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ABSTRACT: Damage to coniferous seedlings and trees by forest rodents, including forest lagomorphs, is a major factor limiting prompt regeneration and causing significant losses in young stands. Manipulating the vegetation to adversely influence food and cover thereby reducing animal numbers is proposed as an approach to alleviating damage. The adaptability, high reproductive potential, opportunistic feeding behavior, and mobility of forest rodents combined with the species diversity of rodent communities, rapid recovery of vegetation, and need for long-term protection make habitat manipulation for damage control a difficult approach. However, an example is presented where herbicide-induced reduction in vegetative cover and availability of summer foods resulted in a significant reduction of clipping damage to Douglas-fir seedlings by snowshoe hares.

INTRODUCTION

Present and future demands for forest products necessitate intensive management of industrial forest lands for optimum yield. Intensive forest management begins with prompt re-establishment of trees following harvest of the natural stand and employs practices like thinning and fertilization to optimize growth.

Damage by forest rodents, including forest lagomorphs, can be a major factor limiting prompt regeneration and causing significant losses in young plantations.

Early attempts at direct seeding to obtain prompt regeneration mostly failed due to depredations by seed-eating rodents, particularly deer mice (*Peromyscus maniculatus*), and birds (Black, 1969; Gashwiler, 1970a; Lawrence and Rediske, 1962; Radvanyi, 1966). A number of methods to protect seed have been developed including reduction of mouse populations through poison baiting and, more recently, seed repellents (Lindsey *et al*., 1974; Radwan, 1970). However, the responses of deer mice and other seed eating animals to treatments, along with germination problems, vegetative competition, stocking and spacing requirements, and recent constraints against using chemicals have contributed to more emphasis on planting to obtain prompt regeneration.

Planting coniferous seedlings eliminates the seed-eating problem, but other species of rodents cause damage in the form of feeding injuries to foliage and stems. The major species causing damage are mountain beaver (*Aplodontia rufa*), snowshoe hare (*Lepus americanus*), rabbits (*Sylvilagus spp.*), wood rats (*Neotoma spp*.), pocket gophers *Thomomys spp*.), and meadow voles (*Microtus spp*.). Other species such as the beaver (*Castor canadensis*) and ground squirrels (*Otospermophilus lateralis*) cause problems in localized situations.

Lawrence *et al*. (1961) review the types of damage caused by these forest rodents. Cutting and girdling stems are the most prevalent injuries resulting in plantation failures and growth losses. Root cutting and undermining also are caused by pocket gophers and mountain beaver.

Weyerhaeuser Company recently completed an economic analysis of damage by the mountain beaver on company lands (Borrecco, Pierson, and Rochelle, 1975, unpublished report). The analysis shows at least 8 thousand acres in Washington and Oregon are sustaining damage annually resulting in an estimated loss in the year 1990 of about $1.5 million. Discounted at 12.5% and 8%, this amounts to a present value of $6 million and $11 million, respectively. Regardless of the exact value, a multi-mi 11 ion dollar problem is caused by this single species of forest rodent; giving some perspective of the magnitude of damage by forest rodents.

The cause of damage is generally a result of optimum habitat conditions and maximum numbers of animals (Lawrence, 1967). Significant levels of damage can also occur where alternate and preferred foods are lacking or in limited supply (Dasmann *et al*., 1967; Roy, 1960).

There are three schemes for controlling wildlife damage: (1) make the crop inaccessible or undesirable by using physical barriers like "Vexar" seedling protectors (Campbell and Evans, 1975a), chemical repellents (Rochelle *et al*., 1974; Welch, 1967) or even the potential selection of genetically resistant stock (Dimock, 1974); (2) provide alternate and preferred foods including establishment of grasses, forbs, and woody browse species (Baron *et al*., 1966; Campbell and Evans, 1975b) and supplemental feeding with hay or cuttings from native vegetation (Aldous and Aldous, 1944); and (3) reduce the number of animals either directly with conventional methods like trapping and toxic-baiting or indirectly through predator management, disease introduction, habitat modification, or chemosterilants (Howard, 1967). Habitat modification can be employed in all three schemes.

