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Non-Target Impacts of Strychnine Baiting to Reduce Pocket Gopher Populations on Forest Lands in the united States

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Abstract

Reforestation efforts are often severely hindered on sites that contain high populations of pocket gophers (Thomomys spp). Strychnine baiting is a technique used to suppress pocket gopher populations until seedlings are established. Strychnine bait is applied below ground in pocket gopher burrows, however, primary and secondary hazards remain a concern. A study to assess primary hazards indicated that some individual rodents died post strychnine baiting but there was not a long-term negative impact on non-target rodent populations. Possible secondary hazards reflect the potential for predators or scavengers to encounter poisoned pocket gophers. Concerns that pocket gophers may surface before they succumb to the bait have been reduced through data acquired in pen trials. Most pocket gophers in trials with natural ground cover died in or near nest and all died below-ground. Carcasses of non-target species may pose some risk. These carcasses, however, are few and are thought to be consumed by insects within a few days. Trials are being conducted to evaluate the fate of these carcasses and to assess whether insects that feed on strychnine-containing carcasses pose a tertiary hazard.

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1 Introduction

Pocket gophers (*Thomomys* spp.) are an impediment to reforestation efforts in the Pacific Northwest (Capp 1976, Crouch 1986, Marsh & Steele 1992). Efforts to establish tree seedlings on sites infested with pocket gophers can be futile unless protective measures are implemented. In preferred forest-habitat, a high population of pocket gophers (37 to 62 per ha) can damage a significant portion of conifer seedlings (Marsh & Steele 1992). Annual seedling losses are reported to vary from 5 to 50 % (Barnes 1973). Plant successions after timber harvest often create favorable pocket gopher habitat and encourage high populations. In some extreme cases, where direct pocket gopher control is not possible or is anticipated to be ineffective, harvest may be ill-advised because successful reforestation is too uncertain (Marsh & Steele 1992).

Pocket gophers commonly prune roots of seedlings and girdle or clip seedling stems (Nolte & Otto 1996). Small seedlings, less than .75-cm in diameter, are the most vulnerable. The stems generally are clipped at or near ground level and pocket gophers may pull harvested seedlings into their burrows. Pocket gophers also prune the roots and girdle the stems of larger trees. Extensive above-ground girdling is fairly easy to detect. Damage to roots, however, may go unnoticed until seedlings tip over or become discolored. Non-lethal damage causes poor overall growth, shortened needles, reduced internodes, premature needle drop, and needle discoloration (Marsh & Steele 1992). A variety of tree species are vulnerable to damage, including ponderosa pine (*Pinus ponderosa*), lodgepole pine (*Pinus contorta*), Jeffrey pine (*Pinus jeffreyi*), red firs (*Abies* spp.), Douglas-fir (*Pseudotsuga menziessi*) and Engelman spruce (*Picea engelmannii*) (Cunutt 1970, Barnes 1973).

Management practices implemented to reduce damage inflicted by pocket gopher include habitat manipulation, such as herbicide treatments (Keith et al. 1959, Hansen & Ward 1966); silvicultural practices, such as planting immediately after logging, minimizing disturbance of a site after logging, or selective cutting (Anderson 1976, Crouch 1986, Marsh & Steele 1992); physical exclusion devices (Hooven 1971, Anthony *et al.* 1978); trapping (Crouch & Frank 1979, Smeltz 1992); fumigation (Sullius & Sullivan 1993); repellents (Sullivan 1987, Sullivan *et al.* 1990); and rodenticides, such as strychnine bait (Marsh & Howard 1978). Except for strychnine, these methods are generally difficult and slow to implement, as well as expensive, and are often ineffective at reducing damage (Anthony *et al.* 1978, Marsh & Steele 1992). Accordingly, strychnine baiting is widely used to reduce pocket gopher populations in areas targeted for reforestation (Chase et al. 1982, Teipner et al. 1983, Marsh 1992).

Strychnine bait is applied below ground in active burrow systems to maximize the control of pocket gophers and to minimize negative impacts on non-target species. Primary poisoning hazards may exist though because some small mammal species use pocket gopher burrows (Howard & Childs 1959). Burrow use and the consequent exposure to bait is affected by several factors including species, habitat type and season (Fagerstone *et al.* 1980). The potential for secondary poisoning hazards also reflects these characteristics as they impact prey and predator or scavenger species. Thus, the potential kill of strychnine baiting on non-target species can be expected to vary among sites (Fagerstone *et al.* 1980).

