REDUCING NON-TARGET HAZARDS OF RODENTICIDES IN FOREST SETTINGS

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Abstract: Mammalian damage to forest resources is widespread and causes annual economic loss. Wildlife damage control is very important to the intensified land use practices and the economics of reforestation using seedlings. Reforestation areas provide ideal habitat for many wildlife species. However, animals negatively impact trees more severely during stand establishment than at any other time. While numerous non-lethal and lethal tools are available for large and medium-sized mammals, fewer tools are available for small mammals. The damage caused by these rodent species has in some cases warranted the use of rodenticides to control populations. Rodenticides are effective tools for reducing damage to trees by three of the more problematic rodent genera, voles (*Microtus* spp), pocket gophers (*Thomomys* spp), and recently, mountain beavers (*Aplodontia rufa*), when economic damage justifies this approach in a reforestation system. All of these rodents impede forest regeneration by impacting seedling establishment. Pocket gophers, mountain beavers and pine voles can also damage saplings and more mature timber through girdling of roots and stems. For the subterranean rodents, primary non-target hazards are reduced from bait placement within the burrow systems during the fall and winter. The timing of bait placement limits exposure of baits to adults and not naïve juveniles who may be more susceptible to predators. Secondary hazards are reduced in that the majority of animals that succumb to bait are recovered below ground in their nests. Above ground application for certain vole species can be more of a challenge due to costs, tools available and potential primary and secondary hazards. Wildlife species are integral to forest health, yet forest management practices can alter available habitat and influence rodent populations. When possible, managers should use rodenticides in an Integrated Pest Management approach to maximize efficacy and minimize secondary hazards.

Key words: forest management, mountain beaver, non-target species, pocket gopher, rodenticide, vole

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INTRODUCTION

Since the advent of artificial forest regeneration efforts in the 1900s, animal damage has been recognized as a hazard to regeneration efforts (Black and Lawrence 1992). Most often damage reduces productivity or delays harvest cycles, however, reforestation efforts after timber harvests or fires can be complete failures because of foraging wildlife (Nolte and Dykzeul 2002). By the early 1970s, direct planting of trees replaced seeding as the preferred silvicultural practice for regeneration (Black and Lawrence 1992), increasing the list of potential foraging species in reforestation areas. In addition, current silvicultural practices in the Pacific Northwest include site preparation (e.g.,

herbicides) that favors forest succession and provides ideal habitat for problem wildlife species (Lawrence 1992). In a western Oregon survey in 2000, on an estimated 4.5 million acres, managers spent $1.9 million annually to reduce forest damage (Nolte and Dykzeul 2002).

Managing animal damage to forest resources falls into two categories: 1) direct techniques that control populations through trapping or rodenticide baiting, or limiting access to seedlings through barriers; and 2) indirect techniques through silvicultural practices (Lawrence 1992). Rodenticides are one method of direct control used to control populations of some forest rodent pests. Two rodent species that are known to cause damage in forest settings include porcupines (*Erethizon dorsatum*) in xeric forests and mice (*Peromyscus maniculatus*). No rodenticides are used to control porcupine, and silvicultural practices have changed from seeding to seedling plantations which all but eliminated mice damage. We will, therefore, not discuss in detail these two species, but will concentrate on the three main species of concern in forest settings: voles (*Microtus* spp.), pocket gophers (*Thomomys* spp.), and mountain beavers (*Aplodontia rufa*).

