FINAL REPORT

for

Vertebrate Pest Control Research Advisory Committee

STUDY TITLE:

A field test of rodenticides for pocket gopher (*Thomomys* spp.) control.

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EXECUTIVE SUMMARY

Pocket gophers (*Thomomys* spp.) are one of the most damaging wildlife species to agriculture in the western U.S. The use of rodenticides is often included as part of an Integrated Pest Management (IPM) approach for managing pocket gophers given that they are relatively quick and inexpensive to apply when compared to other management approaches. Strychnine has historically been the most effective toxicant used for pocket gopher management, but pocket gophers can develop resistance to the product if repeatedly exposed. Furthermore, supplies of strychnine are currently limited in the U.S., thereby minimizing the availability of this management technique. Other toxicants that are currently registered in the U.S. (chlorophacinone, diphacinone, and zinc phosphide) have not proven effective for pocket gopher control, so an alternative to strychnine would be very useful. Recent research with baits coated with cholecalciferol + diphacinone proved effective for California vole (*Microtus californicus*) control, and preliminary laboratory research with cholecalciferol + anticoagulant toxicants proved similarly effective with pocket gophers. Therefore, we established a study to test these cholecalciferol + anticoagulant combinations for pocket gopher management in an agricultural field setting. Specific details for our sampling methodology and findings include:

1. We established three study sites in wine grape vineyards around Lodi, CA. Within each field, we created five treatment blocks with four treatments and a control randomly assigned to each block. The treatments included 0.03% cholecalciferol + 0.005% diphacinone (C+D), 0.015% cholecalciferol + 0.0025% brodifacoum (C+B1), 0.03% cholecalciferol + 0.0025% brodifacoum (C+B2), and 0.5% strychnine.
2. We assessed the impact of each rodenticide through the use of the open-hole method. Following this approach, we determined occupancy estimates of monitoring plots before and after treatment applications.
3. We conducted rodenticide application through the funnel-and-spoon method. These rodenticides were applied 1–3 times per burrow system depending on the extent of the burrow system. We repeated the rodenticide application a second time to increase the likelihood that all pocket gophers had access to the rodenticide at some point during the study. Rodenticides with a mean efficacy ≥70% after a second application were considered effective.
4. Although initial applications of strychnine were not significantly > 70%, the mean efficacy ($\bar{x}$ = 79%) did indicate a substantial reduction in pocket gopher population size after a single application. We observed 100% efficacy across all three strychnine treatment sites after the second application.
5. The cholecalciferol combination products were less effective after the initial application ($\bar{x} \leq$ 59%), but efficacy from C+D ($\bar{x}$ = 83%) and C+B2 ($\bar{x}$ = 75%) were significantly > 70% after a second application. Efficacy for C+B1 did not differ from 70%, but further testing of this combination may be warranted given the high mean efficacy of this product ($\bar{x}$ = 85%).

The use of strychnine for pocket gopher management appears to still be the best option of the rodenticides tested to date. However, cholecalciferol + anticoagulant products also appear to have real potential for pocket gopher IPM programs. These combination rodenticides could be considered further given the need for alternative toxicants to rotate with strychnine to reduce resistance concerns. These alternative toxicants would also provide pest control professionals and land managers with viable options for use when strychnine products cannot be found.

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INTRODUCTION

Pocket gophers (*Thomomys* spp.) are one of the most damaging wildlife species to agriculture and natural resource areas throughout the western U.S. (Crouch 1982, Sullivan et al. 1987, Marsh 1992), with losses in California agricultural areas estimated between 5.3–8.8% when pocket gophers are present (Baldwin et al. 2014). Pocket gophers are fossorial rodents that feed primarily on root systems of plants, on the cambium layer of trees and vines, and occasionally on aboveground herbaceous plant parts (Baker et al. 2003). Many techniques are used to manage pocket gophers including habitat modification, cultural practices, exclusion, trapping, burrow fumigation, and rodenticide baiting. Management of pocket gophers is generally most effective when utilizing an Integrated Pest Management (IPM) approach that incorporates multiple techniques (Engeman and Witmer 2000). Of these potential management tools, rodenticide application is generally the preferred option by pest control professionals and land managers given that it is the quickest and least expensive tool available for pocket gophers (Sullivan et al. 1987, Marsh 1992, Engeman and Witmer 2000, Baldwin et al. 2014).

