedling growth in diameter and height we used one-way ANOVA.

Results

Seedling survival

Both elevation and exclosure had an effect on seedling survival (p=0.0016) for the duration of this experiment. Seedling mortality was high in all treatments, with only about 50% of seedlings surviving 4 yr after planting in the areas excluded for cattle and small mammals (Fig. 1).

Seedling survival was significantly higher in areas excluded from both cattle and small vertebrates, than in areas with cattle exclosures only. Survival was much lower where no exclosure was used (Fig. 1). Many seedlings in the free-range treatment were grazed and trampled, although this did not happen uniformly to all seedlings. This implies that grazing is low and erratic in the area. However, two years after planting, more than 80% of

seedlings had died at the highest elevation. By the fourth year after planting, no free-range seedlings had survived at any elevation. Where small mammals were not excluded, seedlings were found to be nibbled and occasionally had broken stems.

In general, elevation did not account for differences in seedling survival; the patterns found for exclosures were consistent at all elevations. The fact that seedling survival was constant between environments suggests that seedling mortality during these first years is the result of seedling vigor rather than of competition. However, in 1999 seedling mortality was consistently greater at the highest elevation where the surrounding vegetation is *P. culminicola* matorral, perhaps as a result of a very harsh winter.

Seedling growth

Mean stem diameter (Fig. 2) for all seedlings was low during 1998 (5.09 mm), 1999 (5.15 mm) and 2000 (5.66 mm), perhaps at the expense of root growth. In 2001, stem diameter increased to 8.07 mm. There were no differences in stem diameter that could be attributed to elevation or access to cattle and small mammals.

Seedlings doubled their height since planting in 1997 and 2001. The increase in height was smaller during 1998-2000 than in 2001, perhaps as a result of early root growth. The final mean seedling height was ca. 120 mm. After 4 years in the field, plants were still very short and hence in the layer where trampling and grazing by cattle and small mammals may occur.

Discussion

In addition to low density of *Pinus culminicola* due to habitat loss and wildfires (Jiménez et al. 1996), in the present study we have found low levels of natural and planted seedling recruitment to be a further threat to this endemic species. Naturally emerging seedlings were not detected during the four years of this study. It is possible that seeds were consumed by rodents, as found for other habitats (Beagan et al. 1996), or that conditions for seedling establishment occurred in events that do not happen annually, such as masting or above average spring rainfall.

Elevation in general did not account for variations in survival, which is in agreement with Aguirre et al. (2001) distribution of the species within Cerro El Potosí.

Seedling growth was poor during the four years, which implies that seedlings remained susceptible to grazing and trampling by cattle and small mammals. In this study we have shown that free-range cattle severely limit seedling recruitment as suggested by Jiménez et al. (1999), hence its special protection status should be followed by management plans that exclude free-range cattle, and perhaps seed consuming parrots (Guzmán 1998) and rodents (Beagan et al. 1996) from restoration areas. Seedling planting is a must given that natural germination was not observed during the study.

Conclusions

Seedling survival was poor after four years for seedlings protected from cattle and small mammals, and no seedlings survived after being exposed to grazing and trampling for three to four years. Mortality was similar at all sites in spite of differences in environments and plant communities present at different elevations. After four years, surviving seedlings were still very small and thus susceptible to trampling and grazing both by cattle and small mammals.

There were no naturally occurring seedlings found in this study, hence it appears that replanting will be necessary to ensure the continued survival of this endemic species. In addition to protection of natural populations of dwarf pine from wildfires, reforestation programs that include protection for seedlings from cattle and small mammals should be implemented.

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