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Integrated Management Tactics to Assess Risk and Reduce Damage to Conifer Reforestation by Pocket Gophers

Abstract

In the western United States, pocket gophers pose an acute and chronic problem for forest managers to overcome. Gophers cause extensive damage to seedlings and can delay reforestation for decades. Here we examine the predictive factors for assessing the risk for damage and the available control tools and damage control-strategies. The information is reviewed and summarized so that an integrated damage reduction plan can be developed in a logical, cost-effective, and environmentally responsible fashion.

1 Introduction

Pocket gophers (*Thomomys* spp.) are fossorial rodents that probably account for more damage to conifer seedlings in western U.S. forests than all other animals combined (Crouch 1986). Pocket gophers generally are not found in densely forested areas, but rather in grasslands, natural meadows, and areas of early successional vegetation caused by wildfire, logging or other disturbance. Forest harvest results in early successional vegetation, particularly succulent perennial herbaceous plants that provide optimal gopher forage. Reforestation problems result from gopher populations responding to these favorable changes in their habitat (Barnes 1973).

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Pocket gophers forage above and below ground. Severed or girdled stems and roots are common forms of damage, although complete debarking, or complete removal of seedlings also occurs (Black 1994). Sublethal damage can result in reduced growth. If enough trees survive to near canopy closure, pocket gopher densities decline and no longer seriously threaten regenerating forest stands. Unfortunately, repeated complete failures at reforestation are not uncommon.

Damage reduction has usually involved lethal control of pocket gopher populations, but the habitat remains favorable for pocket gopher occupancy and populations often recover rapidly. Control of gopher damage in reforestation sites is an acute and chronic challenge, and a variety of control methods exist to address damage. Predicting the risk for damage and using multiple methods to reduce damage potential can provide an effective, integrated pest management programme to address pocket gopher damage to reforestation.

2 Factors affecting the risk for damage

Many factors affect the susceptibility of a reforestation unit to gopher damage. Some are inherent to the local geography, geology, and climate, while others relate to forest management. Each concerns the ecology of pocket gophers and some factors can be manipulated as part of a damage prevention strategy.

2.1 Forest management practices

Recency of harvest

If the site has been cleared of timber, then the successional processes that promote optimal habitat for pocket gophers have been set in motion. If the site has not been cleared, then more latitude exists for planning the harvest to minimize the potential for gopher occupancy. The amount of time that has elapsed after forest harvest or burn usually relates to the extent of plant development. Early successional stages, supportive of high gopher densities, usually establish within 5 years of clearing and can prevail for many years (± 15 yr.) before being curtailed by overstory growth.

Forest harvest method/size

The degree to which an area is cleared (or burned) affects the degree and length of time that plant communities are returned to an earlier seral stage. Clearcuts hold more potential for establishment of high gopherpopulations than partial cuts or shelter wood cuts (that leave > 40 % overstory canopy cover).

Site preparation

The degree of site disturbance parallels the degree of forest harvest. Differences in pocket gopher populations between clearcut and shelterwoodsites are partially due to the soil conditions after harvest (Barnes 1974). Soil scarification and slash piling produce loose soil in which pocket gophers can readily establish burrow systems, and returns plant communities to early stages. Heavily disturbed sites often have many times the gopher density as minimally disturbed sites. In contrast, leaving a substantial litter blanket after clearing can delay establishment of early seral plants, and herbicide usage to reduce vegetative competition with seedlings also delays the development of the plant communities attractive to pocketgophers.

2.2 Site characteristics

Gopher presence

The presence of pocketgophers at a site substantially increases the probability for future damage. The distance to an established pocket gopher population may influence site invasion (Barnes 1974), as young pocket gophers have good dispersal capabilities. Sites adjacent to meadows, glades, or other forest openings, which support pocket gopher populations are more susceptible to invasion.

Soil type

Soil type greatly influences gopher populations (Horton 1987). Deep, well-drained and light-textured soils offer optimal conditions for burrowing and gas-exchange. Soils such as clay loams, granitics and pumices promote establishment of gopher populations, but heavy clays, excessively sandy or rocky soils and poorly drained soils usually have marginal populations.

Plant association

In some areas, the seral stages and plant communities that favor gophers after tree removal have been identified, and categorized according to risk of gopher damage. Plant species combinations and vegetation palatability are criteria indicating the degree to which plant association will promote gopher populations (Black 1994).

Snow accumulation

Pocket gophers are active year-round and much of their damage occurs from late fall to spring when succulent green plants are not available and snow often covers the ground (e.g., Crouch 1982). Above-ground proportions of trees are exposed to damage by gophers as they burrow through the snow, with the risk of damage increasing with snow accumulation and snowpack duration (Barnes 1978). Less than 0.3 m of snow provides minimal risk, whereas a snowpack lasting until May results in a maximal risk for damage (Horton1987).