Although quick and relatively inexpensive to use, the effectiveness of rodenticide applications has often been variable (Marsh 1992). Four primary toxicants are currently available for pocket gopher management in most of the western U.S.: the first-generation anticoagulants chlorophacinone and diphacinone, and the acute toxicants zinc phosphide and strychnine. Historically, strychnine has been the most effective of these toxicants for pocket gopher management, although resistance to strychnine has been a problem in some agricultural areas (Marsh 1992). Additionally, strychnine supplies are quite low in the U.S., leading to the loss of most strychnine pocket gopher products. A number of strychnine-alternative rodenticide products are available for use, but few of those have proven effective (e.g., Tickes et al. 1982, Campbell et al. 1992, Proulx 1998, Stewart et al. 2000, Witmer and Baldwin 2014). This has left pest control professionals and land managers searching for an alternative option when rodenticides are needed to manage extensive problem situations (i.e., large areas where management using other options is cost prohibitive).

Recent investigations have begun to explore the possibility of using a combination of cholecalciferol plus an anticoagulant to manage damaging vertebrate species (Eason and Ogilvie 2009, Witmer et al. 2014, Baldwin et al. 2016). When an anticoagulant is combined with cholecalciferol, the anticoagulant acts as a synergist to increase the potency of a lower concentration of cholecalciferol (Pospischil and Schnorbach 1994, Eason and Ogilvie 2009). This lower concentration can reduce the potential for poor bait acceptance, which is often present at higher concentrations of cholecalciferol, while increasing the effectiveness of the rodenticide when compared to cholecalciferol by itself (Pospischil and Schnorbach 1994). The combination rodenticides also result in shorter times-to-death than when used individually, and often use less of each toxicant; collectively, these reduce secondary toxicity risks (Eason and Ogilvie 2009, Baldwin et al. 2016).

Currently, registration is being sought for cholecalciferol + diphacinone (C+D) in New Zealand for brushtail possum (*Trichosurus vulpecula*), roof rat (*Rattus rattus*), and Norway rat (*Rattus norvegicus*) management, as it has proven quite effective. In the U.S., recent research has indicated that C+D is also effective for California vole (*Microtus californicus*) control in artichoke fields (Witmer et al. 2014, Baldwin et al. 2016). As such, we felt that C+D might be a viable alternative to strychnine for pocket gopher management in the U.S.

Brodifacoum is a second-generation anticoagulant that, along with strychnine, is often considered to be the most effective rodenticide still in use in the U.S. (Eason and Ogilvie 2009). However, brodifacoum is not registered as a field rodenticide in the U.S. given substantial concerns over secondary toxicity (Eason et al. 2010); it would not initially appear to be a good candidate as a pocket gopher rodenticide. That being said, efficacy of rodenticides has often been low for pocket gophers (e.g., Tickes et al. 1982, Campbell et al. 1992, Proulx 1998), potentially due to their avoidance of baits that deliver the active ingredient to the pocket gopher (i.e., pocket gophers typically eat green vegetation while most rodenticide baits are necessarily seeds or pelletized products, Marsh 1992). Strychnine has historically worked well for pocket gopher management, as it is highly toxic yet exhibits good bait acceptance (Marsh 1992). Pocket gophers are the only species in California and most western states where strychnine can still be used, in part because the rodenticide is applied within the burrow system, thereby substantially reducing direct nontarget exposure to the rodenticide. Secondary toxicity concerns are also lower for pocket gopher bait application than for most other rodent species given that pocket gophers spend relatively minimal time above ground (Gettinger 1984). Therefore, a highly toxic product may be more effective at managing a species that often consumes sublethal amounts of less-toxic rodenticides (Marsh 1992), while still posing a low secondary toxicity risk due to minimal exposure to predators and scavengers; brodifacoum could fit this situation. We can further reduce this risk by combining cholecalciferol with brodifacoum, which allows a decrease in the concentration of both active ingredients that is needed to maintain efficacy, while combining cholecalciferol with an anticoagulant could shorten time-to-death, further reducing any secondary nontarget exposure.

