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Double-stocking for overcoming damage to conifer seedlings by pocket gophers

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A 5-yr study was conducted on national forests in Idaho and Oregon to evaluate how doubling the seedling stocking rate of lodgepole pine *(Pinus contorta)* would relate to 5-year survival and the uniformity of distribution of seedlings in the presence of northern pocket gopher (*Thomomys talpoides*) damage. Either 4 or 8 seedlings were planted in 40-m^2 subplots (1000 or 2000 seedlings/ha) and monitored for gopher damage. We found that the number of seedlings attacked by gophers, and consequently, the number of seedlings surviving for 5 years, were directly proportional to the stocking rate, but the consistency of seedling distribution within each site (as measured by the proportion of 40-m^2 subplots with ≥ 2 surviving seedlings) did not double with stocking rate. In some situations, increasing the stocking rate should be considered as a method for overcoming pocket gopher damage.

Keywords: animal damage; non-lethal control; reforestation; stocking rates; *Thomomys*

Introduction

Damage to conifers by pocket gophers (*Thomomys* spp.) is a major concern of forest managers in the western United States, as it probably exceeds damage by all other animals combined (Borrecco and Black, 1990; Crouch, 1986). Gophers damage conifers at almost all stages of stand development, but the most severe damage generally occurs during early regeneration, principally from gophers cutting or gnawing off roots and main stems of seedlings. This commonly results in seedling mortality and eventual stocking below the target rate. Control methods presently available to land managers generally are aimed at population reduction and include trapping, and machine or hand application of toxic grain baits. These methods, however, have not adequately reduced seedling losses because of rapid reproduction and reinvasion, and other problems inherent to direct population control (e.g., Barnes, 1973; Capp, 1976; Sullivan, 1986).

Besides the inefficiencies associated with lethal control methods, there is an increasing public interest in the use of non-lethal means to reduce animal damage (Acord, 1992). One promising approach for reducing pocket gopher damage in some reforestation situations is indirect population control by reducing the abundance of gopher forage with herbicides (Black and Hooven, 1977; Borrecco, 1976; Engeman *et al.*, 1995, 1997). An alternative to controlling gopher populations is to protect seedlings from contact by gophers using mechanical barriers, especially plastic mesh tubes (Campbell and Evans, 1975). These have been shown to be highly effective at maintaining desired stocking rates (Engeman *et al.*, 1998), although Pipas and Witmer (1998) still found substantial losses of seedlings heavily forested areas.

Increased costs and/or inefficiencies are inherent in each of these damage control approaches. Plastic mesh cylinders may be effective, but they are relatively expensive and require additional labor to install. Lethal control of gophers frequently requires repeated applications, even within the same season. In addition, environmental restrictions curtail the usage of pesticides and herbicides in the environment. In this paper we examine whether doubling the initial stocking rate of seedlings (double-stocking) achieves the desired stocking rates over time in the presence of gopher damage, without the use of additional control methods.

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Materials and methods

Study areas

Areas representative of forest types in which gophers most severely affect reforestation were selected for study in central Oregon and eastern Idaho, USA. Within each area, specific study sites were selected based on past history of reforestation failure due to gophers, uniformity of gopher distribution, and homogeneity of vegetative composition and distribution. In the Deschutes National Forest (DNF) in central Oregon a high-elevation lodgepole pine (*Pinus contorta*) community was chosen for study. Slash had been machine piled and burned prior to planting lodgepole pine. The other site was established in the Targhee National Forest (TNF) of eastern Idaho on large (> 40 ha) clearcuts located in a high (1900 m) caldera occupied by lodgepole pine forests. Here, lodgepole pine seedlings were planted in machine-scalped spots. The northern pocket gopher (*T. talpoides*) was found at each site.

Design and procedures

The DNF site consisted of four clearcuts, 6–10 ha in size, at 1700 m elevation. Eight 0.4-ha blocks were delineated in each of the clearcuts (32 total blocks). Four of these blocks in each clearcut (16 total) were planted with 400 seedlings (baseline stocking rate, 1000 seedlings/ha) and four (16 total) were planted with 800 seedlings (double-stocking rate, 2000 seedlings/ha). Within each block there were ten randomly located 40-m^2 subplots containing four or eight seedlings (160 subplots total for each stocking rate), depending on the stocking rate for the block in which each subplot was contained. Each seedling was individually marked by a numbered wooden stake. Thus, a sample of 640 seedlings at the baseline stocking rate and a sample of 1280 seedlings at the double-stocked rate were monitored. The TNF study site consisted of large contiguous clearcuts in which the 32 0.4-ha blocks were placed. The subplot structure and seedling stocking rates in these blocks followed the same design as in the DNF. Thus, 1280 sample seedlings at a baseline stocking rate and 2560 at a double-stocked rate were monitored across the two areas over the course of the study (3840 total seedlings). Gopher activity was verified on each site using 80–81 m^2 circular plots, where mound counts and plugged burrows (Anthony and Barnes, 1984) were used to provide a present–absent assessment 48 h after all gopher signs in each plot had been erased. At least two gopher activity plots were placed in each 0.4-ha block. No pocket gopher control was conducted at either study site during the course of the study, nor within the year prior to planting.

