FINAL REPORT

for

Vertebrate Pest Control Research Advisory Committee

STUDY TITLE:

Identifying the level of use of aluminum phosphide for controlling burrowing pests in California.

PROJECT LEADER:

Roger A. Baldwin
University of California – Kearney Agricultural Research and Extension Center
9240 South Riverbend Ave, Parlier, CA 93648

June 2012

EXECUTIVE SUMMARY

Aluminum phosphide (ALP) is used extensively for burrowing mammal control for a variety of reasons including the fact that it is highly effective, kills quickly, is relatively cheap, kills ectoparasites associated with target species, poses no risk of secondary exposure to non-target animals, and has a strong safety record when applied appropriately. However, recent changes have been made to the ALP label which could substantially limit its utility for burrowing mammal control in the future. As such, I developed a survey for both agricultural and residential users to help quantify the impact that these changes are likely to have on ALP usage and vertebrate IPM in California. These survey findings were compared to information gathered from the California Department of Pesticide Regulation's Pesticide Use Report for 2010 to relate the survey findings to the broader spectrum of users throughout California. Through the surveys, I also explored the potential acceptability of several mitigation alternatives that could reduce the impact of new label changes while making ALP safer to use. Results from this study included:

1. In 2010, 49,005 lbs (46% of total used in California) of active ingredient (AI) of ALP was used for burrowing mammal control. Residential users applied 81% of this total, while agricultural users applied the remaining 19%. Most agricultural applications occurred in almond, wine grape, and alfalfa fields, while most residential applications were in residential yards.
2. I received completed surveys from 21 agricultural users and 26 residential users. These respondents indicated that they used an average of 31 and 137 lbs of AI for burrowing mammal control for agricultural and residential areas, respectively, during 2010. Collectively, their applications represented 7% and 9% of all ALP applications for agricultural and residential users, respectively, during that year.
3. The majority of all agricultural applications were made to control pocket gophers (*Thomomys* spp., 63%); ground squirrel (*Spermophilus* spp.) burrows were also frequently treated with ALP in agricultural areas (37%). The majority of residential applications were made to control pocket gophers (79%); mole (*Scapanus* spp., 14%) and ground squirrel (5%) burrows were occasionally treated with ALP as well.
4. New buffer restrictions are likely to have a substantial impact on the amount of ALP used to control pocket gophers in agricultural areas (51% reduction in AI applied), but will have less of an impact on applications for ground squirrels (2% reduction in AI applied). An additional 39% and 24% reduction in average application rates of AI are anticipated from new posting restrictions for pocket gophers and ground squirrels, respectively. Collectively, new buffer and posting restrictions resulted in expected losses of 70% and 26% of agricultural applications of ALP for pocket gophers and ground squirrels, respectively.
5. The loss of ability to apply ALP in many prohibited residential sites will dramatically decrease the level of ALP usage in all residential areas (pocket gophers = 68% reduction, moles = 91%, ground squirrels = 47%). New buffer and posting restrictions will have a similar proportional impact on ALP applications in residential areas where ALP can still be utilized (pocket gophers = 76% reduction, moles = 80%, ground squirrels = 44%). A combination of these new restrictions suggests a dramatic drop (pocket gopher = 92%, mole = 98%, ground squirrel = 70%) in the use

of ALP for burrowing mammal control in residential areas following the implementation of new restrictions.