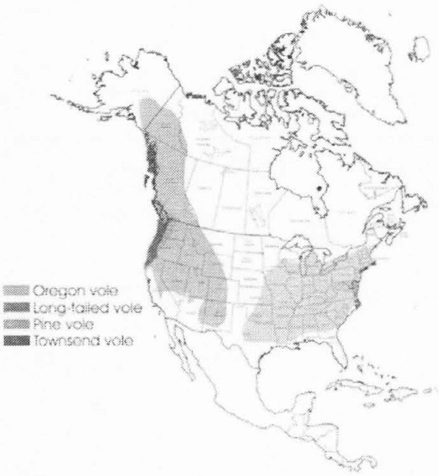
VOLES

Voles are a conspicuous part of the mammalian fauna in almost every corner of the North American continent (Reid 2006). Population densities of Microtus (voles) vary considerably and seem to run in cycles (Nowak 1999). A report generated by Piper (1909) in the U.S. Department of Agriculture Farmer's Bulletin reported populations of *Microtus montanus* to be as high as 8,000 to 12,000 voles per acre in irrigated crop land around Lovelock Nevada (Hall 1995). The general population dynamics for *Microtus* allows for a large build up of population in a short amount of time. Breeding may occur year round, with litter sizes ranging from one to eight offspring. Females are capable of producing young 30-40 days after they are born and can continue to produce offspring every 21 days thereafter (Askam 1992). This allows for exponential growth of the population in a very short time. Silviculture treatments may alter a sites carrying capacity for voles. In monocultures such as forest plantations, seedling nurseries, seed orchards and Christmas tree plantations the carrying capacity may increase many times improving the success of rapid population growth (Askham 1992).

Damage Identification

Voles prefer to eat green herbaceous growth, grasses, seeds, fruits, and insects, but as these plant species die or go dormant in autumn and winter voles switch their diet to available dead plants, seeds, roots or on insects and other small animals (Tamarin 1985). In a 24-hour period, they may consume amounts of green feed nearly equaling their own weight (Gaafar et al. 1985). A few species, for example, *M. californicus, M. ochrogaster, M. oregonii, M. pennsylvanicus, M. pinetorum,* and *M. townsendii* feed on the bark of young trees in forestry plantations of the United States (Figure 1). The feeding on palatable woody plants such as trees is done to obtain the food from the cambium layer thus disrupting the flow of nutrients created during the photosynthesis process in the leaves. If all the bark is removed from around the trunk (i.e., the trunk is girdled) the tree usually will die except with certain species that have the potential to regenerate growth below the line of the girdling damage. Smaller amounts of feeding can also result in a seedling being more susceptible to other biological and environmental stressors such as pathogens and drought. Areas with environmental conditions conducive to vole

population growth during the spring and summer months can experience large populations of voles competing for less food as the season progress into the fall and winter months. These conditions can result in great amounts of feeding damage to trees.



1A

1B

Figure 1. Distribution of vole species associated with seedling damage: (1A) M. oregonii, *M. longicaudus, M. pinetorum,* and *M. townsendii*, and (1B) *M. californicus* and *M. pennsylvanicus*.

Mortality of forest plantings caused by rodents, especially voles, can be a significant but misunderstood cause in some cases. Land owners and foresters alike are often not aware of the damage voles can cause and are surprised when they discover survival of planted trees is dramatically reduced over the winter and small trees are chewed off at ground level or root systems totally destroyed. In 2005 more than 1,000 acres of newly planted pines were reported destroyed by voles in the state of Virginia alone (Asaro 2006). Damage may occur to lateral and terminal shoots of small seedlings and several bites can result in the stem being severed. Vole damage is not limited to newly planted seedlings, but can be found on larger trees $\geq$ 7.5 cm. Vole gnawing on the bark of larger seedlings can result in exposed sapwood having a fuzzy appearance and texture. Below ground damage to root systems can be similar to that found above ground.

Snow cover provides an advantage to the voles in that they can move around more freely avoiding birds of prey and other predators. In northern regions the voles establish well defined burrows that they continue to use even after the upper regions of the soil have frozen. This allows for feeding on root systems throughout the winter. With snow accumulation around tree trunks, damage can result at much higher levels on the tree as voles tunnel through the snow and snow melts away from the tree trunks. By the time the damage is noticed, at snow melt or later in the spring, it is too late to control the population.