Slope

Damage tends to be inversely related to the slope of a site. Slopes greater than 35 % usually can support only low gopher populations, whereas slopes less than 10 % are optimal for gopher populations (Horton 1987).

3 Damage control methods

Traditionally, damage has been addressed using lethal methods to directly reduce populations, but this often offers only short-term control and usually requires repeated applications. Besides cost-effectiveness, the public increasingly prefers non-lethal means of damage reduction. Many non-lethal strategies have been investigated, including vegetation management to minimize gopher food supplies, silvicultural practices that prevent production of optimal gopher forage and soil conditions, or the use of barriers or repellents to deter gopher access to seedlings. Pesticides and herbicides are becoming more limited in their usage, thereby increasing the need for preventive management practices. To effectively address and resolve the acute and chronic natures of pocket gopher damage requires a customized damage prevention strategy using a combination of tools and approaches appropriate for the specific situation.

3.1 Direct population reductions

Control of pocket gopher populations is conducted through the placement of traps or the application of toxicants in burrow systems. An effective lethal control program should provide significant additional mortality beyond natural mortality (i.e., $> 75\,\%$). Due to the high reproductive potential of pocket gophers and their ability to rapidly invade an area of high quality habitat, repeated lethal treatments are often needed to provide adequate population suppression until the seedlings have grown beyond the most vulnerable size (Bonar 1995).

Oral toxicants

Poisons are usually applied as a coating to grain baits or as an ingredient of manufactured pelleted baits. Baits can be applied by hand or mechanically by use of a baiting probe or a burrow builder. Hand baiting cannot be conducted effectively until mounding activity becomes extensive enough to identify the locations of burrow systems. The burrowbuilder is a tractor-drawn implement that creates parallel artificial burrows into which bait is automatically dispensed (Barnes 1973). Burrow builders require favorable soil conditions without serious impediments such as large rocks and stumps. Baits placed within burrows pose a low hazard to non target species (e.g., Bonar1995).

Acute toxicants, designed to be lethal with a single feeding, are a relatively inexpensive means to rapidly reduce populations, although sublethal doses can produce a learned bait aversion that leaves enough survivors to quickly rebuild the population (e.g., Nolte & Otto 1996). Strychnine alkaloid and zinc phosphide are the most commonly used acute toxicants for pocket gopher control in the U. S., with zinc phosphide less effective than strychnine (Bonar 1995), probably due to taste aversions.

Chronic toxicants normally require multiple ingestions to be lethal and include anticoagulants such as warfarin, chlorophacinone and diphacinone. Cholecalciferol (vitamin D_3) also usually requires multiple doses to produce mortality (Nolte & Otto 1996). Vitamin K can be given as an anticoagulant antidote to humans or pets. A single chronic toxicant ingestion is not likely to be lethal to non-target species, but scavenging animals can be exposed to secondary hazards from anticoagulants. Chronictoxicants are not likely to produce taste aversions because the delayed onset of symptoms does not permit association of symptoms with feeding. The need for multiple ingestions also means that chronic toxicants may not reduce populations as rapidly as acute toxicants and mortality rates may suffer if baits deteriorate or run out.

Fumigants

Toxic gases may be introduced into burrow systems to kill gophers. Smoke cartridges can be used to used to produce carbon monoxide and carbon dioxide gases, while aluminium phosphide pellets placed in burrows react with ambient moisture to produce phosphine gas. Fumigants tend to be more expensive to apply than toxic baits and they often produce low efficacy due to gas leakage, and because pocket gophers can rapidly seal off affected burrows (Marsh 1992). Fumigants also pose greater hazards than poison baits to non-target animals in the burrow system.

Trapping

Trapping is a labor-intensive method that is rarely well-suited for large areas or dense gopher populations (Barnes 1973), but it merits consideration to remove animals remaining after toxic baiting, or to remove small populations from a site before clearing, or in situations where toxicants cannot be used. Most gopher traps are pincher traps, which crush the animal with two spring-loaded jaws, or box chokers, which pin an animal to the floor of the box with a spring-loaded wire jaw similar to a snap trap (Marsh 1998).

Enhancing predation

Many animals prey on pocket gophers, but prey density typically controls predator density for co-evolved species, rather than the other way around. However, enhancing natural predation through low-cost means, such as using artificial raptor perches to deter above ground dispersal (Howard *et al.* 1985), can complement other management strategies.

3.2 Indirect population reductions through habitat manipulation

Habitat manipulation reduces the food or burrowing resources available per individual, thus promoting a negative feedback response whereby reproduction is also likely to diminish in the face of limited resources (Caughley & Sinclair 1994).