6. Agricultural respondents indicated that trapping will be the primary control method used for pocket gophers ($\bar{x}$ = 51%) in areas where they can no longer use ALP, while baiting will be the primary replacement for ground squirrels ($\bar{x}$ = 65%). For residential respondents, baiting will serve as the primary tool used for pocket gopher ($\bar{x}$ = 59%), mole ($\bar{x}$ = 50%), and ground squirrel control ($\bar{x}$ = 71%) in areas where ALP can no longer be applied. Interestingly, a relatively large proportion of individuals in both agricultural and residential areas indicated that they would no longer control pocket gophers (agricultural $\bar{x}$ = 18%, residential $\bar{x}$ = 16%), moles (residential $\bar{x}$ = 34%), and ground squirrels (agricultural $\bar{x}$ = 22%, residential $\bar{x}$ = 13%) in these areas.
7. Agricultural respondents considered ALP to be the most efficacious management tool for both pocket gophers ($\bar{x}$ = 83%) and ground squirrels ($\bar{x}$ = 82%). Trapping ($\bar{x}$ = 59%) was considered the most effective alternative for pocket gopher control in agricultural areas where ALP can no longer be applied, while baiting was considered the most effective alternative for ground squirrels ($\bar{x}$ = 65%). In residential areas, ALP ($\bar{x}$ = 94%) was considered to be by far the most effective option for pocket gopher control. Both ALP and baiting were considered equally effective for mole (ALP: $\bar{x}$ = 56%, baiting: $\bar{x}$ = 55%) and ground squirrel control (ALP: $\bar{x}$ = 72%, baiting: $\bar{x}$ = 71%).
8. Residential respondents indicated that 52% of all ALP applications were made to eliminate potential injury hazards associated with open burrows and mounds, while 8% of ALP applications were made to kill disease vectors such as fleas on burrowing mammals. This indicates that new restrictions on ALP could have an impact on human health and safety.
9. Overall, potential options to mitigate the new restrictions on ALP use for burrowing mammals were positively received. For agricultural users, 100% of respondents indicated that they would be willing to receive training for a special certification category if restrictions were reduced to allow the user to apply ALP for burrowing mammal control in areas up to 25 feet from any occupied structure and if posting restrictions were removed. Acceptance of mitigation alternatives in residential areas ranged from 22–87%. Greatest acceptance (87%) was for the implementation of a special certification category for aluminum phosphide. A second alternative that would increase the buffer to 25 feet *for pocket gophers only* while eliminating the residential application exclusion received almost the same level of support (85%). The presence of a 100-foot buffer was clearly deemed too restrictive (22% acceptance) to allow much of an increase in ALP usage in residential areas where ALP cannot currently be applied.

Collectively, these findings highlight the importance of ALP for burrowing mammal control in California, although this importance is likely to diminish dramatically over the next few years if new regulations remain in effect. This impact will be felt most strongly by individuals attempting to manage pocket gophers, especially licensed pest control operators that specialize in vertebrate control, but will also impact ground squirrel and mole control programs as well. Insufficient or ineffective management programs targeted at these pests could result in increased

economic damage and greater human health and safety concerns. We may also see an increase in environmental concerns due to increased water usage and soil erosion associated with a greater abundance of burrow systems, as well as greater non-target toxicity concerns due to a larger number of rodenticide bait applications to replace ALP burrow fumigation. Given the fact that there have been no fatalities from many millions of ALP applications for burrowing mammal control in California during this century, I would argue that ALP has a proven, safety track record. Even so, ALP users in California are willing to obtain greater training on its safe use while adhering to a 67% increase in the previous 15-foot buffer restriction if it meant the elimination of the 100-foot buffer and posting restrictions. Because of the extreme importance of burrowing pest control, combined with the high efficacy and safe track record of ALP, perhaps these or alternative mitigation steps should be considered to ensure the safe and effective use of this burrow fumigant. Otherwise, it is quite possible that the estimated 85% reduction in future ALP applications for burrowing mammal control in California could result in far greater negative consequences than that which is gained from the new regulations.

TABLE OF CONTENTS

INTRODUCTION

Burrowing mammals such as pocket gophers (*Thomomys* spp.), ground squirrels (*Spermophilus* spp.), and moles (*Scapanus* spp.) cause many economic, environmental, and human health and safety concerns throughout California. For example, the California ground squirrel (*Spermophilus beecheyi*) will directly consume crops, girdle young trees and vines, and is a reservoir for bubonic plague. Their burrow systems can also lead to a loss of irrigation water, increase soil erosion, and serve as a hazard to humans and vehicles (Marsh 1994, O'Connell 1994, Borchert et al. 2009). Damage caused by pocket gophers is similar (Marsh 1998b, Proulx 2002, Salmon and Baldwin 2009). A variety of techniques are often used to control these pests including habitat modification, exclusion, trapping, baiting, burrow fumigation, and others. Each technique has its strengths and weaknesses, and as such, each provides a valuable tool for developing an Integrated Pest Management (IPM) program for managing each pest. Currently, it is recommended that individuals involved in burrowing pest control utilize an IPM program so as to maximize efficacy while minimizing the impact to the environment (Engeman and Witmer 2000, Sterner 2008).