Given these potential benefits, we recently completed a laboratory study to test the efficacy of cholecalciferol + anticoagulant rodenticides. Three experimental pelletized options proved effective: 0.03% cholecalciferol + 0.005% diphacinone (C+D), Connovation Ltd., Manukau, New Zealand; and 0.015% cholecalciferol + 0.0025% brodifacoum (C+B1) and 0.03% cholecalciferol + 0.0025% brodifacoum (C+B2), Bell Laboratories, Inc., Madison, Wisconsin. A 0.015% cholecalciferol + 0.00125% brodifacoum version was ineffective (60% efficacy; Witmer and Baldwin 2014). Although these results were promising, we needed verification in the field to determine their potential utility as a pocket gopher management tool. Therefore, our Objectives for this study were to: 1) determine if cholecalciferol + anticoagulant rodenticides were effective at reducing pocket gopher activity in treated fields, and 2) determine how the efficacy of cholecalciferol + anticoagulant products compared to a currently registered strychnine product. As long as one or more of the cholecalciferol + anticoagulant rodenticides proved effective, they could serve as a viable addition or replacement to strychnine given the current paucity of strychnine in the U.S., combined with the need to alternate between active ingredients for long-term rodent management (Baldwin et al. 2016).

METHODS

Study sites were located in three vineyards around the city of Lodi in San Joaquin County, California (Fig. 1). Cover crops of mostly monocots were planted every other row; the alternate

Fig. 1. General location of three vineyard field sites in San Joaquin County, CA.

rows were disced to reduce pocket gopher habitat. Drip irrigation was centered underneath the vines to supply water. This forced most pocket gopher activity into these irrigation zones and allowed us to focus most of our treatment efforts in these areas, although rodenticide applications were made outside of these irrigation zones when active burrow systems were present in these areas.

At each study site, we established five treatment blocks. Each block was approximately 1.0 ha (2.5 ac) in size and square in shape. In the interior of each block, we established a 0.4-ha (1 ac) treatment plot. Within each treatment plot, we established a three by three grid structure of monitoring plots, with each monitoring plot 9.1 m (30 ft) by 9.1 m (30 ft) in size. These monitoring plots were separated by 18.2 m (60 ft), allowing us to fit all nine into a 0.4-ha (1 ac) area. The outer 0.6 ha (1.5 ac) served as a buffer zone to help limit movement of pocket gophers into the monitoring area.

Four treatments and a control (i.e., no rodenticide application) were randomly assigned to each treatment block at each study site. The rodenticides we tested included three experimental pelletized baits (C+D, C+B1, C+B2), and a grain bait that consisted of wheat, milo, and oats coated with strychnine (active ingredient concentration = 0.5%; Avalon Gopher Grain Bait, RCO International, Inc., Harrisburg, Oregon). We applied rodenticide baits using the funnel-and-spoon method. For this approach, we used a long screwdriver to probe into tunnel systems. Once a tunnel system was found, we removed the probe and inserted a funnel into the open hole. We then applied the appropriate amount of bait using a 14.8 cc (1 tablespoon; approximately 10–11 grams; C+D, C+B1, C+B2) or 4.9 cc (1 teaspoon; approximately 5 g; strychnine) measuring spoon. Once the rodenticide was applied, we used a small piece of toilet paper to plug the hole, and then covered the plug with soil to eliminate light from the tunnel system. Occasionally, the soil around the probe hole collapsed creating a large opening in the tunnel. When this happened, we applied bait to both sides of the tunnel system, and covered the openings with soil. Rodenticides were applied an estimated 1–3 times per burrow system depending on the size of the burrow system. This increased the likelihood that a pocket gopher would encounter the rodenticide at some point within its burrow system. Each application was marked with a wire flag so that we could count the number of applications post-treatment. We also weighed the amount of rodenticide applied per treatment block to determine the total weight of rodenticide applied per treatment area. This allowed us to determine the mean weight of rodenticide applied per application to ensure there was limited variation in the amount of rodenticide deposited per application. All rodenticide applications occurred between 19 June and 30 July, 2015.