Damage Management Strategies

Research that addresses managing voles in reforestation and forest plantations is limited. Some research has been performed in agricultural crops which might be borrowed from in forming damage control strategies. As with most pest or

damage control situations, there is seldom a single solution to preventing vole damage. Relying only upon pesticide application to control the population may result in short-lived results, extra expense and greater hazard to non-target species. Thus several of the following damage control methods used in an integrated pest management approach may be necessary to prevent or reduce vole damage. Which methods will be used depends on the time, labor, size of area affected, vole population numbers, environmental conditions, effect on non-target species, and personal control philosophies. Population surveys should be used to determine if treatment should be made and to determine the results of population management techniques once a management program has been put into place.

Pre-planting surveys for voles in areas that contain habitat conducive to growth of vole populations are needed. Visual survey of areas, especially in late summer and early fall, may be used to determine if voles are present and how widespread the populations are over the acreage to be planted or areas that have been planted in the past two years. Runways and vole burrows can be looked for during the late summer or early fall. The Department of Forestry in the state of Virginia suggests using about a dozen apple bait stations per acre to determine if vole population management is needed (Asaro 2006). A method of vole survey suggested by the Virginia Department of Forestry is to delineate areas of activity and mark in some manner such as with the use of pin flags or flagging. Establish a network of apple baits at a density of at least one dozen stations per acre. An apple with a one inch slice or disc removed from it should be placed at each station and covered with a shingle or tar paper. Twenty-four hours following placement the apples should be checked for tooth marks. Add up the total number of apples with tooth marks and divide this sum by the total number of stations. If this number multiplied by 100 results in over 25% this indicates that there is a potential for serious damage to seedlings planted on this acreage and a need for vole control. Snap traps can be used in a similar manner using about one dozen traps per acre. High populations of deer mice (*Peromyscus* spp.) can bias this survey technique.

Two techniques used to prepare reforestation sites for planting of conifer seedlings are burning and/or scarifying the slash that results from clear-cut logging. Grassy areas provide a source of food, water, and shelter for the voles. Seedlings planted to such grassy areas that have heavy shrub or post harvest slash cover are especially vulnerable to vole feeding. In areas where grasses and forbs quickly invade clear-cut sites, slash burning and/or scarifying will reduce or eliminate vole cover and help prevent damage (the woodland workbook). The use of herbicides to provide release of seedlings can also help to control the food sources and harborage of voles. On the scale of Christmas tree plantations, tree, and seed nursery managers or smaller land owner property reforestation habitat can be manipulated by removing mulch away from trunks and mowing grass closely (Jackson 1990). In this smaller scale the use of an additional tool such as rodenticides may be economically feasible for vole control.

Mechanical control can be practiced by encircling the tree roots and stem with a protective barrier, such as Vexar© which is available commercially (Pauls 1986). Barriers should encircle the stem to a height of at least 15 cm or in areas that receive snow the height should extend above the expected snow depth. The bottom edge should encircle any surface roots and extend for at least 15 cm below ground level. Snow

can be a problem with this method when the snow cover exceeds the top of the barrier or when it causes the barrier to collapse. Deer mice can find these barriers to be a unique opportunity for building a nest within them. In large tracts of reforestation this method may not prove to be economically feasible.

Repellants can be used to deter voles from feeding on treated seedlings. There are several products on the market that claim to have rodent repelling properties. Thiram (tetramethylthiuram disulfide) is a pesticide that is also registered as a rodent repellant and capsaicin is an active ingredient in several marketed repellents. Although both are registered as vole repellents, their effectiveness has been questioned (O'Brien 1994). In a laboratory trial some efficacy as a repellent to vole feeding has been demonstrated for both chemicals (Witmer et al. 2000). Synthetic predator odors have also been evaluated as repellents to small rodents. One study suggested that the use of predator odors could attract other predators thereby increasing predation as well as to serve as a behavioral-physiological stress in vole populations (Sullivan et al. 1988). Fumigants are typically not used to control voles in reforestation projects and Christmas tree plantations due to the complexity and shallow nature of their burrows.