One important tool in the IPM toolbox for many burrowing mammal species is burrow fumigation with aluminum phosphide (ALP). Aluminum phosphide was initially developed as an insect fumigant, but more recent studies have shown it to be a highly efficacious burrow fumigant (Salmon et al. 1982, Baker 2004, Baldwin and Holtz 2010, Baldwin and Quinn 2012). In addition to high efficacy, ALP has many positive attributes including: 1.) short time from application to death, 2.) it breaks down to safe, low-toxicity aluminum hydroxide, 3.) it kills disease-spreading ectoparasites associated with the target species, 4.) it can be widely used in all cropping systems, 5.) exposure only occurs in burrow systems, 6.) there is no secondary hazard associated with burrow applications, and 7.) phosphine is not appreciably absorbed dermally nor does it cause chronic health problems in humans (Baker and Krieger 2002).

Aluminum phosphide comes both in pellet and tablet form, although the tablet form is primarily what is used for burrow fumigation. The tablets are placed into the burrow system of the target animal and react with the moisture in the soil to evolve phosphine gas. This phosphine gas is toxic to all animals. Because of its high toxicity, ALP is a Federally Restricted-Use material, so only certified individuals are allowed to use this material (Baker 1992). This restricted status has led to a safe track record in California, with millions of applications having been made for burrowing mammal control with no known human fatalities resulting from these applications. This material also has a relatively safe track record nation wide, although a recent misapplication in a residential yard in Utah resulted in the death of two young girls (U.S. Department of Justice 2011). This misapplication led to a prompt review by the U.S. EPA, who subsequently decided to enact substantially stricter regulations on ALP applications. These new regulations have substantial ramifications for burrowing mammal control and include the following changes:

1.) Use of ALP is strictly prohibited around all residential areas, including single and multi-family residential properties, nursing homes, schools (except athletic fields, where use may continue), day care facilities, and hospitals.

2.) ALP must only be used outdoors for the control of burrowing pests, and are for the use on agricultural areas, orchards, non-crop areas (such as pasture and rangeland), golf courses, athletic fields, parks, and other non-residential institutional or industrial sites.
3.) ALP must not be applied in a burrow system that is within 100 feet of a building that is or may be occupied by people or domestic animals. This buffer zone for treatment around non-residential buildings that could be occupied by people or animals has been increased from 15 to 100 feet.
4.) When ALP is used in athletic fields or parks, the applicator must post a sign at entrances to the treatment site containing the signal word DANGER/PELIGRO, skull and crossbones, the words: DO NOT ENTER/NO ENTRE, FIELD NOT FOR USE, the name and EPA registration number of the fumigant, and a 24-hour emergency response number. Signs may be removed 2 days after the final treatment.
5.) When ALP is used out of doors in a site frequented by people, other than an athletic field or park, the applicator shall post a sign at the application site containing the signal word DANGER/PELIGRO, skull and crossbones, the name and EPA registration number of the fumigant, and a 24-hour emergency response number. Signs may be removed 2 days after the final treatment.

Given the anticipated impact that these new restrictions are likely to have on ALP usage for burrowing mammal control, I created a survey to help quantify this impact. The impacts are likely to be substantially different for both agricultural and residential users of ALP, so I developed separate surveys for these two groups. Included in these surveys were questions pertaining to potential mitigation alternatives to allow me to begin to develop ideas on options to reduce this impact if these label changes were deemed too restrictive by respondents for continued usage of ALP for burrowing mammal control. This information was combined with data collected from the California Department of Pesticide Regulation's (CDPR) Pesticide Use Reports (PUR) to relate the survey data to the broader spectrum of ALP users in California.

METHODS

Pesticide Use Reports

The CDPR's PUR's were filtered to separate out applications of ALP for 2010, which was the corresponding year that survey data would be based upon. These reports included applications for both burrowing mammal and invertebrate species. To separate out the burrowing mammal applications, I first removed all applications that provided cubic feet measurements for the area of application or that did not include acreages with the report, as these were indicative of invertebrate fumigation applications. I also excluded all remaining applications where site names were listed as beehives or unknown as we could not be certain if these applications were made for burrowing mammal or invertebrate pest control. I then tabulated the amount of active ingredient (AI) used for burrowing mammal and invertebrate pest control for use in additional analyses.

I was also interested in determining if these applications were made in residential/urban areas (hereafter residential) or agricultural production (hereafter agricultural) areas. For this, I considered all application site names that were listed as landscape maintenance, rights-of-way,

Table 1. Total pounds of active ingredient (AI) of aluminum phosphide used for each commodity for burrowing mammal control within 1 of 5 categories of usage for agricultural applications during 2010.