We applied rodenticide baits throughout the treatment plot and for approximately 9.1 m (30 ft) on all sides of the treatment plot. Treatments throughout the entire buffer zone would have been preferred, but we did not have sufficient labor to achieve this application design given the high density of pocket gophers within the study sites. We anticipated that the area of the buffer zone we treated would be sufficient to eliminate immediate reinvasion of the treatment plot, but acknowledge that some reinvasion could have occurred. However, if such reinvasion did occur, it would bias our efficacy estimates low, so in effect, our efficacy estimates could be somewhat conservative.

To assess efficacy, we compared activity in monitoring plots before and after treatment applications using the open-hole method (Engeman et al. 1993, 1999). Following this approach, we opened holes into two tunnels within each monitoring plot when possible. We made note of plots where one or fewer tunnels were available. We then checked monitoring plots two days after holes were opened and recorded if holes were plugged or remained unplugged; because pocket gophers maintain closed burrow systems, they will plug any holes that open into tunnels if they are present. We initiated bait application following completion of the monitoring process. We repeated the monitoring process post-treatment, with holes in C+D, C+B1, and C+B2 plots opened 14–17 days after rodenticide application was completed, while strychnine plots were opened 9–19 days post-treatment. These timeframes were deemed sufficient to access mortality given recent lab trials that determined time-to-death for these rodenticides ($\bar{x}$ time-to-death [days] for C+D, C+B1, C+B2, and strychnine were as follows: 5.3, 6.4, 10.8, and 1.0, respectively; Witmer and Baldwin 2014). Following this second monitoring period, we again applied rodenticide to all treatment plots unless previous monitoring indicated 100% efficacy of that rodenticide. If we observed no remaining pocket gopher activity in a plot post-treatment (i.e., 100% efficacy), we did not apply the rodenticide a second time. We conducted a final monitoring period again using the open-hole method post-treatment. We calculated efficacy by dividing the number of plots that had no pocket gopher activity post-treatment by the number of plots that had pocket gopher activity pre-treatment. We considered a rodenticide effective for pocket gopher control if it achieved a minimum threshold of 70% reduction in activity after two treatments (Schneider 1982). We used one-sample *t*-tests to observe if our post-treatment efficacy values differed from 70% (Zar 1999). All aspects of this study were approved by the University of California, Davis' Institutional Animal Care and Use Committee (protocol no. 18637).

RESULTS

The number of applications per treatment block varied extensively ($\bar{x}$ range = 82–396, Table 1) across fields and between first and second applications due to differences in density of pocket gophers in each field and the variable efficacy of each rodenticide following the initial application (i.e., high efficacy meant fewer second-treatment applications). The mean weight of cholecalciferol + anticoagulant rodenticide used per application varied some across treatment sites and periods, due in part to inconsistent filling of the measuring spoon given the large size of the pellets. Nonetheless, the mean weight of rodenticide deposited per application was strongly consistent across the cholecalciferol + anticoagulant rodenticides ($\bar{x}$ range = 11.5–11.8 g; Table 1). The weight of strychnine deposited per application was strongly consistent across sites and applications ($\bar{x}$ range 4.9–5.1 g; Table 1), presumable due to the small size of grain fitting within the measuring spoon more precisely than with larger pellet sizes.

We did not observe any rodenticides exhibiting efficacy significantly >70% after a single application ($\bar{x}$ range = 46–79%, $t_2 \leq 0.9$, $P \geq 0.464$; Table 2). Following a second application, strychnine ($\bar{x}$ = 100%, $t_2 = \infty$, $P < 0.001$), C+D ($\bar{x}$ = 83%, $t_2 = 3.1$, $P = 0.089$), and C+B2 ($\bar{x}$ = 75%, $t_2 = \infty$, $P < 0.001$) were significantly above the EPA-mandated efficacy level of 70% (Table 2). Efficacy of C+B1 was also above this 70% threshold ($\bar{x}$ = 85%), although this difference was not significant given slightly lower efficacy for Field 1 combined with substantial variance in efficacy across fields ($t_2 = 1.6$, $P = 0.255$; Table 2). Control blocks generally showed

Table 1. The weight (Wt), number of applications (Apps), and mean weight of rodenticide applied per application (G/App) for four different rodenticides (0.03% cholecalciferol + 0.005% diphacinone [C+D], 0.015% cholecalciferol + 0.0025% brodifacoum [C+B1], 0.03% cholecalciferol + 0.0025% brodifacoum [C+B2], and 0.5% strychnine) tested for pocket gopher control across three fields in San Joaquin County, CA. Composite (Comp) data are provided for comparative purposes.