THE APPROACH - HABITAT MANIPULATION

Wildlife biologists have long recognized the importance of habitat to the abundance and distribution of animals. They have also realized that forest-management practices like prescribed burning, scarification, herbicide treatments, thinning and timber harvest create significant changes in habitat utilized by forest rodents. Initial studies were directed at determining the impact of forestry practices on small mammal populations.

A number of researchers have examined the effect of logging and slash burning on small mammal populations (Ahlgren, 1966; Gashwiler, 1970b; Hooven, 1969; Tevis, 1956a). Ahlgren (1966) examined small mammal populations in logged and burned, logged and unburned, and unlogged-unburned areas. He found that deer mice respond favorably to logging, but burning the logged site resulted in the greatest increase in deer mice. Redback voles (*Clethrionomys gapperi*) and chipmunks (*Eutamias minimus*) increased in the logged-unburned unit, but not in the burned unit until the third year when a variety of vegetation became available.

Gashwiler (1970b) compared vegetative composition and small mammal populations in virgin forest and clearcut areas over a period of 10 years. He found deer mice increased soon after slash burning and Townsend's chipmunks (*Eutamias townsendii*), Oregon voles (*Microtus Oregoni*) and snowshoe hares increased on the area at different periods after burning. Redback voles (*Clethrionomys occidentalis*), Douglas squirrels (*Tamiasciurus douglasii*), and flying squirrels (*Glaucomys sabrinus*) were absent from the clearcut. Tevis(1956a) and Hooven (1969) reported similar results following logging and slash burning.

The effects of both wildfire and prescribed burning on small rodents have been studied (Black and Hooven, 1974; Cook, 1959; Fala, 1975; Tevis, 1956b). Fala (1975) reported a reduction in the number of herbivorous small mammals like meadow voles for two growing seasons after a prescribed burn. Deer mice rapidly invaded the burn within one month. Black and Hooven (1974, Cook (1959) and Tevis (1956b) observed similar responses.

Barnes (1971. 1974 reported that pocket gophers respond to timber harvest and site preparation in central Oregon relative to the effect these practices have on the production of herbaceous vegetation. Black and Hooven (1974) found that complete vegetation control with herbicides reduced abundance of pocket gophers in southwest Oregon. Keith *et al*. (1967) also showed a reduction in the density of pocket gophers on range lands in Colorado after herbicide treatments reduced perennial forbs.

Application of herbicides to control herbaceous vegetation and promote regeneration in western and southwestern Oregon caused significant changes in habitat used by small mammals (Black and Hooven, 1974; Borrecco, 1973). Small mammals responded to these changes according to their habitat preferences. Deer mice and Trowbridge's shrews (*Sorex trowbridgii*) were ritore abundant on treated areas in western Oregon while populations of Oregon voles, vagrant shrews (S. vagrans)and Pacific jumping mice (*Zapus trinotatus*) declined.

From these few examples, we see that populations of rodents respond to changes in habitat, especially changes in food and cover. The response of rodents to forest-management practices and their association with the various stages of forest succession suggests the possibility of manipulating the habitat to control damage. The value of an area as habitat for a species depends on the availability and quality of water, food, and cover. Manipulating habitat in this paper means changing the availability or quality of these essentials to reduce or prevent damage.

Yoakum and Dasmann (1969) describe techniques for developing water resources to improve **habitat** for wildlife. In areas where water is a limiting factor or where animals need **a** supply of free water, manipulating water may be practical. However, in the forest environment, particularly western Oregon and Washington, controlling damage through manipulating water does not appear feasible.