Agricultural use (total active ingredient = 9,294 pounds)									
Nuts	AI	Fruits	AI	Forage	AI	Field crops	AI	Other	AI
Almond	4,493	Wine grape	1,919	Alfalfa	619	Artichoke	251	Uncultivated ag	196
Pistachio	405	Prune	180	Pastureland	129	Oat	13	Nursery	59
Walnut	334	Cherry	155	Rangeland	96	Wheat	8	Christmas tree	19
Sub-total:	5,232	Avocado	58	Forage hay	66	Watercress	3	Preplant	4
		Apricot	56	Corn[a]	7	Asparagus	3	Forest timber	<1
		Apple	54	Oat[a]	2	Pumpkin	<1	Sub-total:	279
		Peach	28	Wheat[a]	<1	Sweet Potato	<1		
		Grape	28	Sub-total:	920	Corn[b]	<1		
		Plum	27			Dried bean	<1		
		Orange	21			Brussels sprout	<1		
		Lemon	16			Mustard	<1		
		Olive	13			Radish	<1		
		Tangerine	10			Sub-total:	280		
		Citrus	8						
		Persimmon	6						
		Nectarine	3						
		Strawberry	<1						
		Kiwi	<1						
		Raspberry	<1						
		Pome fruit	<1						
		Stone fruit	<1						
		Blackberry	<1						
		Blueberry	<1						
		Sub-total:	2,585						

[a] The inclusion of corn, oat, and wheat in the "Forage" category indicates that these applications of aluminum phosphide were made in crops grown as forage or fodder.

[b] Corn in the "Field crop" category was grown for human consumption.

turf/sod, uncultivated non agriculture, and vertebrate control as residential use. All other site names were included in the agricultural use category (Table 1). I further defined agricultural use site names into 1 of 5 distinct subcategories including nut, fruit, forage, and field crops, as well as an "other" category that encompassed all remaining site names (Table 1).

Survey composition

The PUR reports provided general insight into the level of use of ALP for burrowing mammal control, but did not provide the specific information needed to more thoroughly address its importance for burrowing pest control in California. For this, I developed two separate surveys, one each for agricultural (Appendix I) and residential (Appendix II) users of ALP. These surveys were advertised and distributed from February through December, 2011, through a number of outlets including University of California Cooperative Extension newsletters (n = 7), professional publications (n = 2), ALP distributors, and numerous extension presentations. The surveys were made available in both paper and electronic formats.

Specific issues covered in the surveys included questions on the level of usage of ALP for burrowing mammal control, species targeted by applications, the potential impact of new regulations on usage of ALP, anticipated level of usage of alternative control options in lieu of ALP, efficacy of various control options, and potential mitigation alternatives. For residential users, I also included questions pertaining to the economic impact of the new restrictions and the level of usage of ALP for reducing human health and safety issues as they pertain to target species. A breakdown of these questions is provided below. Unfortunately, due to a low response rate on economic questions, I will not be including any results or discussion on this issue although I have included the complete survey in Appendix II in case they are of further interest.

Amount of ALP used for burrowing mammal control.—Survey respondents were asked to identify whether or not they used pellets or tablets, the flask size, and the number of flasks they used the year prior to these surveys. To relate these values to the data available in the PUR, I converted these to pounds of AI. The amount of AI present in the different ALP products ranged from 55–60%. Therefore, for calculations of AI used by survey respondents, I calculated the average percentage used in the 2010 PUR which was 57%. I then compared the total amount of AI used by survey respondents to the total amount used in the 2010 PUR to quantify the proportion of ALP applications represented by this survey.

I was also interested in how this varied by species of burrowing mammals. Therefore, for agricultural users, I multiplied the proportion of applications made for pocket gophers, moles, voles, ground squirrels, and rats by the amount of AI used to reflect this per species level of use. For residential users, I recorded the hours of labor exerted per month for species specific use of ALP. This was deemed the most practical method to capture this effort given that almost all residential users were pest control companies or government agencies.

Impact of new regulations on amount of ALP used for burrowing mammal control.—I asked agricultural survey participants for the proportion of applications by species that were made between 15 and 100 feet from any occupied structure to assess the impact of new buffer

restrictions. I separately asked these same survey participants what proportional reduction they anticipated in applications due to new posting restrictions to assess this impact. These values were subtracted from the total amount used for burrowing mammal control to estimate the total percent reduction anticipated from new restrictions.