The DNF study area was auger-planted in 1976 with lodgepole pine seedlings that were nursery grown for 3 years. The TNF study area was auger-planted in 1977 in machine-scalped spots with lodgepole seedlings that were nursery grown for 2 years. Data were collected in spring/early summer and late summer for five consecutive years after planting. Seedlings were inspected for damage and mortality, and identity of injury sources to the seedlings by animal and non-animal agents. The late summer observations also included measurements on the height of the surviving seedlings.

The data from each study site were analyzed separately because sites were at distant locations and characterized by different planting practices. Times until the occurrence of first gopher damage and survival times between seedlings from the two stocking rates were analyzed nonparametrically using product-limit survival analyses (Kaplan and Meier, 1958) and Wilcoxon comparisons of survival curves (Kalbfleish and Prentice, 1980), applied to evaluate whether a greater saturation of seedlings affected damage rates. Seedling heights were analyzed using analyses of variance. The percentage of subplots planted at each stocking rate where at least two seedlings (500 seedlings/ha) survived gopher damage was used as a measure of adequacy and consistency of final stocking rate (J. Booser, USFS, personal communication) at each study site.

Results

The rates at which seedlings were first attacked by gophers were similar for both stocking rates at DNF (Wilcoxon comparison of product-limit survival curves $\chi^2 = 0.34$, df = 1, $P = 0.55$). However, a difference in times until first gopher damage was detected between the stocking rates at TNF (Wilcoxon comparison of product-limit survival curves $\chi^2 = 12.65$, df = 1, $P = 0.0004$). This difference in the shapes of the survival curves is not reflected in the final percentages of seedlings attacked, as only 13% of the seedlings from the double-stocking rate escaped damage, vs 11% at the baseline stocking rate. In comparison, at the DNF, 40% of baseline seedlings never received gopher damage while 38% of the double-stocked seedlings were not damaged by gophers.

As gopher damage was the primary component of mortality, the survival results (*Table 1*) produced similar results as the time until first gopher damage. Survival rates were similar for the two stocking rates at DNF (Wilcoxon comparison of product-limit survival curves $\chi^2 = 0.41$, df = 1, $P = 0.52$), but different for TNF (Wilcoxon comparison of product-limit survival curves $\chi^2 = 4.69$, df = 1, $P = 0.03$). Again, even though the shapes of the survival curves could be distinguished statistically, the final survivals for TNF were not substantially different between the baseline (32%) and double-stocking (35%) rates. Similarly, the baseline stocking rate for DNF showed 37% seedling survival vs 35% seedling survival at the double-stocking rate. A similar survival rate for baseline and double-stocked seedlings insured that the number surviving at each stocking rate was in proportion to the stocking rate.

Uniformity of stocking after 5 years fell slightly short of the rate at which seedlings were planted. That is, for each site the proportion of subplots with at least two surviving seedlings was a little less than twice as great for double-stocked seedlings compared

Table 1. Seedling survival percentages measured in early (E) and late (L) summer each year on the Deschutes (DNF) and Targhee (TNF) national forests at baseline and double stocking rates

	% Surviving each year after planting												
	0	1		2		3		4		5		Final height	% subplots with ≥2
Site/treatment	L	E	L	E	L	E	L	E	L	E	L	Mean (SE)	seedlings
DNF													
Baseline stocking	90	77	59	48	45	41	40	38	37	37	37	69 (2.5)	44
Double stocking	91	75	59	46	43	38	37	35	35	35	35	68 (1.5)	70
TNF													
Baseline stocking	96	69	62	51	43	39	35	35	34	34	32	57 (1.8)	37
Double stocking	96	72	66	61	48	44	39	38	37	37	35	57 (1.3)	62

Mean final seedling heights (cm), their standard errors (SE), and the percentage of 40-m^2 subplots with two or more surviving seedlings are also given.

with the baseline seedlings. For the DNF, 44% of the baseline subplots had two or more surviving seedlings vs 70% of the double-stocked subplots. Results were similar for the TNF, where 37% of the baseline vs 62% of the double-stocked subplots had two or more surviving seedlings.

No differences were detected in average heights among the seedlings planted at the two stocking rates for either site ($F < 1.0$, $P > 0.69$, for each site). The mean seedling heights for the baseline and double-stocking rates were 69 and 68 cm, respectively, for DNF. For the TNF, the average seedling heights for the baseline and double-stocking rates were each 57 cm.