This paper outlines an extensive series of studies we are conducting to assess the immediate risk and potential long-term impacts of strychnine baiting on the Rogue River National Forest in Klamath County, approximately 30 km east of Ashland, Oregon, USA. These studies are investigating primary hazards to herbivorous rodents, and possible secondary or tertiary hazards. Secondary hazard studies include the fate of strychnine poisoned pocket gophers, above-ground carcass degradation, and below-ground pocket gopher interactions with mustelids. Insects generally consume above-ground carcasses and we are investigating whether strychnine-containing carcasses are a direct risk to insects or whether these insects may pose a risk to insectivorous birds and mammals. We also are trying to identify feasible alternative means to further minimize risk to non-target species while reducing pocket gopher populations.

2 Strychnine

General information on strychnine is summarized from Timm (1994). Strychnine is one of the alkaloids processed from raw dried ripe seed of *Strychnos nux vomica*, a small tree native to India, North Australia, Vietnam, and Ceylon. These seeds were used to poison dogs, cats, and birds in Europe at least as early as 1640. The seeds consist of approximately 2.0 % to 2.7 % strychnine alkaloid which was discovered by Pelletier and Caventon in 1817.

Strychnine is a quick acting toxin, with a very slight odor and bitter taste. Toxicity is high, but varies among animals. LD_{50} values range from 0.7 mg/kg for some canines to 27.0 mg/kg for nutria. The LD_{50} for mallards is 2.3 to 2.9 mg/kg, for pheasants it is 24.7 kg/mg. LD_{50} for pocket gophers is approximately 8 mg/kg. Strychnine enters the blood rapidly and acts on the central nervous system. Symptoms may appear within 5 to 30 minutes post ingestion. Intoxicated animals have frequent tetanic convulsions interspersed with quiescent periods. Ultimately these convulsions lead to death through respiratory failure. Death generally occurs in pocket gophers within 20 minutes of ingesting a lethal dose of strychnine.

Strychnine does not assimilate into tissues or bone. Sublethal doses of strychnine are rapidly detoxified and excreted (Savarie 1991). Strychnine also is photodegradable and biodegradable (Howard *et al.* 1991). Undigested strychnine, however, frequently remains in the gastrointestinal tracts of poisoned animals because it is a rapid-acting toxin that is not readily absorbed (Colvin 1984, Hegdal & Gatz 1976, Redig *et al.* 1982). These residues can pose a hazard to predators and scavengers if they ingest the gastrointestinal tract (Copeman 1957). Thus, secondary exposure to raptors that eviserate prey is unlikely to occur.

Baits to control pocket gophers on reforestation units generally are steam-rolled oats treated with 0.5 % strychnine. A contractor applies the baits to active burrow systems, as indicated by fresh pocket gopher mounds. Frequently, the contractor applies the bait twice before monitoring efficacy. Efficacy is determined by the open-hole method (Richens 1967, Barnes *et al.* 1970). Briefly, one or more holes are made into a pocket gopher system and then checked 48 hours later to determine whether the holes remain open or have been closed. Burrow systems with holes that remain open are considered to be inactive. Contractors are required to re-treat target sites until they achieve a targeted 80% reduction in pocket gopher activity.

3 Primary hazard study

A capture and release program was conducted before and after strychnine baiting to monitor small mammal populations on treated and untreated sites (El Hani *et al.* submitted). Two experimental plots (200 × 140 m) were established on each of 2 reforestation units targeted for pocket gopher population reduction. Seventy 20 × 20 m grids were overlayed across each plot for ease of mapping and spacing of traps. One plot within each unit was randomly selected for strychnine application, while the other plot served as an untreated control to monitor temporal effects not related to strychnine baiting. Vegetation and woody debris were evaluated on each experimental plot to ensure similarity among sites. These habitat characteristics can greatly affect the distribution and abundance of small mammals (Rosenzweig & Vinakur 1969, Dueser & Shugart 1978, Maser et al. 1979) as well as capture success (Hayes & Cross 1987).