For residential users, I asked what proportion of applications were made for each burrowing mammal species in the following land-use categories: 1.) residential yards, 2.) school landscaping/nursing homes/day cares/hospitals, 3.) athletic fields/parks/golf courses/cemeteries, and 4.) institutional and commercial sites/right-of-ways. Applications are no longer allowable in categories 1 and 2, so they were removed from 2010 applications to assess this impact on ALP use in residential areas. I further asked survey participants what percent reduction in ALP applications the new buffer and posting restrictions would collectively have on applications to land-use categories 3 and 4. These restrictions were combined for residential users as preliminary feedback indicated that separating out the two impacts would be very difficult. Finally, all reductions in ALP applications were combined to determine the composite impact of new ALP restrictions on usage levels in residential areas.

Alternative control options.—I asked all survey participants what proportion of future control actions will be made using gas or smoke cartridges, toxic bait, trapping, some other control method in areas where they will no longer be able to apply ALP. Respondents also had the option of indicating a proportion of 2010 control actions where they will no longer treat burrowing mammals due to new restrictions. I tested for differences within each species using the Kruskal–Wallis test (Zar 1999). If significant, I used Fisher's least significant difference (LSD) post hoc test to determine which control methods differed (Zar 1999).

Efficacy of control methods.—I asked all survey respondents what percent reduction in population size they typically observe following applications of ALP, gas or smoke cartridges, toxic bait, trapping, or some other control method. These values were averaged to assess the perceived efficacy of these control methods. I tested for differences within each species using the Kruskal–Wallis test (Zar 1999). If significant, I used Fisher's LSD post hoc test to determine which control methods differed (Zar 1999).

Human health and safety.—For residential users, I asked what percentage of ALP applications were made to kill disease vectors such as fleas on burrowing mammals. I also inquired into the percentage of ALP applications that were made to reduce risk of human injuries caused by burrowing mammal holes and mounds in public and private areas.

Mitigation alternatives.—Agricultural survey participants were asked if they would be in favor of a special certification category for use of ALP for burrowing mammal control if: 1.) the buffer was reduced from 100 feet to 25 feet from any occupied structure, and 2.) the 48-hour posting restriction was eliminated.

Residential users were provided a greater number of mitigation alternatives given the more complicated circumstances associated with ALP applications in these areas. These included the following options: 1.) To increase public safety, do you support takings moles, voles, rats, and mice off the ALP label for burrowing pests, except for agricultural use or public health

emergencies?, 2.) Would you support use of ALP in residential and other areas if restricted to only pocket gophers with a 50-foot buffer from occupied buildings?, 3.) Would you support use of ALP in residential and other areas if restricted to only pocket gophers with a 100-foot buffer from occupied buildings?, 4.) Would you support a separate certification category for individuals applying ALP for burrowing mammals in residential areas or other areas frequented by people?, and 5.) Would you support a special certification category for use of ALP for use in residential and other public areas for only pocket gophers if the buffer was reduced from 100 feet to 25 feet from any occupied structure? I used the exact binomial test to see if the proportion of any of these responses differed significantly from 0.5 (McDonald 2009).

RESULTS

Usage of ALP in 2010 totaled 106,380 lbs of AI. Of this, 49,005 lbs (46%) were used for burrowing mammal control. Of these 49,005 lbs, 81% (39,711 lbs) was applied in residential areas, while 19% (9,294 lbs) was used for agricultural purposes. In agricultural areas, burrow fumigation was most common in nut (56% of total) and fruit (28% of total) commodities, and was least common in field crops (3% of total, Table 1). Each category had one commodity that accounted for the vast majority of applications, with almonds (86%), wine grapes (74%), alfalfa (67%), and artichokes (90%) most common in each of their respective categories (Table 1). Most applications for pocket gophers (63%) and moles (83%) in residential areas were in residential yards, while applications for ground squirrels were spread fairly consistently across yards, schools, parks, and commercial sites (Fig. 1).

I received completed surveys from 21 agricultural users and 26 residential users. These respondents indicated that they used an average of 31 (SE = 12 [649 total lbs]) and 137 (SE = 47 [3,421 total lbs]) lbs of AI for burrowing mammal control for agricultural and residential areas, respectively, during 2010. Collectively, their applications represented 7% and 9% of all ALP applications for agricultural and residential users, respectively, during that year.

The majority of all agricultural applications were made to control pocket gophers ($\bar{x}$ AI per user = 19 lbs [SE = 9]; 63%); ground squirrel burrows were also frequently treated with ALP in agricultural use areas ($\bar{x}$ AI per user = 11 lbs [SE = 7]; 37%). The vast majority of all residential applications were made to control pocket gophers ($\bar{x}$ AI per user = 108 lbs [SE = 35]; 79%); mole ($\bar{x}$ AI per user = 20 lbs [SE = 16]; 14%) and ground squirrel ($\bar{x}$ AI per user = 6 lbs [SE = 2]; 5%) burrows were occasionally treated with ALP as well. Voles and rats received ≤ 2% of ALP applications, and as such, were not analyzed further.