Two methods of direct population control of voles include trapping and fertility control. Generally trapping is not an economically feasible method to control voles, but may be used to identify the vole species present or as a monitoring technique. In special circumstances where vole populations are very low and limited to a small area within a Christmas tree plantation or nursery, intensive snap-trapping may prove effective. Research done with fertility drugs have shown that certain chemicals are capable of affecting vole fecundity. Marsh and Howard (1969) discovered that voles accepted mestranol baits and experienced a reduction in pregnancy rate. Female voles that consumed mestranol passed it to their nursing pups, making them irreversibly sterile (Conover 2002). Currently there are no fertility control drugs registered by Federal EPA that have proven to be efficient, safe and economical to use in controlling vole populations.

Two types of rodenticides have proven effective in controlling voles in various agricultural settings and have labeling for use in Christmas tree plantations, tree nurseries and reforestation projects: zinc phosphide and chlorophacinone. Consult rodenticide labeling to make sure the specific rodenticide has labeling for such sites and what application methods are allowed. Zinc phosphide, an acute rodenticide, has also been shown to be effective at controlling voles. There are currently several zinc phosphide formulations registered by the Federal Environmental Protection Agency labeled for use in vole control. There is also an anticoagulant registration, chlorophacinone, that can be used in reforestation projects, Christmas tree plantations, tree plantations, and nurseries, but limited in which states this can be used (please refer to labels before applying rodenticides). In areas of the northeast where pine and meadow voles are both present it has been found that continued reliance upon anticoagulant baits (i.e., chlorophacinone) will allow for the meadow vole to become the most prevalent of the two species. When zinc phosphide is relied upon selection for pine voles as the dominant species occurs.

Non-target Issues

Zinc phosphide is federally registered as a rodenticide to use in the control of a variety of small mammal species. This rodenticide has been used to control voles in agricultural settings for

many years. Formulations for this use pattern vary from grain-based pellets, whole grain coated with zinc phosphide to rolled grains with zinc phosphide, along with a concentrate form with labeling which allows for the treatment of grain, fruit and meat based baits. Zinc phosphide rodenticide baits labeled for above-ground use patterns are labeled as restricted use pesticides by the Federal EPA. Formulation choice is an important consideration especially where gallinaceous and other seed-eating bird species may occur. Waxed cracked corn bait has historically been used in the state of Vermont to control voles. Unfortunately this type of waxed seed bait allows the toxicant and bait to be available over a long duration. Cracked corn baits seem to be more attractive to wild turkeys (*Meleagris gallopavo*) as well as certain other gramnivorous non-target species. Wild turkeys populations have dramatically increased in area of the United States where they have previously been extirpated (Dickson 1992, Poppenga et al. 2005). Bait formulations of non-hulled steam-rolled or crimped oats may be least attractive to non-target bird species. Crimped oats may hold the rodenticide better in that it does not have a hull that can fall off the seed bait, but the lack of the protective hull on the crimped oat may allow it to break down more rapidly in moisture. A green dye may also help to reduce the bait attractiveness to non-target species.

The multi-feed anticoagulant active ingredient chlorophacinone is formulated in a paraffinized pellet that is federally registered to be used in the control of voles. Studies performed in dormant apple orchards of Washington State have shown low secondary hazard to non-target species due to the low amount of toxicant residue found in vole carcasses and the small number of voles that were found dead above ground (Bryson 2004). As with zinc phosphide these labels that include above-ground use patterns have Federal EPA restricted use labels. Registered rodenticides are useful tools in controlling vole damage, but other alternatives should be considered as well in putting together an Integrated Pest Management (IPM) program.

POCKET GOPHERS

Of the three genra of pocket gophers found in North America (*Cratogeomys, Geomys,* and *Thomomys*) the northern (*T. talpoides*) and Mazama (*T. mazama)* pocket gophers are the two most widely distributed species associated with forest damage (Figure 2; Marsh and Steele 1992). This fossorial rodent, named for their external, fur-lined cheek pouches, maintains a complex network of 5-8 cm diameter tunnels that parallel the surface as well as subsurface tunnels (10-25 cm below ground) for feeding (Marsh and Steele 1992). Pocket gophers spend the majority of their time below ground carrying out functions such as foraging, reproduction, and waste disposal (Baker at al. 2003). Populations are patchily distributed and limited by soil type, excessive moisture, or unsuitable forage (Marsh and Steele 1992). Pocket gophers are generalist herbivores consuming mostly roots, tubers, rhizomes, corms, and stems both below and above ground (Baker et al. 2003).

