Efficacy of Cholecalciferol Baits for Pocket Gopher Control and Possible Effects on Non-Target Rodents in Pacific Northwest Forests

Suzanne E. Rizor and **Wendy M. Arjo**
USDA APHIS Wildlife Services, National Wildlife Research Center, Olympia Field Station, Olympia, Washington
Stephan Bulkin
USDA Forest Service, Rogue River National Forest, Medford, Oregon
Dale L. Nolte
USDA APHIS Wildlife Services, National Wildlife Research Center, Fort Collins, Colorado

ABSTRACT: Population reduction measures need to be implemented to reforestation plots infested with pocket gopher in the Pacific Northwest. This 1-year investigation assessed the efficacy of 0.15% cholecalciferol (vitamin D_3) bait application to reduce pocket gophers and the long-term effects on non-target small rodent populations within treated plots. The study site was a reforested clear cut containing pocket gopher populations of 10 to 14 animals per ha. Six plots (2.8 ha each) were randomly selected at the study site, 3 plots of untreated controls and 3 plots baited with cholecalciferol. A trap-and-release program was used to assess non-target populations. Radio telemetry and the open hole method were used to monitor pocket gopher activity before and after the fall application of cholecalciferol bait. A 70-80% reduction of pocket gopher activity from telemetered animals occurred in the treated plots, whereas only 10-20% mortality occurred on the control plots. Pocket gopher activity in most of the plots increased by June, and by September of the following year, activity was back to original levels. Time, not treatment, had a significant effect on yellow pine chipmunk, Townsend chipmunk, and golden-mantled ground squirrel populations. We conclude that 0.15% cholecalciferol bait appears to have application for pocket gopher control. Risks to non-target species may exist.

KEY WORDS: cholecalciferol, mark-recapture, non-target species, pocket gopher, rodenticide, secondary hazard, *Thomomys* spp.

Proc. 22nd Vertebr. Pest Conf. (R. M. Timm and J. M. O'Brien, Eds.)
Published at Univ. of Calif., Davis. 2006. Pp. 166-170.

INTRODUCTION

Pocket gophers (*Thomomys* spp.) are an impediment to reforestation efforts in the Pacific Northwest. Efforts to establish tree seedlings on plots infested with pocket gophers can be futile unless population reduction measures are implemented. Pocket gophers will eat the roots of conifers from their underground burrows, girdle trees, or clip them entirely and pull them into their burrow systems. Strychnine baiting has been used as a standard tool to limit pocket gopher populations. However, negative perceptions and the potential hazards associated with strychnine baiting may jeopardize future use. Alternative means to reduce pocket gopher populations need to be continually explored.

Cholecalciferol (vitamin D_3) is a possible alternative to strychnine baiting to reduce pocket gopher populations on reforested areas. Cholecalciferol is a lipid-soluble, amber, crystalline solid that has been shown to be stable and very effective under extreme field conditions (Marshall 1984, Brown and Marshall 1988). An oral lethal dose causes serum calcium levels to rise unchecked. The resultant hypercalcemia causes renal failure and cardiopulmonary failure, secondary to soft tissue mineralization of the kidneys, heart, and lungs (Marshall 1984, Peterson and Talcott 2001).

Cholecalciferol can be a single high-dose toxicant or a cumulative multiple low-dose toxicant (Bennett *et al.* 1988). Cholecalciferol is registered for commensal rodent control, and 0.15% cholecalciferol baits have shown potential for effective control of pocket gopher populations (Witmer *et al.* 1995). Pen trials indicate that cholecalciferol may have relatively low risk of secondary toxicity to some non-target species, particularly avian species (Marshall 1984).

This 1-year investigation was conducted to improve our knowledge of the efficacy of 0.15% cholecalciferol baits. Our goals were to 1) demonstrate efficacy on pocket gopher populations, 2) determine the immediate risk of a cholecalciferol application to non-target vertebrates, and 3) assess the long-term effects on populations of rodents within treated plots. Application of bait occurred in September 2000. Plots were monitored 2 weeks prior to treatment (September 2000), 2 weeks post (October 2000), 4 weeks post (October 2000), 40 weeks post (June 2001), and 52 weeks post treatment (September 2001).