Vegetation is of primary importance in that it provides food, cover, and in some situations, water. Barnes (1974) reported, "vegetative composition and herbage production, overall, appear to be the most important factors controlling gopher abundance". Hooven emphasized that the succession of small mammals is related to vegetative succession. Others have reported similar relationships between wildlife and vegetation (Ahlgren, 1966; Black and Hooven, 1974; Gashwiler, 1970b; Tietjen et al., 1967).

Logging debris such as branches, tops, chunks of shattered wood, and non-merchantable material (collectively called slash) also provides cover for mountain beavers, rabbits and hares, woodrats, and various other rodents.

In the practical application then, habitat manipulation means managing vegetation and logging debris to influence food and cover. There are two approaches: one affects the carrying capacity resulting in a change in animal numbers, the other seeks to change the utilization of the crop without influencing the number of animals (Howard, 1967).

This second approach has dealt primarily with providing alternate foods to lure animals from feeding on trees (Aldous and Aldous, 1944; Baron et al., 1966; Campbell and Evans, 1975b; Dasmann et al., 1967; Ray, 1960). Most studies have been concerned with deer browsing and results are conflicting. Evans et al. (1970) reported that supplemental winter feeding failed to prevent damage by jackrabbits Lepus californicus) to grain and hay crops. One problem with this approach, especially with forest rodents, is the possibility that animal numbers would cancel the benefit provided by supplemental foods. Aldous and Aldous (1944) warned that supplying extra food for snowshoe hares might attract more animals than would normally be present. This approach may have merit especially if combined with other techniques of tree protection like repellents or physical barriers.

Also included in this second approach are practices like clearing and cultivating strips (Allen, 1942) or providing vegetative barriers (Lewis, 1946) around crops. Evans et al_. (1970) felt these approaches had little value when populations were high, and reported that 1/4 mile wide buffer areas of vegetation or cleared land failed to prevent jackrabbit damage. Others have reported vegetation and logging debris providing protection from deer browsing (Allen, 1969; Grisez, 1960). However, these same conditions are generally considered to provide cover for forest rodents and increase the potential for clipping damage. Perhaps the greatest limitation of this approach is the unproductive utilization of land.

The emphasis of my paper is on the first approach of managing vegetation to adversely affect carrying capacity or animal abundance thereby alleviating damage. I shall also concentrate on habitat types and damage problems in the Douglas-fir region of western Oregon and Washington. However, there are a few problems associated with the complexity of the forest environment and the adaptability and mobility of pest species which should be considered when contemplating habitat alteration for damage control.

One of the obvious problems is that we seldom deal with a single species. In the process of making an area unfavorable for one species, a more suitable habitat may result for another pest. For example, removal of logging debris and brush reduces the attractiveness of habitat for most rodents, but increased browsing by deer or elk may result (Grisey, 1960; Swanson, 1970). Spencer (1955) wrote, "...the rodent community is often complex and not subject to manipulation or control by a single means".

Most species of forest rodents and rabbits causing substantial damage are adaptable to a wide range of environmental conditions. This is shown by their rather extensive geographic distributions and variety of habitat used. While most of these species generally find optimum habitat in the early and intermediate stages of forest succession, they may occur in all stages. For example, I have observed mountain beaver and snowshoe hares in recently logged areas, open and dense stands of saplings, and mature timber. Habitat manipulation may cause significant changes in habitat, but the impact on the pest species may not be sufficient to stop or prevent damage. As Spencer (1955) stated, even "completely denuded areas continue to support some species of rodents".

One factor contributing to the adaptability of these animals is their opportunistic feeding behavior. The variety of plant species selected as food is quite catholic. Grasses, forbs, shrubs, and trees are accepted as food by most rodents qualifying as forest pests. Coniferous trees may not represent preferred foods, but they seldom rank as only survival forage. There are even seasonal periods when coniferous vegetation is favored (Black, 1965; Dodds, 1960; Voth, 1968). If habitat management removes a majority of plant species, feeding pressure may simply transfer to our crop of planted seedlings.