New buffer restrictions are likely to have a substantial impact on the amount of ALP used to control pocket gophers in agricultural areas ($\bar{x}$ reduction of 10 lbs [SE = 8] of AI applied per applicator [51% reduction]), but will have less impact on applications for ground squirrels ($\bar{x}$ reduction of 0.3 lbs [SE = 0.1] of AI applied per applicator [2% reduction]). Additional reductions in average application amounts of AI are anticipated from new posting restrictions (pocket gophers = 4 lbs [SE = 2] per applicator [39% reduction]; ground squirrels = 3 lbs [SE = 1] per applicator [24% reduction]). Collectively, new buffer and posting restrictions resulted in expected losses of 70% and 26% of agricultural applications of ALP for pocket gophers and ground squirrels, respectively (Fig. 2).

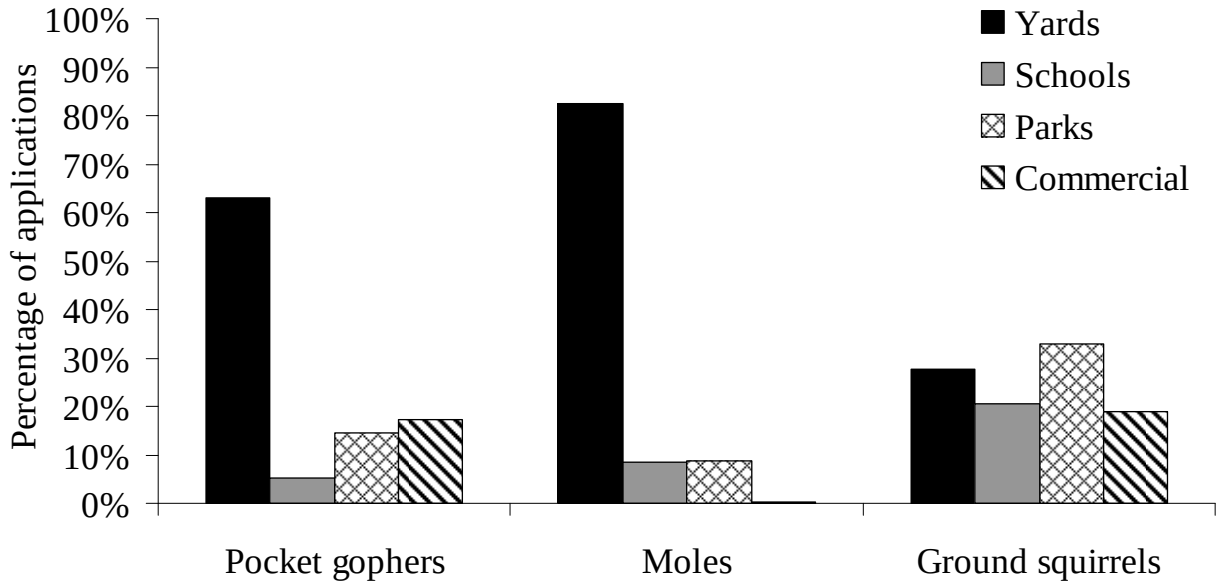

Figure 1. Average percentage of applications of aluminum phosphide applied for pocket gophers, moles, and ground squirrels in four residential categories during 2010: 1.) Yards = residential yards; 2.) Schools = school landscaping, nursing homes, day cares, and hospitals; 3.) Parks = parks, athletic fields, golf courses, and cemeteries; and 4.) Commercial = institutional/commercial sites and right of ways.