METHODS

The study site was located on the USFS Rogue River National Forest, Oregon, on a recently-planted clear cut, previously identified as an area that had limited reforestation success because of pocket gopher damage to seedlings. Pocket gopher populations were expected to be between 10 and 14 animals per hectare. Six plots (2.8 ha) were placed on the study site; 3 of these plots were randomly selected for baiting with cholecalciferol (Plots 1, 2, and 5), while the other 3 plots served as untreated controls (Plots 3, 4, and 6). Each plot (140 × 200 m) had a 20 × 20-m (quadrant) grid system established across it to ease mapping of captured animals.

Small mammal monitoring was implemented by using a trap-and-release program and was used to assess the

relative abundance of non-target populations. Non-target populations were estimated 2 weeks prior to treatment, and then again at 2 and 4 weeks after treatment. Populations were monitored again the following June 2001 (40 weeks) and September 2001 (52 weeks). Non-target populations were estimated by live-trapping on 4 consecutive days. Two Sherman live traps were placed within each of the 70 quadrants on each plot. Sherman traps were baited with a mixture of oat meal, peanut butter, raisins, and bacon. Captured animals were identified, individually marked with AVID microchips (American Veterinary Identification Devices, Norco, CA) and released. Due to environmental variations, all traps were checked at least 3 times a day: dawn, mid-day, and dusk. Traps were closed when temperatures exceeded 35°C or were below 0°C.

Prior to treatment, all active pocket gopher burrows on the treated and untreated plots were identified. Fresh mound activity was checked by the open hole method (Richens 1967, Barnes *et al.* 1970). The open hole method is the most reliable way to indirectly measure abundance and activity (Engeman *et al.* 1993). Areas were considered active if 1 or more holes in an area were closed. Each active plot was marked with flagging. Subsequently, 10 animals on each treated and untreated plot were live-trapped, a radio-transmitter collar affixed, and an AVID microchip inserted. Animals were released at the capture location. The open hole method was used to monitor pocket gopher activity on flagged plots at 2-week intervals prior to baiting and for 2 and 4 weeks post treatment. Activity was assessed again in June 2001 (40 weeks) and in September 2001 (52 weeks). Pocket gophers with radio transmitters were located using radio telemetry no more than 2 weeks before baiting and then at 2 and 6 weeks after the bait treatment (October and November 2000, respectively). Lack of movement by individual pocket gophers was used as an indication of mortality.

A 0.15% cholecalciferol concentration was prepared by the National Wildlife Research Center using oat groats and a 7.5% concentration of cholecalciferol provided by Bell Laboratories (Madison, WI) following Witmer *et al.* (1995). Approximately 8 g (1 tablespoon) of bait was placed in 2-3 opened, shallow burrows per individual system. Burrows were then re-closed. The 0.15% cholecalciferol bait application was applied by contractors for the U.S. Forest Service once, in early September 2000. Baiting guidelines, as established and monitored by the Forest Service, followed product label specifications with additional information gleaned through the literature survey (Witmer *et al.* 1995).

Pocket gopher response to the open hole method was used to calculate activity scores by dividing closed burrows (active) by total burrows (opened + active). A preference score of 0.5 indicates indifference; >0.5 indicates high proportion of activity; <0.5 indicates low proportion of activity. For analysis of variance (ANOVA), the test response was created by subtracting the activity score from 0.5. Thus, a test response of 0 similarly corresponds to indifference while also lending itself to simple statistical tests of significance. A 2-way mixed-model ANOVA was conducted with time, treatment, and the 2-way interactions as the fixed effects (PROC Mixed, SAS® Version 8.0, SAS Institute Inc., Cary, NC). The random effects were plot nested within treatment and plot × time nested within treatment. Residuals from the model resulting from the test response were examined for distribution and constant variance by examining residual plots.

Analysis of the non-target population data was estimated using MARK (Colorado State University, 1999). Short sampling periods of 4 days were conducted; therefore, the closed population model was used to estimate non-target population abundance. A 2-way mixed model ANOVA effects was used to assess differences among population estimates for each species among the most common small mammals captured. Fixed effects included time, treatment, and time × treatment interaction. The random effects were plot nested within treatment and plot × time nested within treatment. Least mean squares were used to isolate significant differences among means over time ($P < 0.05$).