Discussion

The number of seedlings surviving on double-stocked subplots was approximately twice that of baseline-stocked subplots (1.9 times greater for DNF and 2.2 times greater for TNF), but the number of subplots with two or more surviving seedlings fell short of that (1.7 times greater for DNF and 1.6 times greater for TNF). Doubling the stocking rate did not saturate the areas with enough seedlings to overwhelm the damage rate by pocket gophers. However, double-stocking also did not suffer extensively the consequences warned by Marsh and Steele (1992) whereby a doubling in stocking rate could result in somewhat less than double the number of seedlings surviving, although some evidence of this effect occurred when examining the number of subplots with two or more surviving seedlings. The results in *Table 1* also demonstrate the well-known (e.g., Barnes, 1973) effect of most damage occurring over winter for the first few years after planting. After 3 years the seedlings had grown beyond the size of greatest vulnerability and their cumulative survival declined very slowly. It is also interesting to note that the different harvesting regimes between TNF (large contiguous clearcuts) and DNF (smaller openings) did not appear to affect the degree of gopher damage or survival (*Table 1*).

Economics probably will be one of the foremost concerns of many forest managers when contemplating use of pocket gopher control methods. It is possible that for areas of moderate gopher densities, increasing the stocking rate might overcome gopher damage levels to achieve target survivorship and adequacy of distribution, although in some situations patchiness of gopher distributions could degrade the uniformity of stocking rates (Marsh and Steele, 1992). In these situations, other management measures such as direct population reductions may be necessary. Nevertheless, this simple one-application strategy may produce the desired results at lower costs than the use of plastic mesh barriers, multiple applications of toxicants, or the use of herbicides. Increasing the stocking rate also would not be subject to environmental restrictions with which pesticide and herbicide usage is limited. Forest managers should consider all options when devising reforestation strategies, including simple approaches such as increasing the stocking rate.

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References

Acord, B. R. (1992) Responses of the ADC program to changing American society. *Vertebrate Pest Conference* **15**, 9–16

Anthony, R. M. and Barnes, V. G., Jr. (1984) Plot occupancy for indicating pocket gopher abundance and conifer damage. Vertebrate Pest Control and Management Materials: Fourth Symposium, ASTM STP 817, ed. D. E. Kaukeinen. American Society for Testing and Materials, Philadelphia, pp. 247–255

Barnes, V. G., Jr. (1973) Pocket gophers and reforestation in the Pacific Northwest: a problem analysis. USDI Fish and Wildlife Service, Special Scientific Report, Wildlife No. 155, Washington, D.C. 18 pp

Black, H. C. and Hooven, E. (1977) Effects of herbicide-induced habitat changes on pocket gophers in southwestern Oregon. 29th Annual California Weed Conference. Sacramento, pp. 119–127

Borrecco, J. E. (1976) 'Vexar' tubing as a means to protect seedlings from wildlife damage. For. Res. Tech. Rep., Weyerhaeuser Co., Centralia, WA, 18 pp

Borrecco, J. E. and Black, H. C. (1990) Animal damage problems and control activities on national forest system lands. *Vertebrate Pest Conference* **14**, 192–198

Campbell, D. L., and Evans, J. (1975) 'Vexar' seedling protectors to reduce wildlife damage to Douglas-fir. USDI Fish and Wildlife Service Leaflet 508, Washington, D.C.

Capp, J. C. (1976) Increasing pocket gopher problems in reforestation. *Vertebrate Pest Conference* **7**, 221–228

Crouch, G. L. (1986) Pocket gopher damage to conifers in western forests: a historical and current perspective on the problem and its control. *Vertebrate Pest Conference* **12**, 196–198

Engeman, R. M., Barnes, V. G., Anthony, R. M. and Krupa, H. W. (1995) Vegetative management for reducing damage to ponderosa pine seedlings from Mazama pocket gophers. *Crop Protection* **14**, 505–508

Engeman, R. M., Barnes, V. G., Anthony, R. M. and Krupa, H. W. (1997) Effect of vegetation management for reducing damage to lodgepole pine seedlings from northern pocket gophers. *Crop Protection.* **16**, 407–410

Engeman, R. M., Anthony, R. M., Barnes, V. G., Krupa, H. W. and Evans, J. (1999) Evaluations of Plastic Mesh Tubes for Protecting Conifer Seedlings from Pocket Gophers in Three Western States. Western Journal of Applied Forestry, in press

Kalbfleish, J. D. and Prentice, R. L. (1980) *The Statistical Analysis of Failure Time Data*. John Wiley, New York, 321 pp

Kaplan, E. L. and Meier, P. (1958) Nonparametric estimation from incomplete observations. *J. Am. Stat. Assoc.* **53**, 457–481

Marsh, R. E. and Steele, R. W. (1992) Pocket gophers. In: *Silvicultural Approaches to Animal Damage Management in Pacific Northwest Forests*, ed. Black, H. C. U.S. Department of Agriculture, Portland, OR, pp 205–230

Pipas, M. J. and Witmer, G. W. (1999) Evaluation of physical barriers to protect ponderosa pine seedlings from pocket gophers. Western Journal of Applied Forestry, in press

Sullivan, T. P. (1986) Understanding the resiliency of small mammals to population reduction: poison or population dynamics? In: *Control of Mammal Pests*, eds. Richards, C. G.J. and Ku, T. Y. Taylor and Francis, London, pp. 69-82. (Suppl. to Tropical Pest Mgt. 32:69-82.)

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