	C+D			C+B1			C+B2			Strychnine		
	Wt (g)	Apps	G/App	Wt (g)	Apps	G/App	Wt (g)	Apps	G/App	Wt (g)	Apps	G/App
Field 1	3271	273	12.0	2246	186	12.1	2552	199	12.8	632	131	4.8
Field 2	4395	396	11.1	4424	381	11.6	4046	353	11.5	1743	355	4.9
Field 3	2956	249	11.9	902	89	10.1	2410	214	11.3	415	82	5.1
Comp	10622	918	11.6	7572	656	11.5	9008	766	11.8	2790	568	4.9

Table 2. Percent efficacy of four different rodenticides (0.03% cholecalciferol + 0.005% diphacinone [C+D], 0.015% cholecalciferol + 0.0025% brodifacoum [C+B1], 0.03% cholecalciferol + 0.0025% brodifacoum [C+B2], and 0.5% strychnine [Strych]) plus a control (Cont) for pocket gopher management across two different treatment periods. Rodenticide applications occurred in summer 2015 across 3 fields in San Joaquin County, CA. Mean values are provided for comparative purposes.

	First treatment					Second treatment				
	C+D (%)	C+B1 (%)	C+B2 (%)	Strych (%)	Cont (%)	C+D (%)	C+B1 (%)	C+B2 (%)	Strych (%)	Cont (%)
Field 1	75	33	50	71	0	75	67	75	100	25
Field 2	56	44	25	67	0	89	89	75	100	0
Field 3	14	100	63	100	-20	86	100	75	100	-40
Mean	48	59	46	79	-7	83*	85	75*	100*	-5

* $P < 0.10$; mean efficacy differed from 70%.

a slight increase in activity, indicating that the observed reduction in pocket gopher activity was due to the applied treatments (Table 2).

DISCUSSION

Both strychnine and cholecalciferol + anticoagulant rodenticides proved effective at reducing pocket gopher populations in vineyards. Although our results with strychnine were similar to those observed in some past studies (e.g., Barnes et al. 1970, Evans et al. 1990, Campbell et al. 1992, Ramey et al. 2002), other investigations have not shown strychnine bait application to be an effective management option (e.g., Tickes et al. 1982, Proulx 1998). Reasons for this disparity are unclear but could be due to differences in the concentration of the active ingredient applied, the bait used to carry the active ingredient (e.g., wheat, milo, oats, and pellets), variability in bait acceptance across different species of pocket gophers, and the ability of the applicator to place the rodenticide into an active tunnel system (Baldwin 2014). Alternatively, continual reliance on strychnine for pocket gopher management can lead to behavioral or physiological resistance to the toxicant where individuals within the population learn to either avoid or consume sublethal amounts of the rodenticide (Lee et al. 1990, 1992, Marsh 1992). We observed this same response in a related captive study of potential rodenticides (Witmer and Baldwin 2014); this highlights the need to utilize an integrated approach when managing pocket gophers rather than relying on strychnine as the sole method for pest control.

It is worth noting that although efficacy from the initial strychnine application did not differ significantly from 70%, the actual mean efficacy was above the 70% threshold ($\bar{x}$ = 79%; Table 2). Pocket gophers are fossorial rodents that actively tunnel throughout the year. However, they do not create mounds on a daily basis. In some situations, it can be several days or more between mounding activities for some pocket gophers within a population (Miller 1948, Bandoli 1981). No removal activities (e.g., rodenticides, burrow fumigants, traps) are effective if they are not applied within an active tunnel system. As such, repeat applications are often needed to maximize exposure of all individuals in a population. The fact that we observed such high efficacy for pocket gophers after a single application of strychnine suggests that it can continue to be one of the more effective tools for pocket gopher management as long as it is just one part of an IPM program.