RESULTS

The open hole method of monitoring pocket gopher showed a large reduction in activity and abundance in treated Plots 1 and 2, 2 and 4 weeks after treatment, with an increase to almost normal population levels by the following June, and a gradual increase in treated Plot 5 (Figure 1). Control Plots 3 and 4 showed constant activity through the baiting time period and a reduction by the following June. Control Plot 6 activities remained

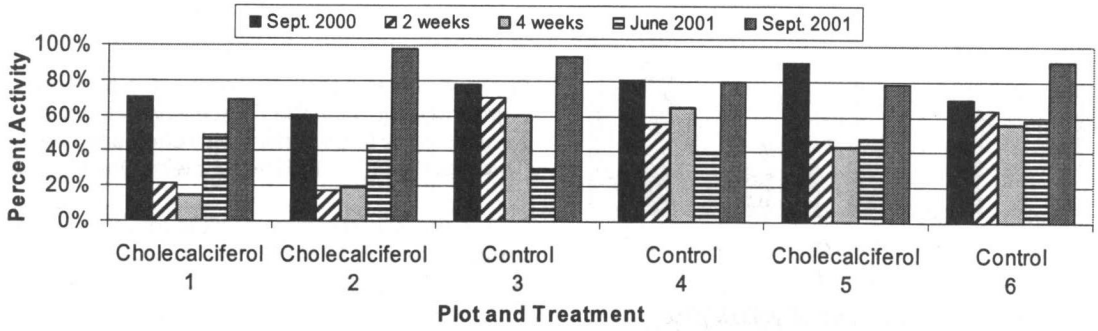

Figure 1. Percentage of active pocket gopher holes to total holes present in the Rogue River National Forest, 2 weeks prior to treatment with cholecalciferol, 2 weeks and 4 weeks post treatment, and the following June and September.

constant through June and increased by September 2001. Examination of the test responses indicated that a low proportion of activity occurred on both treated (P = 0.006) and control plots (P = 0.004) with time, not treatment, contributing to the model. Residuals were normally distributed and exhibited constant variance.

On each of the treated plots, 70-80% bait mortality of radio-collared pocket gophers occurred by November 2000. Mortalities that occurred due to predation were not used to calculate efficacy in treated plots. On Plot 1 (treated), one animal was still alive in June 2001 but had moved, and the signal was lost on the other animal alive in November 2000. One animal in Plot 2 (treated), moved outside the plot in October 2000, and the signal was lost on another gopher in November 2000. Two animals in Plot 5 survived through November and one until June 2001. The signal was lost on the second animal by June 2001. As of November 2000, 6 weeks post-baiting, 20% of the animals in Plot 3 died, 10% in Plot 4 with an additional 3 transmitters lost, and 20% in Plot 6 of the controls. In addition, 3 animals in these control plots were not heard in October.

Four non-target species were captured pre- and post-treatment: voles (*Microtus* spp.), yellow pine chipmunk (*Eutamias amoenus*), Townsend chipmunk (*E. townsendii*), and golden-mantled ground squirrel (*Spermophilus lateralis*). Data collected on voles was not analyzed because so few animals were caught, and determining fluctuations in populations was not feasible. Yellow pine chipmunks on both the treated and control plots followed the same trend. Populations decreased 2 and 4 weeks post treatment, the populations fluctuated slightly by June 2001, and by September 2001 they began to rebound (Figure 2). Yellow pine chipmunks were the most common small mammal captured on all plots. However, like the other small mammals, treatment ($F_{1,4}$ = 0.8, P = 0.8) did not appear to significantly effect the population, but time did (P = 0.002). Both fixed effects in the activity model were significant, with time contributing greatly to the model (P < 0.0001). Treatment was slightly significant (P = 0.05), indicating activity within the 2 treatments differed.