Figure 2. Distribution pocket gophers (*Thomomys* spp.) associated with reforestation damage.

Pocket gopher damage in the early 1970s was mainly limited to the eastern Oregon and Washington in ponderosa pine (*Pinus ponderosa*) and lodgepole pine (*P. contorta*; Anthony and Barnes 1978). However, pocket gopher damage today now limits reforestation efforts in the mixed conifer and true fir forests as well (Black and Lawrence 1992). Plantation failure in Montana and Idaho was mostly caused by pocket gophers from 1976 to 1983 with estimated costs of control and replanting over $9 million (Black and Lawrence 1992). Hooven (1971) documented only 12% seedling survival in areas occupied by pocket gophers compared to 87% in non-occupied areas. Reforestations efforts can be hindered in high density pocket gopher areas.

Damage Identification

The most common forms of damage associated with pocket gophers are stem girdling and pruning of roots on newly established seedlings (Marsh and Steele 1992). Root girdling or pruning may go unnoticed until seedlings turn brown or fall over. Seedling consumption can occur when pocket gophers forage in snow tunnels during the winter and encounter seedlings (Barnes et al. 1970, Hooven 1971, Smallwood 1999). Although once trees reach 10 years of age they tend to be less vulnerable to pocket gophers, some damage to maturing saplings can occur from girdling of roots and stems (Marsh and Steele 1992).

Damage Management Strategies

Population recovery can be quick in harvest areas with favorable surrounding habitat (Barnes et al. 1970, Smallwood 1999). Generally repopulation occurs from dispersing subadults which can readily occupy vacant resident burrows and can live at higher densities owing to smaller home range requirements (Howard and Childs 1959 in Smallwood 1999, Reichman et al. 1982). Planting immediately after harvest, but no longer than 8 months, prior to gopher repopulation may help decrease seedling damage (Marsh and Steele 1992). Control of herbaceous vegetation with herbicide reduces pocket gopher activity and seedling damage (Black and Hooven 1977, Marsh and Steele 1992). Natural barriers or undisturbed strips of > 120 m in width can protect against rapid reinvasion from gopher occupied sites into harvested areas (Marsh and Steele 1992). Fumigants, such as aluminum phosphide, in small areas have been successful in controlling small numbers of pocket gophers (Marsh and Steele 1992). Application of this methodology is somewhat cost prohibitive and has therefore not been used in reforestation efforts. The long-term protection and economics of using tree protectors has not been thoroughly explored as a means to reduce pocket gopher damage (Marsh and Steele 1992), although some efficacy was found in small-scale studies (Anthony and Barnes 1978).

Most available tools for managing pocket gophers are expensive and difficult to implement; therefore, strychnine (hand application or burrow builder) has been the preferred method of pocket gopher control in reforestation efforts (Marsh and Steel 1992). Additional both zinc phosphide and chlorophacinone are registered for burrow building and hand-baiting. Effective pocket gopher management includes a combination of vegetation management and baiting (Lawrence 1992). Strychnine, zinc phosphide, and chlorophacinone are registered for control of pocket gophers. Review label to make sure that product includes use pattern before applying.

Non-target Issues

Strychnine baiting is a standard means to limit pocket gopher populations (Fagerstone et al. 1980, Barnes et al. 1985). Bait is applied below ground, in active burrow systems, to maximize contact with pocket gophers and minimize negative impacts on above-ground non-target species (Hegdal and Gatz 1976). Although the plugging of open holes by pocket gophers reduces access by predators and other burrow inhabitants, a few species occupy pocket gopher burrows. Ground squirrels are a strong competitor for pocket gopher burrows and can occasionally force gophers from the burrows (Vaughan 1961). Baiting after other small mammal species such as golden-mantled ground squirrels (*Spermophilis lateralis*) have hibernated may be one way to reduce primary toxicant hazards (Nolte and Wagner 2002).