Steam-rolled oats with 0.5 % strychnine was applied by contractors according to U.S. Forest Service specifications. This operation consisted of applying bait twice, first on August 28 (0.45 kg/ha) and then again on September 4 (0.05 kg/ha). Open hole monitoring by the contractor indicated that the initial 2 baitings failed to achieve the required 80% decline in pocket gopher activity. Therefore, a third baiting was conducted on September 30 (0.4 kg/ha).

A capture and release program was used to monitor the occurrence of small mammals. Trapping was conducted once prior to baiting, then 3 times at 2-week intervals after treatment, with a follow-up trapping period the next spring, shortly after snow melt, and then twice the next fall at 2-week intervals that reflected the pre-treatment and the first post-treatment trapping periods. Trapping was conducted on five consecutive days each time. One Sherman live-trap (23 × 8 × 9 cm) and 1 Sprague live-trap (25 × 9 × 9 cm) were set approximately 1 m apart at the center of each of the 70 grids in all study areas. On first capture, animals were weighed, sexed, and inserted with an AVID (American Veterinarian Identification Device) micro-chip for identification. On subsequent captures the location and micro-chip number were recorded. Animals were then released at the site of capture.

Location of any animal carcass encountered during the study was recorded and the animal was examined to determine whether it had been previously marked with a micro-chip. When possible, micro-chip numbers were recorded; if a micro-chip was not present, the species of the animal was recorded.

Ten-non target species were captured and released during the study. The golden mantled ground squirrel (*Spermophilis lateralis*) and yellow pine chipmunk (*Eutamis amoenus*), however, were the only species present in sufficient numbers to adequately assess population changes. Other species encountered much less frequently were Townsend chipmunk (*Eutamis townsendii*), Siskiyou chipmunk (*Eutamis siskiyou*), Oregon vole (*Microtus oregoni*), longtail weasel (*Mustela frenata*), bushytail woodrat (*Neotoma cinera*), deer mouse (*Peromyscus maniculatus*), mole (*Scallop* spp.), and Douglas squirrel (*Tamiasciurus douglasii*).

Non-target populations were estimated with the CAPTURE software package (Otis *et al.* 1978). Sampling periods were relatively short (5 days), therefore the closed population model was selected to estimate non-target population abundance (Otis *et al.* 1978, White *et al.* 1982, Pollock *et al.* 1990). A 2-factor repeated measures ANOVA then was used to assess differences among population estimates for each species. The independent factors were treatment (2 levels) and trapping dates (7 levels). Least significant difference (LSD) tests were used *post hoc* to isolate significant differences among means.

Population responses of golden mantled ground squirrel and yellow pine chipmunk post-baiting in this study were similar to results reported in other studies. Immediately after baiting, ground squirrel numbers declined ($P < 0.05$) in treated areas relative to control areas. The next spring, ground squirrel populations in reference areas were similar ($P > 0.05$) to pre-treatment levels, while populations in the treated areas remained slightly, but not significantly, below pretreatment levels. Anthony *et al.* (1984) reported a 72 % decline in golden mantled ground squirrels shortly after strychnine baiting, with a population recovery the following spring.

Yellow pine chipmunk populations in our study were not reduced by strychnine baiting. Fagerstone *et al.* (1980) also failed to detect lower populations of chipmunks post strychnine baiting. In contrast, our study indicated an increase in chipmunks on treated plots relative to control plots by the following spring. This increase may reflect an invasion of chipmunks to fill the void created by the decrease in ground squirrel numbers.

Though strychnine baiting did not induce long-term population changes, obviously some individual animals were killed. Ground squirrel numbers declined immediately post baiting and several ground squirrel (15) and chipmunk (7) carcasses were recovered above ground. These carcasses were consumed by insects (e.g., wasps, ants) and were virtually eliminated within 48 hours. Strychnine bait was detected in the cheek pouches of some of the ground squirrels demonstrating that they had had access to underground strychnine baits. Anthony *et al.* (1984) reported the majority of the ground squirrel carcasses (19 of 26) recovered in their study were located above ground. Chemical assays revealed that strychnine was present in 25 of these animals (Anthony *et al.* 1984). Fagerstone *et al.* (1980) also reported individual non-target loss attributed to strychnine poisoning. Three of the 30 chipmunks fitted with radio collars died and strychnine residues were detected in the body and gastrointestinal tract of two of these animals.