This problem might be reduced if sufficient time is allowed for rodent populations to respond to unfavorable habitat conditions before planting seedlings. However, the initial conditions created seldom persist. Following logging or some other disturbance in the coastal Douglas-fir type, the first stage of forest succession is dominated by herbaceous species followed by a shrub-dominated period which gives way when overtopped by tree saplings, generally Douglas-fir (Franklin and Dryness, 1969). The Douglas-fir dominates the site until replaced by western hemlock or some disturbance like logging starts the pattern over. Manipulating the habitat tends to either set succession back to an early stage or, by reducing vegetative competition, shorten the time period needed for Douglas-fir to dominate the site. In either event, succession proceeds and vegetation recovers, often quite rapidly.

I studied the effects of herbicide-induced changes in habitat on vegetation and small mammals in western Oregon (Borrecco, 1973). Following treatments, significant differences in both vegetation and animal numbers were observed between treated and untreated plots. However, Black and Hooven (1974) found no differences in vegetation or animal numbers on these same plots 2 years after the last herbicide treatment. While significant changes in habitat and animal numbers can be produced, the beneficial effects in terms of damage control may be short-lived.

In the forest environment, protection is needed for years rather than months as with most other agricultural crops. Spencer (1955) reported that as forests develop there is a progressive shift in rodent species and types of damage. Deer mice feed on seeds, meadow voles destroy succulent new germinants and cause girdling injuries to older seedlings, rabbits and hares clip seedlings up to heights of 50 centimeters and higher depending on snow depth, mountain beaver clip seedlings and girdle saplings up to 15 years old, and porcupines damage trees through maturity. Controlling vegetation for one or two years may eliminate the potential for rabbit damage, but 10 to 15 years of protection may be required to prevent mountain beaver, pocket gopher, or porcupine damage. Such long-term protection is seldom realized without repeated treatments.

1 have briefly reviewed some problems that should be considered before planning a program of habitat manipulation for damage control. Lawrence (1967) stated, "To utilize an ecological approach to wildlife damage control requires basic information concerning food preference, habitat requirement, seasonal activity patterns for the animal as well as detailed information on the ecology of the vegetative type in which control would be attempted".

Examples of reducing rodent damage to coniferous trees through habitat modification are limited. The following account describes a situation where manipulation of cover and, to a limited extent, availability of summer foods resulted in the significant reduction of snowshoe hare clipping in a Douglas-fir plantation.

EXAMPLE

Background

Regeneration surveys on Weyerhaeuser Company plantations following the 1973-74 planting season revealed severe levels of clipping damage to Douglas-fir seedlings by snowshoe hares. Some plantations with high levels of clipping damage did not contain the concentrations of logging debris or heavy brush cover generally associated with heavy clipping pressure. These sites did have a uniform dense cover of herbaceous vegetation during the growing season.

The species composition and density of the cover along with the pattern of use by snowshoe hares suggested that alteration of cover conditions through herbicide application might reduce the use of the areas by snowshoe hares. Clipping of woody stems by snowshoe hares generally begins with the first frosts of fall and continues until the emergence of new growth in the spring (Baker _et al._, 1921; Black, 1965; Cook and Robeson, 1945;

Carson and Cheyney, 1928; Dodds, 1960). I have also observed that levels of damage tend to fall off during late winter. This corresponds to the period when we would expect animal numbers to be lowest. I hypothesized that by reducing the favorableness of the habitat during the growing season, population levels would be reduced prior to the period of intensive clipping of conifer seedlings. Giving the seedlings 1 or 2 years of protection should allow them to grow beyond the size generally considered susceptible to "rabbit" clipping.

Procedures

Two sites were chosen, one near Raymond and one near Snoqualmie Falls, Washington. Both sites were characterized by gentle slopes, high site productivity, dense herbaceous cover, and high levels of snowshoe hare damage. A paired plot design was used and half of each site treated with a combination of herbicides formulated to kill the predominant herbaceous vegetation. Established seedlings were located along random transects in each plot and examined for damage at monthly intervals over a period of 14 months. Livetrapping of hares was conducted every three months.