Pocket gophers very rarely die above ground (Barnes et al. 1985, Evans et al.

1990, El Hani et al. 2002); however, other primary exposed non-target small mammals may die above ground (El Hani et al. 2002, Smallwood 1999). Although some residues may be found in the body, the majority of strychnine residues in carcasses are usually found in the gastrointestinal tract (GI) and in bait stored in cheek pouches (Hegdal and Gatz 1976, Anthony et al. 1984) thus posing a potential hazard to scavengers and predators. These carcasses become available for scavengers and insects which can play a large role in degrading carcasses in drier forests (El Hani et al. 2002, Arjo et al. 2006). However, even with high strychnine concentrations (0.2756 μg/g), risk assessments showed that insect mediated tertiary risks associated with underground strychnine baiting was negligible (Arjo et al. 2006).

Species that use the pocket gopher burrow systems or feed upon pocket gopher carcasses are at risk to secondary poisoning. Long-tailed weasels (*Mustela frenata*) are a common predator within the pocket gopher burrows. Weasels are likely to be at higher risk of poisoning than most predator species due to their higher basal metabolic rate compared to other mammals of similar size (Brown and Lasiewski 1972, Moors 1977). Unlike larger predators who may only use baited areas infrequently because of their large home ranges, the demand for fresh meat and physiologically confined home ranges, may concentrate weasels in baited areas. In addition, increased secondary risks to weasels may occur due to the animal's ability to cache large quantities of small mammals (Muths 1998). Weasels readily killed pocket gophers, healthy and strychnine-baited, in simulated environments; however, the weasels were not attracted to dying pocket gophers nor did they cache available carcasses. In addition, weasels preferred to forage on fresh carcasses rather than older carcasses (Arjo, unpublished data).

A burrow-builder is often used mainly in agricultural areas, to create an artificial tunnel system for bait placement. Although the system allows for greater speed for pocket gopher control and does not rely on identification of active systems (Marsh and Steele 1992), additional non-target hazards may exist. Baits may not be as concealed with the mechanical system compared to hand-baiting and the artificial burrow system creates additional pathways for reinvasion (Smallwood 1999).

MOUNTAIN BEAVERS

Mountain beavers are an archaic semi-fossorial rodent species endemic to the Pacific Northwest and portions of California (Figure 3). Although mountain beavers can be found up to 3000 m in elevation (Feldhamer et al. 2003), the species prefers humid, open-canopied habitats created after timber harvest (Neal and Borrecco 1981, Arjo and Nolte 2006, Arjo et al. 2007a). Extensive burrow systems, containing a highly variable number of openings, with high humidity and good soil drainage are used year-round and fulfill both reproductive and non-reproductive functions (Voth 1968, Beier 1989). Management of this species is somewhat unique in that in the southern and northern extremes of its range it is managed as a species of concern, and the most contiguous distribution of its range, as a pest species.

Figure 3. Distribution of the mountain beaver (*Aplodontia rufa*).

Although current damage figures are unknown, in a 1977 survey, over 111 thousand hectares of primarily Douglas-fir (*Pseudotsuga menziesii*) stands were reported damaged by mountain beaver in northern California, Oregon, and Washington (Borrecco et al. 1979, Borrecco and Anderson 1980). Western red cedar (*Thuja plicata*), western hemlock (*Tsuga heterophylla*), and Sitka spruce (*Picea sitchensis*) may also incur mountain beaver damage to a lesser extent. Seedling damage is the most prevalent up to 3 months after planting when little other available forage occurs in the harvested areas (Arjo and Nolte 2006).