4 Secondary or subsequent hazard studies

Few predators or scavengers were encountered during our initial study, therefore, it was impossible to assess secondary hazards. The presence of non-target animals that succumbed to strychnine bait, however, indicated some potential for exposure to secondary poisoning. Furthermore, though we suspect that most pocket gophers die below-ground it is not well documented. In addition, pocket gophers can pouch sufficient quantities of toxic grain (300 kernels) that, if captured live or dead on the surface, they could present a secondary hazard to several predatory species (Hegdal & Gatz 1976). The likelihood or extent of secondary strychnine exposure, however, is reduced because of the rapid disappearance of carcasses, due largely to insect activity.

We are conducting several studies to assess further the potential for secondary poisoning of non-target species. The objective of one study was to document the likelihood of pocket gophers ingesting strychnine bait and subsequently succumbing to the toxin above-ground. Another study is assessing the means and rate of above-ground carcasses disappearance or degradation. The third study will determine whether strychnine poisoned pocket gopher are likely to be ingested by weasels.

4.1 Fate of strychnine poisoned pocket gophers

Field trials have suggested that most pocket gophers probably succumb to strychnine poisoning below ground, but failed radios or other reasons have inhibited the complete tracking of all animals in previous studies. It has been speculated that missing animals may have been carried off by predators.

The NWRC Olympia Field Station has been working to assess the potential of strychnine poisoned pocket gophers to pose a secondary hazard to other wildlife species. The first trial at the station monitored pocket gophers established in pens (2.5 × 5 m; with 75 cm of sandy-loam soil) with ground cover (grasses, forbs, shrubs, tree seedlings, woody debris and stones) that mimicked pocket gopher sites on the Rogue River National Forest. Individual pocket gophers were introduced to pens and given at least three weeks to adapt to their environment and construct nest and burrow systems prior to baiting. Baiting procedures simulated those used during operational baiting of pocket gopher. Baiting was repeated up to three times if open-hole monitoring indicated animal activity continued after previous baitings.

A second trial was identical to the first except, rather than simulating natural ground cover, a heavy mat of straw (8 cm) was applied to the soil surface. We reasoned that pocket gophers were more likely to spend additional time on the soil surface with an increase in ground cover. Burrow systems established during the first trial were collapsed and the soil turned over before the second trial was initiated. Thus, pocket gophers in the second trial had to construct their own burrow system and the chance of these animals encountering cached strychnine bait from the first trial was virtually eliminated.

Pocket gophers within this study, regardless of ground cover, died below-ground. Animals were found either in their nest or in a burrow, generally close to the nest. Five pocket gophers had cached strychnine bait in their nest. Though the size of pens dictated that baits had to be placed in close proximity to animals, six pocket gophers survived the first two baitings and three animals survived all three baitings. One of these animals later demonstrated a reluctance to eat more than small quantities of bait. Marsh and Howard (1978) noted pocket gophers may exhibit some shyness towards bait after they ingest sublethal amounts of strychnine bait. Pocket gophers can also acquire a physiological tolerance to strychnine (Lee *et al.* 1990).

These trials support the notion that fossorial rodents baited below-ground are unlikely to become above-ground secondary hazards. However, this does not preclude the possibility of the occasional death above-ground, and there is potential for some predators, such as weasels, to encounter pocket gophers below-ground. Further, non-target individuals that encounter bait may present some risk of secondary exposure for predatory species.

4.2 Carcass degradation

Although strychnine baiting in our study did not induce long-term reductions of non-target populations, it did kill individuals. The most common non-target species at risk of primary exposure to strychnine bait on the Rogue River National Forest were golden mantled ground squirrels and yellow-pine chipmunks. A few ground squirrel (15) and chipmunk (7) carcasses were found above-ground and some of these had strychnine bait in their cheek pouches. Thus, the possibility existed for secondary exposure. These carcasses were believed to have been rapidly consumed by insects, which is consistent with other studies that report insects as major contributors to carcass degradation (Sullivan 1988, Witmer *et al.* 1995).