Results

The results of this study confirm previous reports regarding the seasonal nature of conifer clipping by snowshoe hares (Figure 1). Little clipping of seedlings occurred during the June through September and February through May periods of observation, and no significant differences between treated and control plots were indicated. However, significantly more clipping (22%) occurred in control plots during the October through January period ($p = 0.01$).

These data indicate only monthly activity and not the cumulative effect of injury. The cumulative number of sample seedlings receiving one or more occurrences of clipping injury over 14 months was also significantly greater on control plots (Figure 2). This difference was observed for both total injuries and injuries to terminal shoots.

While total clipping activity was higher at the Snoqualmie Falls site than the Raymond site, terminal damage was less (11% vs. 38% in control plots, respectively; Figure 2). This difference is attributable to the differences in mean heights of seedlings at each site. Mean heights at Snoqualmie Falls were 64 to 65 centimeters while seedlings at Raymond averaged 33 to 36 centimeters. Lawrence et al. (1961) report that snowshoe hares clip stems 1/4 inch (6.35 milimeters) or less in diameter up to heights of 20 inches (50.8 centimeters). The seedlings at Snoqualmie Falls exceeded the size generally considered susceptible.

Live-trapping results provide only limited supportive data to the damage observations since few animals were captured. However, the data do suggest greater use of control plots by snowshoe hares (Figure 3).

Summary

The changes in habitat induced by the treatments were a reduction in cover and, to a limited extent, availability of summer foods. The importance of cover to the distribution, movement, and utilization of habitat by snowshoe hares is well documented (Adams, 1959; Bider, 1961; Black, 1965; Dolbeer, 1972). Results of this study show snowshoe hares are responsive to herbicide-induced reduction of cover. More importantly, damage was reduced significantly by manipulating the habitat. The protection provided to the seedlings should allow them to grow out of reach of snowshoe hares.

CONCLUSION

Manipulating habitats to alleviate damage by forest rodents and rabbits is one approach to solving damage problems. The adaptability, high reproductive potential, opportunistic feeding behavior, and mobility of forest rodents combined with the species diversity of rodent communities, rapid recovery of vegetation, and need for long-term protection make habitat manipulation for damage control a difficult approach. Howard (1967) warned that habitat manipulation to reduce vertebrate pest problems may alter the entire ecosystem far more than conventional control methods. However, where we have knowledge of the problems, responses, and ecological consequences; habitat alteration may be used to control or prevent damage.

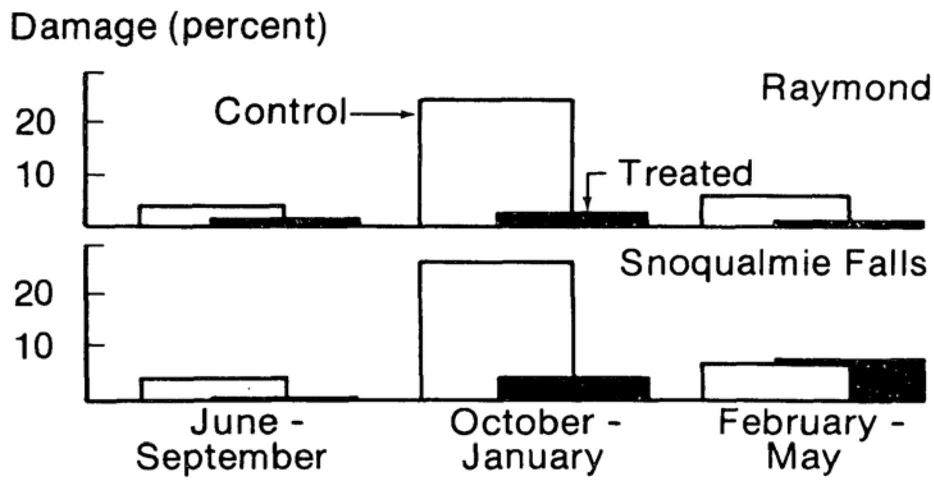

Figure 1. Seasonal clipping of Douglas-fir seedlings by snowshoe hares in control and herbicide-treated plots at two locations.