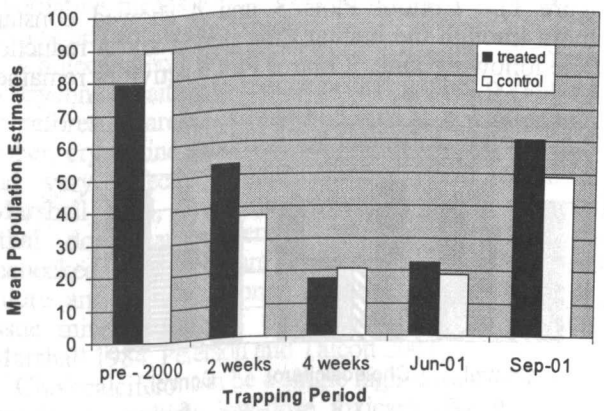

Figure 2. Mean population estimates of yellow pine chipmunk in the Rogue River National Forest, 2 weeks prior to treatment with cholecalciferol and post 2 weeks, 4 weeks, and the following June and September.

Townsend chipmunk populations decreased dramatically on the treated plots post treatment, reaching their lowest levels in June 2001 and starting to rebound by September 2001. Populations of Townsend chipmunks fluctuated slightly on control plots in the fall, but a decline in June 2000 was observed, similar to that in the treated plots. Populations returned to previously-documented levels by September 2001 (Figure 3). Time was the only significant fixed effect (P = 0.018) on Townsend chipmunk populations; no treatment effect was observed ($F_{1,4}$ = 0.8, P = 0.79). Populations in all plots were different between all sampling periods, with the highest populations observed in September 2000 prior to baiting. No treatment effect was observed.

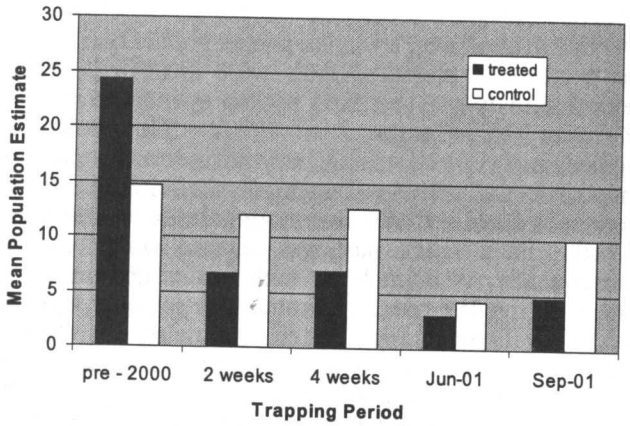

Figure 3. Mean population estimates of Townsend chipmunk in the Rogue River National Forest, 2 weeks prior to treatment with cholecalciferol and post 2 weeks, 4 weeks, and the following June and September.

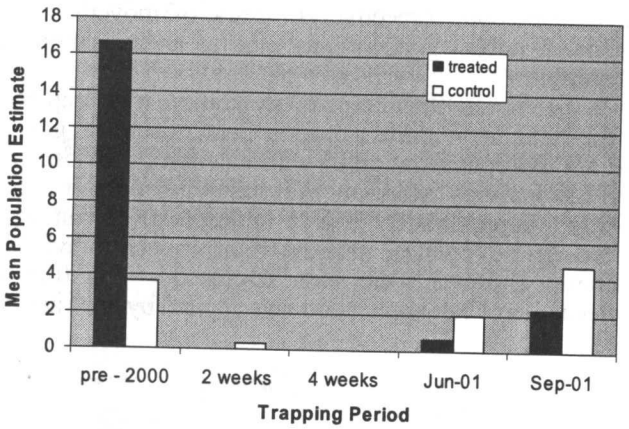

Figure 4. Mean population estimates of golden-mantled ground squirrel in the Rogue River National Forest, 2 weeks prior to treatment with cholecalciferol and post 2 weeks, 4 weeks, and the following June and September.

Of the 3 non-target species analyzed, golden-mantled ground squirrels were the smallest population represented. Populations declined to zero in the treated plots following baiting, but they slowly rebounded starting in June 2001 (Figure 4). Populations did not return to previously documented levels by September 2001. Populations of golden-mantled ground squirrels on

control plots also declined 2 and 4 weeks post treatment, but they were nearly back to the previously documented level by June 2001 and surpassed those levels by September 2001. Populations of golden-mantled ground squirrels were low throughout all plots and time periods. Again, there was no treatment effect observed ($F_{1,4} = 0.6$, $P = 0.48$); only time had a significant effect on the population ($P = 0.026$).