Damage Identification

Mountain beavers can damage all species of conifers within their geographic range from > 1 year old to less than 20 years old. Although burrowing activity may bury or uproot seedlings (Voth 1968), the most prevalent injury is the clipping of small seedlings, up to 19 mm in diameter (Hooven 1977, Borrecco et al. 1979, Cafferata 1992), especially after planting. Young seedlings are often clipped at ground-level at a 45° angle leaving no viable lateral shoots. In a study to determine if seedling size influenced degree of damage, Bruce and Anderson (1982) found that an average of 29.9 ± 4.8 percent of 2-1 (2 years nursery grown and 1 year out-planted) seedlings and 48.2 ± 10.6 percent of 2-0 seedlings after 3 years, died from mountain beaver damage in

western Washington. Seedlings were 0.9 and 1.4 years behind undamaged tree height for 2-0 and 2-1 seedlings respectively (Bruce and Anderson 1982). The clumped distribution of mountain beaver damage creates openings that will continue to enlarge with continual mountain beaver activity (Neal and Borrecco 1981, Cafferata 1992). Mountain beavers clip lateral branches and terminals of larger seedlings and saplings. The most serious injury inflicted on saplings is the undermining of roots and basal girdling (Hooven 1977, Neal and Borrecco 1981, Borrecco and Anderson 1980, Cafferata 1992).

Damage Management Strategies

Several techniques have been explored to reduce mountain beaver damage that includes: indirect control of populations, limited access to seedlings, and direct control measures. Habitat manipulation (e.g., slash removal, burning or herbicide treatments) and planting larger seedling stock are used to increase the competitive advantage of the newly planted seedling and reduce site attractiveness for mountain beaver. If complete slash removal is not possible, creating smaller slash piles that decay quicker and offer less refugia can often deter mountain beaver inhabiting newly harvested areas (Arjo and Nolte 2006). Size and shape of the harvest unit can also have an impact on mountain beaver damage. Narrow and small units are more highly susceptible to invasion from adjoining areas (Cafferata 1992) especially if the surrounding areas riparian hardwood.

Exclusion devices such as individual tree protectors, although labor intensive, can be effective in brushy pockets and on the edge of units where reinvasion is likely to first occur (Cafferata 1992). A significant decrease in damage to seedlings (from 44% to 3%) with the application of tree barriers has been documented (Borrecco and Anderson 1980); however, even with barriers, damage to seedlings can occur. Tubes can be penetrated by mountain beaver, especially those tubes with perforations or seams that allow the mountain beaver to hold onto the plastic (unpublished data).

Direct control methods (Conibear No. 110 or padded foot-hold traps) are the most frequent techniques employed for reducing mountain beaver populations prior to planting. Although effective at reducing the mountain beaver population initially, but not 100% efficacious, units are often re-trapped after the first growing season because of invading populations. Increased periods of time between initially trapping and seedling planting increase the likelihood that harvest units will be reinvaded and the direct control measures effectively negated (Arjo and Nolte 2006). Several approaches have been used in the past to incorporate rodenticides into control measures: strychnine placed on native vegetation or apples (Nelson 1969), and strychnine-based Boomer-Rid. Although efficacy was questionable, Boomer-Rid was registered for use for a brief period in Oregon (Orco Boomer-Rid mountain beaver bait SLN Reg No OR-840029; Cafferata, 1992; Campbell et al., 1992). After initial screening of four registered underground-use rodenticides (0.5% strychnine, 2.0% zinc phosphide, 0.005% chlorophacinone, and 0.005% diphacinone), chlorophacinone was shown to be effective in mountain beaver control (Arjo and Nolte 2004). Chlorophacinone, Rozol®, is currently registered for mountain beaver control as a state local needs permit in both Oregon (OR-060026) and Washington (WA-060019; Arjo 2006).