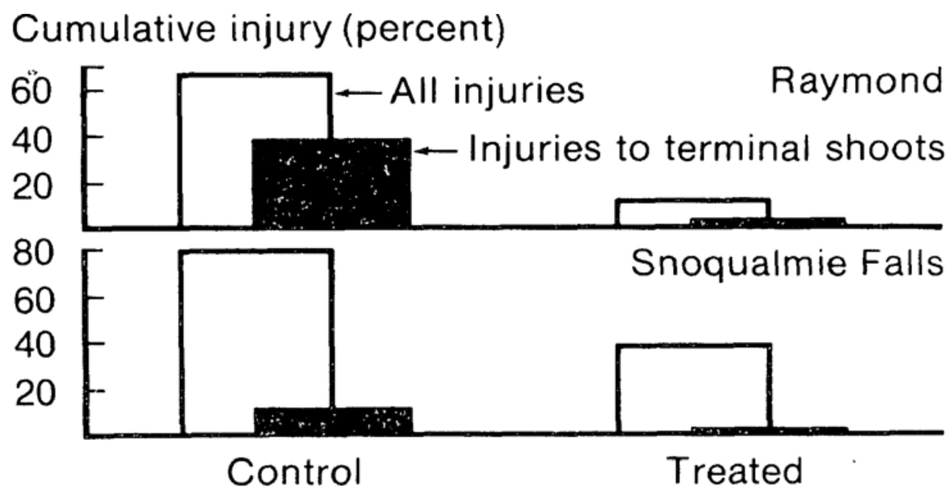

Figure 2. Cumulative injury to Douglas-fir seedlings by snowshoe hares in control and herbicide-treated plots at two locations.

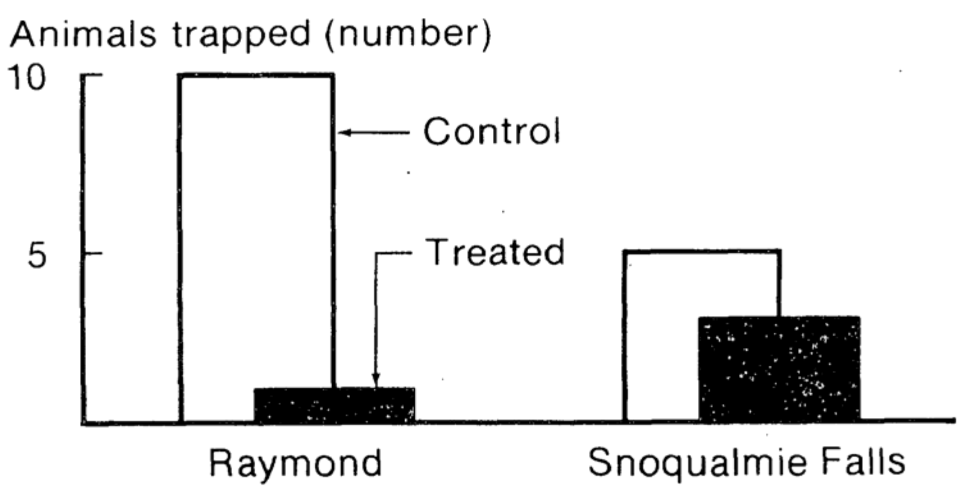

Figure 3. Numbers of snowshoe hares trapped in control and herbicide-treated plots at two locations.

This approach to controlling damage will probably find greatest use when combined with other damage-control techniques. There is evidence that the efficacy of direct control measures can be increased when combined with habitat management.

Successful use of habitat manipulation for damage control depends on the intelligent use of knowledge concerning the biology and ecology of rodent pests and their habitats.

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