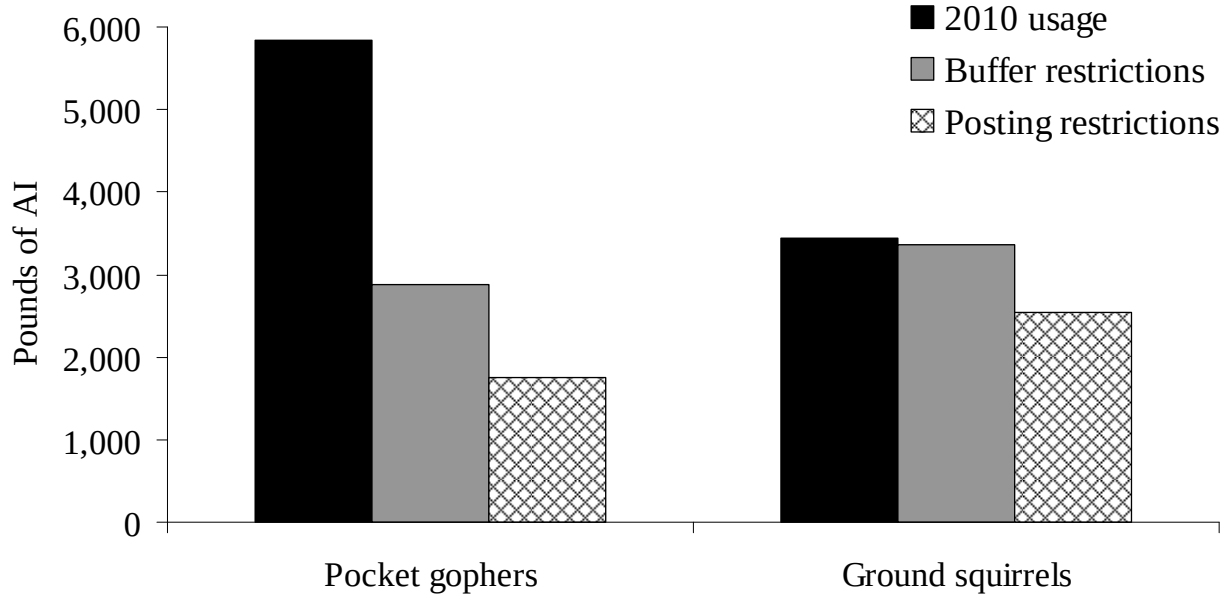

Figure 2. Pounds of active ingredient (AI) of aluminum phosphide (ALP) used in 2010 before new restrictions were enacted, the anticipated reduced amount to be used in the future due to buffer restrictions, and the anticipated reduced amount to be used in the future due to posting restrictions for both pocket gophers and ground squirrels in agricultural areas.

The loss of ability to apply ALP in many residential sites will dramatically decrease the average level of ALP usage in these areas ($\bar{x}$ reduction: pocket gophers = 83 lbs [SE = 31] per applicator [68% reduction]; moles = 20 lbs [SE = 17] per applicator [91% reduction]; ground squirrels = 3.1 lbs [SE = 1.7] per applicator [47% reduction]). New buffer and posting restrictions will have a similar proportional impact on ALP applications in residential areas where ALP can still be utilized ($\bar{x}$ reduction: pocket gophers = 30 lbs [SE = 11] per applicator [76% reduction]; moles = 1.6 lbs [SE = 1.4] per applicator [80% reduction]; ground squirrels = 1.5 lbs [SE = 0.7] per applicator [44% reduction]). A combination of these new restrictions suggests a dramatic drop (pocket gopher = 92%, mole = 98%, ground squirrel = 70%) in the use of ALP for burrowing mammal control in residential areas following the implementation of new restrictions (Fig. 3).

I observed a significant difference in control options that agricultural respondents will use in place of ALP in areas where they can no longer treat with this material (pocket gopher: $H_3 = 15.3$, $P = 0.002$; ground squirrel: $H_3 = 19.6$, $P < 0.001$). These respondents indicated that trapping would be the primary tool used for pocket gophers ($\bar{x} = 51\%$, SE = 11), while baiting would be the primary control method for ground squirrels ($\bar{x} = 65\%$, SE = 11; Fig. 4). I also observed a significant difference for residential applicators (pocket gopher: $H_3 = 27.7$, $P < 0.001$; mole: $H_3 = 10.2$, $P = 0.017$; ground squirrel: $H_3 = 29.0$, $P < 0.001$) with baiting serving as the primary tool for pocket gopher ($\bar{x} = 59\%$, SE = 8), mole ($\bar{x} = 50\%$, SE = 14), and ground squirrel control ($\bar{x} = 71\%$, SE = 9; Fig. 5). Interestingly, a relatively large proportion of individuals in both agricultural and residential areas indicated that they would no longer control pocket gophers (agricultural $\bar{x} = 18\%$, SE = 9; residential $\bar{x} = 16\%$, SE = 6), moles (residential $\bar{x} = 34\%$, SE = 13), and ground squirrels (agricultural $\bar{x} = 22\%$, SE = 10; residential $\bar{x} = 13\%$, SE = 7) in these areas (Figs. 4 and 5).