DISCUSSION

Cholecalciferol appears to have some application for pocket gopher control, based on the reduction in population seen 2-4 weeks post baiting. We documented a 70-80% reduction in activity in the treated plots and 10-20% reduction in activity on control plots, based on radio-collared pocket gophers. With open-hole monitoring (a secondary monitoring technique), we also documented a short-term decrease in treated populations; however, population changes did not mirror observations from radio-collared animals. Secondary monitoring systems that index populations in actuality are sampling an open population where animals immigrating into the study plots are also monitored, whereas the telemetry technique censuses a known population of animals (closed population) and more accurately reflects efficacy. The open-hole monitoring showed cholecalciferol to be efficacious as a short-term tool, although our study did not show that cholecalciferol was as efficacious as previously documented (Witmer *et al.* 1995). Campbell *et al.* (1992) also found there was not a significant population reduction of pocket gopher 6 months to 1 year after baiting with strychnine. El Hani *et al.* (2002) reported that 3 applications of strychnine were effective in lowering populations by 92%. We used 1 application of cholecalciferol; multiple applications may prove to be more efficacious.

The rapid recovery of the pocket gopher populations in the treated plots may be due to a lack of competition for resources. Pocket gopher populations are dynamic, resilient, and adaptable; they are affected greatly by changes in their environment. Pocket gophers tend to reinvade baited plots more readily than dispersing into new areas entirely (Capp 1976, Marsh and Steele 1992). Pocket gophers suffer from high winter mortality, and juveniles often suffer the greatest rate of loss (Marsh and Steele 1992). This could explain the decline in activity seen in the control plots from 4 weeks post treatment to the following June.

Although cholecalciferol baiting did not appear to cause long-term population changes, short-term population declines were noticed in the 3 main species. Of the non-targets monitored, we documented the largest decline in population numbers of golden-mantled ground squirrels on treated plots; however, control plots also showed a significant decline. Studies have shown that golden-mantled ground squirrel populations are negatively affected by strychnine baiting (Anthony *et al.* 1984, El Hani *et al.* 2002). Although populations may have been too small to accurately determine treatment effect, we may have seen a confounding effect of time and treatment on golden-mantled ground squirrel populations. Time, not treatment, appears to have the most significant effect on all 3 non-target populations, evidenced from declines in both treatment and control plots, 4 weeks post-baiting. By September 2001, all populations were recovering, although golden-mantled ground squirrel populations were still well below pre-treatment levels on treated plots. Small mammal populations typically show such trends– low populations following winter, with populations fully rebounded or surpassing original levels by fall. Studies have suggested that the low numbers observed in the non-target populations may be due to hibernation, reproduction, and gestation (Kenagy and Barnes 1988). Yellow pine and Townsend chipmunks emerge from hibernation in early to mid spring, and parturition occurs from early to mid summer. These chipmunks lactate through August and begin to hibernate for 4 to 5 months in November (Sutton 1992, 1993). Golden-mantled ground squirrels enter hibernation in August to November and emerge March to May, depending on elevation and snowfall. Parturition usually occurs in July (Bartels and Thompson 1993).

DeCalesta *et al.* (2003) suggest that the most effective time to bait pocket gophers is in the spring, when non-targets are not preparing for hibernation. Impending hibernation can increase feed consumption by non-targets and possibly reduce the availability of bait to pocket gophers. Spring baiting may therefore increase the effectiveness of cholecalciferol baiting for pocket gophers and reduce some of the risks to non-targets. Incorporating a flavor into the bait that is avoided by non-targets may also be a potential approach to increasing the effectiveness of cholecalciferol. A flavor avoidance learning study showed that ground squirrels and chipmunks will discriminate against denatonium benzoate, while pocket gophers will not (El Hani *et al.* 1998). Thus, such bittering agents may serve as effective means of repelling omnivorous non-targets.

This study demonstrated that cholecalciferol was effective in controlling pocket gopher populations for a short time period; however, short-term reductions in non-target species' populations were also observed. Time was the significant factor, not treatment, in these observed short-term reductions in non-target populations. Cholecalciferol can be a feasible alternative to strychnine baiting, and the addition of a bittering agent may reduce the possible confounding effects of time and treatment, by reducing or eliminating bait consumption by the non-target populations. However, until a bait is developed that controls pocket gopher populations for an extensive time period, a fully integrated pest management program may be the only way for foresters to alleviate damage.