Vegetation management through herbicides

Herbicide removal of vegetation that competes with seedlings (while providing forage for gophers) has been associated with increased seedling stocking rates (e.g. Cristensen *et al.* 1974, Crouch 1979). Longer-term studies that monitored individual seedlings for damage and survival showed substantially improved seedling survival and long-term reductions in gopher populations following atrazine treatments (Engeman *et al.* 1995), and 2,4-D treatments (Engeman *et al.* 1997).

Nonchemical vegetation management

Lower pocket gopher densities have been reported on heavily grazed sites, although overgrazing presents detrimental environmental consequences and may eventually lead to some livestock browsing on seedlings. Cattle grazing has been found to be inversely proportional to above-ground gopher damage (Kingery & Graham 1987). Intensive sheep grazing may reduce pocket gopher densities more than free-range cattle grazing, but soil compaction and burrow disruption probably contribute to lower gopher densities (Owsiak 1996). Another non-chemical method to reduce gopher forage is to leave logging debris, organic litter, or residual shrub cover on the site after forest harvest to delay growth of herbaceous vegetation.

Planting unpalatable vegetation

Planting vegetation unpalatable to gophers may deter the growth of preferred gopher forage. Fine-rooted grasses have been used to deter a buildup of bull thistle (Marsh & Steele 1992), while Engeman *et al.* (1998b) used grass seeding in addition to herbicide treatment to reduce production of preferred gopher forage, but did not demonstrate conclusive beneficial results.

Extent of overstory removal

In addition to providing some natural regeneration, retaining a relatively high level of forest overstory may limit sunlight to inhibit the growth of herbaceous ground vegetation. The existing understory vegetation receives less damage and is more able to compete with early seral plants that could become established.

Soil disturbance

The means by which logs are removed and the site prepared for replanting can greatly affect gopher burrowing capabilities. In general, greater overstory removal creates greater soil disturbance, which results in better quality habitat for pocket gophers by facilitating burrowing and promoting a flush of herbaceous plant growth favored by gophers (Black 1994).

3.3 Reducing gopher access to seedlings

Another damage reduction strategy is to use physical or sensory obstructions to minimize gopher access to individual seedlings or larger areas, or to minimize the time seedlings are vulnerable to gophers.

Mechanical barriers

Wire mesh fencing installed from below ground to above the height of snow accumulation can exclude gophers from an area, but is rarely an affordable solution. Plastic mesh tubes made physical barriers practical for extensive forestry use (Campbell & Evans 1975). Originally developed for reducing damage by lagomorphs and ungulates, seedling protectors surround the seedling's roots as well as the above-ground parts to protect against gopher damage. Their efficacy has been demonstrated in long-term geographically extensive evaluations that individually monitored large numbers of protected and unprotected seedlings planted in areas of historically high gopher damage (Engeman *et al.* 1999). Seedling protector use increases short-term planting costs, but also may reduce damage by other wildlife species.

Repellents

Repellents are intended to ward off gophers from individual seedlings on contact, or repel gophers from the general area planted with seedlings. Few commercially available compounds deterred captive gophers during feeding trials (Witmer *et al.* 1997). An extremely bitter compound (denatonium benzoate) was not effective as a systemic repellent (Witmer *et al.* 1998), and while predator odours seem promising as area repellents (e.g., Sullivan *et al.* 1990), their volatility makes long-term delivery systems for field conditions problematic.

Seedling size and vigor

Larger seedlings at planting more quickly reach a size where they are less vulnerable to gopher damage. Seedlings less than 1.3 cm in diameter are commonly clipped by gophers, whereas larger seedlings may be chewed, but often escape clipping or complete girdling (Capp 1976). Seedlings with high vigor not only grow more rapidly to less vulnerable sizes, they also tolerate more damage than weaker seedlings (Marsh & Steele 1992).

Rapid restocking

Seedlings that are in the ground before herbaceous growth has had an opportunity to proliferate and before gophers have had an extended opportunity to increase population density have a greater chance to grow to a less vulnerable size. Prompt restocking (within 8 months of harvest) may be the most important silvicultural practice for preventing of gopher damage (Marsh & Steele 1992).

Buffer zones

Retaining buffer zones of mature forest around the periphery of harvested units can slow invasion by pocket gophers. Buffer strips > 180 m of mature lodge pole pine forest were rarely crossed by pocket gophers after 4 years (Barnes 1974), but a buffer as narrow as 60 m would be helpful (Marsh & Steele 1992).