A follow-up study is being conducted to document the fate of carcasses left above ground on the Rogue River National Forests at the time of year when strychnine baiting is normally conducted. Multiple dates and locations are being used because of the variable conditions expected under natural conditions. Initial results indicate that wasps and ants are the insects predominately responsible for carcass degradation. Rate of disappearance reflects the species and number of insects. Carcasses placed close to active wasp nests disappeared rapidly. Temperature influenced the numbers and activity level of insects. During warm weather carcasses disappeared within 72 hours, while carcasses placed out during cool damp periods remained for over a week. A few carcasses were carried off by unidentified larger scavengers. Ravens (*Corvus corax*) were seen in the vicinity where carcasses disappeared. A weasel is suspected of taking one carcass that disappeared at night and was later located in a food cache.

We are also investigating whether insects consuming strychnine poisoned animals are likely to pose a tertiary threat to insectivores. Many insects have been demonstrated to be unaffected by strychnine, with the compound passing unchanged through the digestive tract of beetles (unpublished USDA bibliography, no date). Strychnine administered orally to ants (0.1 to 0.5 mg/kg) produced disturbed motor coordination but no mortality (Kostowski *et al.* 1965). Therefore, it is possible that insects ingesting strychnine would be contaminated for a short period. We are collecting insects while they are feeding on carcasses for subsequent strychnine residue assays. At present, the assays are not complete. However, it seems unlikely that an individual insect will contain a sufficient quantity of strychnine to constitute a viable threat. Rather a bird would need to take a substantial number of contaminated insects within a relatively short time-frame to ingest a lethal dose. This situation seems unlikely, unless a bird ate insects while they were foraging on the gastrointestinal tract of a poisoned carcass.

4.3 Pocket gopher interactions with mustelids

Mustelids, primarily weasels (*Mustela frenata*, *M. erminea*), move within pocket gopher burrows to prey on pocket gophers. Thus, it is probable that strychnine poisoned pocket gophers pose a greater secondary risk to weasels than they do to other predators. Anthony *et al.* (1984) assessed the fate of mink (*Mustela vison*) fed strychnine contaminated golden mantled ground squirrels and concluded that secondary poisoning of mustelids was possible provided the predating animals ingested the stomach contents along with the carcass. Concurrent tests indicated that strychnine concentrations of 1 mg/kg body weight is lethal to some individuals and 3.0 mg/kg body weight is lethal to all mink tested (Anthony *et al.* 1984).

Subterranean and nocturnal predator activity is difficult to observe. Thus, predator-prey interactions between weasels and strychnine poisoned pocket gophers is largely unknown. Weasels may completely avoid sick or dead pocket gophers. In contrast, weasels may be attracted by the antics of poisoned pocket gophers and feed extensively on them, perhaps caching carcasses for subsequent use. If the later is true, then strychnine-poisoned pocket gophers may pose a consequential hazard to weasels.

5 Implications for management

Strychnine baiting can be an effective, albeit short-term, means to reduce pocket gopher populations. Our findings have been consistent with those of other studies that underground baiting of forest pocket gophers with 0.5 % strychnine-treated grain is unlikely to induce long-term adverse effects on non-target wildlife species (Hegdal & Gatz 1976, Fagerstone *et al.* 1980, Anthony *et al.* 1984). Nevertheless, precautions can be taken to further minimize potential risk (Anthony *et al.* 1984). Product labels and application instructions must be followed carefully throughout the operation. Anthony *et al.* (1984) suggested pre-poisoning surveys for sensitive species, post-baiting carcass searches and removals, use of grain baits rather than fresh baits, late baiting, and non-toxic alternatives. Species such as golden mantled ground squirrels have a relatively early hibernation. Ground squirrel activity in our study had virtually ceased by the late monitoring periods. Thus, a window of opportunity may have existed to treat pocket gophers with minimal exposure to ground squirrels. Management plans also need to consider the use of non-toxic alternatives, such as trapping, barriers, repellents, cultural methods (i.e., planting trees undesirable to pocket gophers), and habitat manipulation (Case & Jasch 1994). Unfortunately, many of these techniques have been demonstrated to be either cost prohibitive or ineffective. Finally, aversive agents could be added to baits to render the baits less desirable to non-target species or in some instances aversive conditioning could be used to train some non-target individuals to subsequently avoid baits (El Hani *et al.* 1998).

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