ACKNOWLEDGEMENTS

We thank Bruce Kimball (NWRC, Fort Collins, CO) for his assistance with data manipulation and statistical analysis. Our thanks are extended to Julie Harper (NWRC, Olympia Field Station) for her support in compiling literature and analyzing data. We also thank the employees at the USFS Rogue River National Forest for their logistical support.

LITERATURE CITED

ANTHONY, R. M., G. D. LINDSEY, AND J. EVANS. 1984. Hazards to golden-mantled ground squirrels and associated secondary hazard potential from strychnine for forest pocket gophers. Proc. Vertebr. Pest Conf. 11:25-31.

BARNES, V. G., P. MARTIN, AND H. P. TIETJEN. 1970. Pocket gopher control on ponderosa pine plantations. J. Forestry 68:433-435.

BARTELS, M. A., AND D. P. THOMPSON. 1993. *Spermophilus lateralis*. Mammalian Species 440:1-8.

BENNETT, G. W., J. M. OWENS, AND R. M. CORRIGAN. 1988. Truman's Scientific Guide to Pest Control Operations, Fourth Ed. Edgell Communications, Duluth, MN. 495 pp.

BROWN, L. D., AND E. F. MARSHALL. 1988. Field evaluations of Quintox (cholecalciferol) for controlling commensal rodents. Proc. Vertebr. Pest Conf. 13:70-74.

CAMPBELL, D. L., J. P. FARLEY, P. L. HEGDAL, R. M. ENGEMAN, AND H. W. KRUPA. 1992. Field efficacy evaluation of diphacinone paraffin bait blocks and strychnine oat groats for control of forest pocket gophers (*Thomomys* spp.). Proc. Vertebr. Pest Conf. 15:299-302.

CAPP, J. C. 1976. Increasing pocket gopher problems in reforestation. Proc. Vertebr. Pest Conf. 7:221-228.

DECALESTA, D. S., K. ASMAN, AND N. ALLEN. 2003. Controlling pocket gopher damage to conifer seedlings. The Woodland Workbook, EC 1255, Oregon State University, Corvallis, OR. 8 pp.

EL HANI, A., J. R. MASON, D. L. NOLTE, AND R. H. SCHMIDT. 1998. Flavor avoidance learning and its implications in reducing strychnine baiting hazards to nontarget animals. Physol. Behav. 64(5):585-589.

EL HANI, A., D. L. NOLTE, J. R. MASON, AND S. BULKIN. 2002. Response of nontarget species to underground strychnine baiting for pocket gopher in southwest Oregon. W. J. Appl. Forestry 17:9-13.

ENGEMAN, R. M., D. L. CAMPBELL, AND J. EVANS. 1993. A comparison of 2 activity measures for northern pocket gopher. Wildl. Soc. Bull. 21:70-73.

KENAGY, G. J., AND B. M. BARNES. 1988. Seasonal reproductive patterns in four coexisting rodent species from the Cascade Mountains, Washington. J. Mammal. 69(2): 274-292.

MARSH, R. E., AND R.W. STEELE. 1992. Pocket gophers. Pp. 205-230 (Ch. 10) *in:* H. C. Black (Ed.), Silvicultural Approaches to Animal Damage Management in Pacific Northwest Forests. USDA Forest Service, Pacific Northwest Research Sta., Gen. Tech. Rep. PNW-GTR-287, Portland, OR.

MARSHALL, E. F. 1984. Cholecalciferol: a unique toxicant for rodent control. Proc. Vertebr. Pest Conf. 11:95-98.

PETERSON, M. E., AND P. A. TALCOTT. 2001. Cholecalcipherol. Pp. 452-461 *in*: Small Animal Toxicology. W. B. Saunders Co., Philadelphia, PA.

RICHENS, V. B. 1967. The status and use of gophacide. Proc. Vertebr. Pest Conf. 3:118-125.

SUTTON, D. A. 1992. *Tamias amoenus*. Mammalian Species 390:1-8.

SUTTON, D. A. 1993. *Tamias townsendii*. Mammalian Species 435:1-6.

WITMER, G. W., G. H. MATSCHKE, AND D. L. CAMPBELL. 1995. Field trials of pocket gopher control with cholecalciferol. Crop Protect. 14:307-309.