3.4 Supplemental feeding

Limited tests with supplemental feeding have given mixed results. Strategies tested have included providing gophers with a preferred, alternate forage to seedlings, or saturating the area with seedlings so that a sufficient number survive and outgrow their vulnerable stages.

Alternate forage

Borrecco (1976) used supplemental foods to lure gophers from seedlings, although Bonar (1995) contended that supplemental feeding would improve the carrying capacity for gophers to create a cycle of increasing need for alternate forage to keep up with increasing gopher population density. Furthermore, much seedling damage occurs during the winter when supplemental growth of herbaceous plants would not be possible.

Increased stocking rate

A 5-year study found that the number of seedlings surviving on double-stocked plots was approximately double that for the baseline subplots (Engeman *et al.* 1998a). For some situations, increasing the stocking rate may be an effective and less costly alternative to other more expensive or legally restricted damage control methods.

4 Devising a damage reduction strategy

Strategies for reducing animal damage have evolved considerably from essentially reactive lethal control programs to organized integrated pest management approaches using a combination of tactics. A blending of lethal and non-lethal control techniques is available for the forest manager to select the most cost-effective route for minimizing damage, while also minimizing ad-

Table 1

Summary of methods for the reduction of damage to conifers by pocket gophers and qualitative assessment of the relative attributes for each method.

Method	Cost per Application	Applica-tions/Year	#years of Application	Efficacy	Duration
A. Direct population reductions					
1. Rodenticide baits:	mod.*	1–2	1–5	high	short
2. Fumigants:	high	1–2	1–5	low	short
3. Trapping:	mod.	1–2	1–5	high	short
4. Enhance predation:	low	1	1	low	long
B. Indirect population control through habit manipulation:					
1. Herbicide removal of forage:	low-mod.	1–2	1–2	mod.	interm.†
2. Nonchemical forage removal:					
a. Cattle, sheep grazing:	low-mod.	1–3	1–3	mod.	interm.
b. Litter layer:	low	1	1	mod.	long
3. Unpalatable vegetation:	low	1	1	mod.	long
4. Limited overstory removal:	mod.	1	1+	mod.-high	long
5. Minimizing soil disturbance:	mod.-high	1	1	mod.	long
C. Reducing access to seedlings:					
1. Mechanical barriers (costs are substantially less if they prevent damage from other species)					
a. Fencing off area:	high	1	1	high	long
b. Seedling tubes:	mod.	1	1	mod.-high	long
2. Repellents:	mod.-high	1–3	2–5	low	short
3. Buffer zones:	low-mod.	1	2+	mod.	interm.
4. Increase seedling size/vigor:	mod.-high	1	1	mod.	long
5. Rapid restocking:	low	1	1	mod.-high	long
D. Supplemental feeding:					
1. Alternate forage:	low	1	1–3	low-mod.	interm.
2. Increase stocking rate:	mod.-high	1	1	mod.-high	long

* mod. = moderate
† interm. = intermediate

verse environmental effects. The specific steps to minimize the impact of pocket gophers to reforestation efforts should be considered sequentially.

First, the risk factors for future damage on a currently forested site should be evaluated before tree harvest. If a site already has been cleared of trees and replanted, risk assessment would also involve evaluating the current damage levels and projecting the damage likely to accumulate before seedlings outgrow their vulnerability. If damage or the risk for damage is excessive, then an integrated damage reduction strategy should be developed and implemented.

Second, the feasibility, costs, effectiveness, durability and legality of all possible damage reduction methods (Table 1) should be evaluated if damage appears probable. The further in advance of a serious damage situation that this assessment is accomplished, the more flexibility the manager will have to prevent or respond to damage. The advantages and disadvantages of each method should be carefully considered and the compatibility of methods should be assessed for each situation. Some methods have greater restrictions on their use, especially the application of chemicals, while the use of any lethal control method may be of concern in areas where endangered species are present. Numerous criteria in addition to economics and legality need to be considered in the selection of damage reduction methods and strategies. These include potential environmental impacts, socio-political acceptability of the methods (especially concerning lethal methods), the effect on other damaging wildlife, the effects on non-target species, potential negative effects on seedling survival, and safety.

Third, a comprehensive damage prevention strategy should be developed that is customized to suit the particular site, management objectives, and constraints. No one strategy will suit all situations, because of the large number of combinations of site variables, damage reduction methods, and management objectives and constraints.

Lastly, an implemented damage reduction strategy should not be considered inalterable. The efficacy of the methods used, such as population reductions or forb removal, should be monitored and evaluated. If efficacy appears insufficient, or if secondary or unanticipated problems arise, then alternatives or modification of the strategy should be examined. The strategy selected and implemented should be well-documented to assist future actions, new personnel, and for use in any controversy or legal action that might ensue.

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