One way to mitigate the potential for behavioral or physiological resistance to strychnine is to rotate rodenticide applications with another toxicant. Additionally, effective alternative toxicants would be greatly beneficial given the current limited availability of strychnine products in the U.S. Although both C+D and C+B2 were effective alternatives, the C+D product has the advantage of utilizing a first-generation anticoagulant as the synergist to cholecalciferol. Diphacinone is much less toxic and has a substantially shorter half-life in tissues when compared to brodifacoum (Eason and Ogilvie 2009). Therefore, it should pose less risk of secondary toxicity than C+B2 to nontarget scavengers and predators. That being said, pocket gophers are strongly fossorial rodents that spend relatively little time above ground (Gettinger 1984). As such, secondary exposure should be fairly minimal regardless of the toxicant used. Additionally, C+B2 contains half the toxicant normally included in brodifacoum baits, so this should substantially lessen risks as well. We did test a lower concentration cholecalciferol (0.015%) + brodifacoum (0.00125%) rodenticide in a laboratory setting, but we did not find it to be as effective (efficacy = 60%, Witmer and Baldwin 2014). It is possible that a rodenticide bait that contained 0.03% cholecalciferol + 0.00125% brodifacoum might be more effective but has yet to be identified.

We should note that although the C+B1 combination rodenticide did not differ from 70%, it did have a greater mean efficacy value ($\bar{x}$ = 85%) than any of the other combination products tested (Table 2). Further testing may prove this combination to be an effective option as well, which would be beneficial given the lower concentration of cholecalciferol (0.015%) when compared to the other tested combination rodenticides (0.03%). Regardless, a growing body of literature exists highlighting the efficacy and potential benefits of cholecalciferol + anticoagulant toxicants (Eason and Ogilvie 2009, Witmer and Baldwin 2014, Witmer et al. 2014, Baldwin et al. 2016). These toxicants seem to exhibit great promise as an effective tool in the proverbial IPM tool box.

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LITERATURE CITED

Baker, R. J., R. D. Bradley, and L. R. McAliley, Jr. 2003. Pocket gophers. Pages 277–287 *in* G. A. Feldhamer, B. C. Thompson, and J. A. Chapman, editors. Wild mammals of North America: biology, management, and conservation. Second edition, revised. The Johns Hopkins University Press, Baltimore, MD.

Baldwin, R. A. 2014. Determining and demonstrating the importance of training and experience for managing pocket gophers. Wildlife Society Bulletin 38:628–633.

Baldwin, R. A., R. Meinerz, and G. W. Witmer. 2016. Cholecalciferol plus diphacinone baits for vole control: a novel approach to a historic problem. Journal of Pest Science. DOI: 10.1007/s10340-015-0653-3

Baldwin, R. A., T. P. Salmon, R. H. Schmidt, and R. M. Timm. 2014. Perceived damage and areas of needed research for wildlife pests of California agriculture. Integrative Zoology 9:265–279.

Bandoli, J. H. 1981. Factors influencing seasonal burrowing activity in the pocket gopher, *Thomomys bottae*. Journal of Mammalogy 62:293–303.

Barnes, V. G., Jr., P. Martin, and H. P. Tietjen. 1970. Pocket gopher control on Oregon ponderosa pine plantations. Journal of Forestry 68:433–435.

Campbell, D. L., J. P. Farley, P. L. Hegdal, R. M. Engeman, and H. W. Krupa. 2012. Field efficacy evaluation of diphacinone paraffin bait blocks and strychnine oat groats for control of forest pocket gophers (*Thomomys* spp.). Proceedings of the Vertebrate Pest Conference 15:299–302.

Crouch, G. L. 1982. Pocket gophers and reforestation on western forests. Journal of Forestry 80:662–664.

Eason, C. T., K. A. Fagerstone, J. D. Eisemann, S. Humphrys, J. R. O'Hare, and S. J. Lapidge. 2010. A review of existing and potential New World and Australasian vertebrate pesticides with a rationale for linking use patterns to registration requirements. International Journal of Pest Management 56:109–125.