Non-target Issues with Chlorophacinone

Several species other than mountain beavers frequent mountain beaver burrow systems (Feldhamer et al. 2003), such as long-tailed weasels (*Mustela frenata*),

woodrats (*Neotoma sp.*), rabbits (*Sylvilagus sp.*), mink (*M. vison*), and spotted skunks (*Spilogale gracilis*). Non-target species must be exposed to bait and the bait must be palatable for primary poisoning to occur (Kaukeinen et al. 2000). Bait placement and timing of bait, as well as the packaging are used to decrease primary non-target risks. Baits are placed at least 30 cm into the burrow system to prevent any aboveground removal of baits. The bait packaging of Rozol® relies more upon the animal's "hoarding behavior or curiosity" rather than an actual bait attractant (smell). Plastic is an item of curiosity for mountain beavers as documented by the number of nests, both in pen trials and in the wild, that contain pieces of flagging, bags, or other plastic from their environment. The unique caching behavior of mountain beavers allows for bait placement within a burrow system, that is incorporated into the nest or food cache of the target species and reduce primary non-target exposure. Greater than 78% of the systems baited had at least one bait bag removed and cached by mountain beaver during the efficacy study (Arjo 2006).

Mountain beavers are prey species for a number of terrestrial and aerial predators (Arjo et al. 2007a). One concern about using baits, even if they are below ground, is the secondary exposure to non-targets from carcasses. Mountain beavers that consumed chlorophacinone died below ground (98%; Arjo 2006, and Arjo unpublished data); therefore, secondary hazards to predators exposed to baited carcasses are limited to semi-fossorial species such as found in the mustelid family. Additionally, baiting is curtailed from mid-May through mid-September in the Pacific Northwest to reduce possible hazards to spotted owls (*Strix occidentalis caurina*). According to Forsman et al. (2004), mountain beavers make up a relatively small portion of spotted owl diets, and are only represented in the early summer when juvenile mountain beavers are present and naïve. Even when using the worst-case scenario for chlorophacinone concentration in mountain beaver carcasses (0.354 ppm) obtained from lab data, the mammalian risk quotient was exactly at the threshold of acceptable risk defined by the EPA for threatened and endangered species (Arjo et al. 2004). It is unlikely, but remotely possible that a raptor might kill or scavenge on a poisoned mountain beaver. Using the same risk assessment procedures as described for mammals, the risk quotient fell well below the EPA-defined threshold of acceptable risk for threatened and endangered species (Arjo et al. 2004).

An Integrated Pest Management (IMP) strategy that incorporates both baiting and trapping may be the most effective way to control mountain beaver populations, while also minimizing rodenticide usage. Seedlings are most vulnerable to damage the first 3 to 4 months after planting, prior to emergence of forbs within harvested units. The integration of an additional tool to supplement trapping, such as baiting with chlorophacinone, may allow for additional seedling protection between trapping and forage green-up. Two IPM strategies of mountain beaver management were compared using a cost effectiveness analysis (Arjo et al. 2007b). In treatment 1, the units were baited and later trapped to remove remaining animals for a per acre cost of $42.47. In treatment 2, traps were placed in the units to remove mountain beaver, and then baits were placed in active areas for a per acre cost of $49.69. This indicates that the cost minimizing or efficient method of mountain beaver management was treatment 1. Although seedling damage did not differ between the two treatments, overall activity based on fern monitoring demonstrated that a greater overall reduction in activity occurred on the treatment 2 plots. In

addition, although higher in costs, fewer baits were placed on treatment 2 plots, since population were reduced initially, than the treatment 1 plots. An Integrated Pest Management strategy that includes trapping followed by baiting, therefore, is more socially acceptable and reduces non-target hazards, since fewer baits are placed in the environment with this treatment (Arjo et al. 2007b).

CONCLUSIONS

Forest management practices have likely increased early successional habitat favored by several wildlife species and therefore, increased wildlife conflicts with managed timber. Although rodenticides play a role in forest pest management, they are usually incorporated in an Integrated Pest Management strategy that minimizes rodenticide amounts in the environment. In addition, the fossorial or semi-fossorial nature of these species, pocket gophers and mountain beavers, further reduces non-target exposure with proper bait placement.

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