Eason, C. T., and S. Ogilvie. 2009. A re-evaluation of potential rodenticides for aerial control of rodents. DOC Research & Development Series 312. Department of Conservation, Wellington, New Zealand.

Engeman, R. M., D. L. Campbell, and J. Evans. 1993. A comparison of 2 activity measures for northern pocket gophers. Wildlife Society Bulletin 21:70–73.

Engeman, R. M., D. L. Nolte, and S. P. Bulkin. 1999. Optimization of the open-hole method for assessing pocket gopher, *Thomomys* spp., activity. Canadian Field-Naturalist 113:241–244.

Engeman, R. M., and G. W. Witmer. 2000. Integrated management tactics for predicting and alleviating pocket gopher (*Thomomys* spp.) damage to conifer reforestation plantings. Integrated Pest Management Reviews 5:41–55.

Evans, J., G. H. Matschke, D. L. Campbell, P. L. Hegdal, and R. M. Engeman. 1990. Efficacy data for registration of strychnine grain baits to control pocket gophers (*Thomomys* spp.). Proceedings of the Vertebrate Pest Conference 14:82–86.

Gettinger, R. D. 1984. A field study of activity patterns of *Thomomys bottae*. Journal of Mammalogy, 65:76–84.

Lee, L. L., W. E. Howard, and R. E. Marsh. 1990. Acquired strychnine tolerance by pocket gophers. Proceedings of the Vertebrate Pest Conference 14:87–90.

Lee, L. L., W. E. Howard, and R. E. Marsh. 1992. Laboratory studies of more durable baits for controlling pocket gophers. Proceedings of the Vertebrate Pest Conference 15:303–307.

Marsh, R. E. 1992. Reflections on current (1992) pocket gopher control in California. Proceedings of the Vertebrate Pest Conference 15:289–295.

Miller, M. A. 1948. Seasonal trends in burrowing of pocket gophers (*Thomomys*). Journal of Mammalogy 29:38–44.

Pospischil, R., and H-J Schnorbach. 1994. Racumin Plus®, a new promising rodenticide against rats and mice. Proceedings of the Vertebrate Pest Conference 16:180–187.

Proulx, G. 1998. Evaluation of strychnine and zinc phosphide baits to control northern pocket gophers (*Thomomys talpoides*) in alfalfa fields in Alberta, Canada. Crop Protection 17:135–138.

Ramey, C. A., G. H. Matschke, P. L. Hegdal, G. R. McCann, and R. M. Engeman. 2002. Safe efficacy of three strychnine alkaloid bait concentrations for hand-baiting control of plains pocket gophers. International Biodeterioration and Biodegradation 49:139–143.

Schneider, B. 1982. Pesticide assessment guidelines: subdivision G, product performance. U.S. Environmental Protection Agency, Office of Pesticide and Toxic Substances, Springfield, VA.

Stewart, W. B., G. H. Matschke, G. R. McCann, J. B. Bourassa, and C. A. Ramey. 2000. Hand baiting efficacy of chlorophacinone and diphacinone grain baits to control Valley pocket gophers. Proceedings of the Vertebrate Pest Conference 19:393–397.

Sullivan, T. P., J. A. Krebs, and H. A. Kluge. 1987. Survey of mammal damage to tree fruit orchards in the Okanagan Valley of British Columbia. Northwest Science 61:23–31.

Tickes, B. R., L. K. Cheathem, and J. L. Stair. 1982. A comparison of selected rodenticides for the control of the common valley pocket gopher (*Thomomys bottae*). Proceedings of the Vertebrate Pest Conference 10:201–204.

Witmer, G., and R. A. Baldwin. 2014. Identifying possible alternative rodenticide baits to replace strychnine baits for pocket gophers in California. Draft Final Report QA-2146. USDA/APHIS/WS National Wildlife Research Center, Fort Collins, CO. 12 pp.

Witmer, G., R. Moulton, and R. A. Baldwin. 2014. An efficacy test of cholecalciferol plus diphacinone rodenticide baits for California voles (*Microtus californicus* Peale) to replace ineffective chlorophacinone baits. International Journal of Pest Management 60:275–278.

Zar, J. H. 1999. Biostatistical analysis. Fourth edition. Prentice-Hall, Upper Saddle River, NJ.