Agricultural survey respondents did not consider all control methods equally efficacious (pocket gopher: $H_3 = 18.0$, $P < 0.001$; ground squirrel: $H_3 = 14.8$, $P = 0.002$). Aluminum phosphide was considered to be the most effective management tool for both pocket gophers ($\bar{x} = 83\%$, SE = 4) and ground squirrels ($\bar{x} = 82\%$, SE = 3; Fig. 6). Trapping ($\bar{x} = 59\%$, SE = 8) was considered the most effective alternative for pocket gopher control in areas where ALP can no longer be applied, while baiting was considered the most effective alternative for ground squirrels ($\bar{x} = 65\%$, SE = 7; Fig. 6). Efficacy was not considered equivalent across control methods in residential areas either (pocket gopher: $H_3 = 38.3$, $P < 0.001$; mole: $H_3 = 12.6$, $P = 0.006$; ground squirrel: $H_3 = 12.9$, $P = 0.005$). In residential areas, ALP ($\bar{x} = 94\%$, SE = 2) was considered to be by far the most effective option for pocket gopher control (Fig. 7). Both ALP and baiting were considered equally effective for mole (ALP: $\bar{x} = 56\%$, SE = 7; baiting: $\bar{x} = 55\%$, SE = 11) and ground squirrel control (ALP: $\bar{x} = 72\%$, SE = 6; baiting: $\bar{x} = 71\%$, SE = 7; Fig. 7).

New restrictions on ALP could also have an impact on human health and safety. Residential respondents indicated that 52% (SE = 8) of all ALP applications were made to eliminate potential injury hazards associated with open burrows and mounds, while 8% (SE = 5) of ALP applications were made to kill disease vectors such as fleas on burrowing mammals.

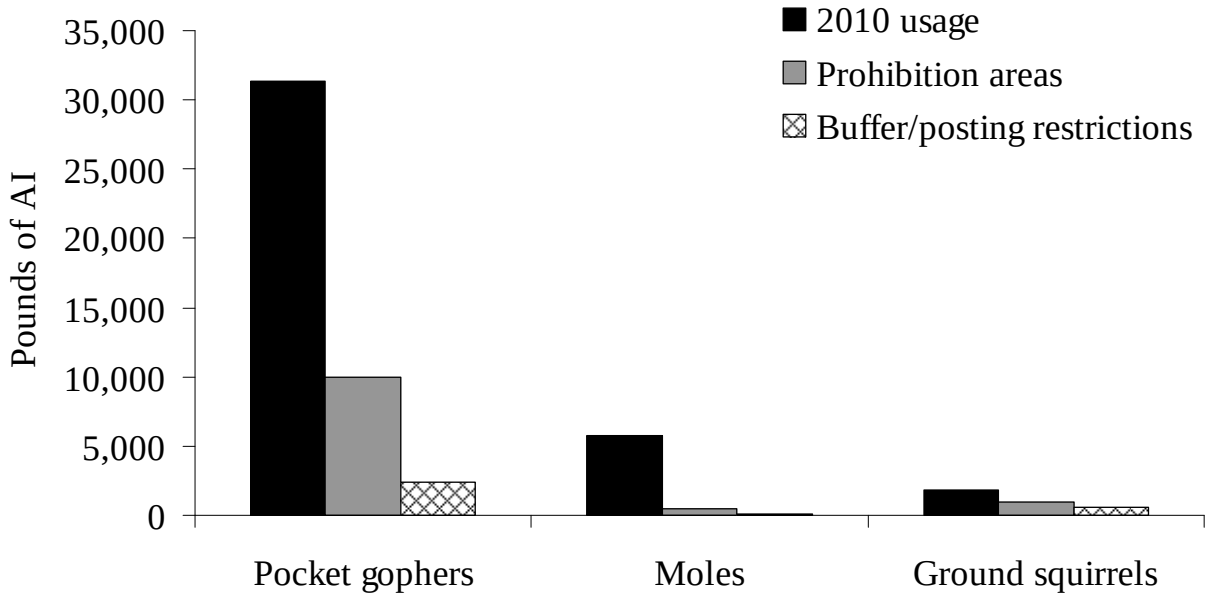

Figure 3. Pounds of active ingredient (AI) of aluminum phosphide (ALP) used in 2010 before new restrictions were enacted, the anticipated reduced amount to be used in the future due to the prohibition of applications in many residential areas (see text for description), and the anticipated reduced amount to be used in the future due to increased buffer and posting restrictions for pocket gophers, moles, and ground squirrels in residential areas.

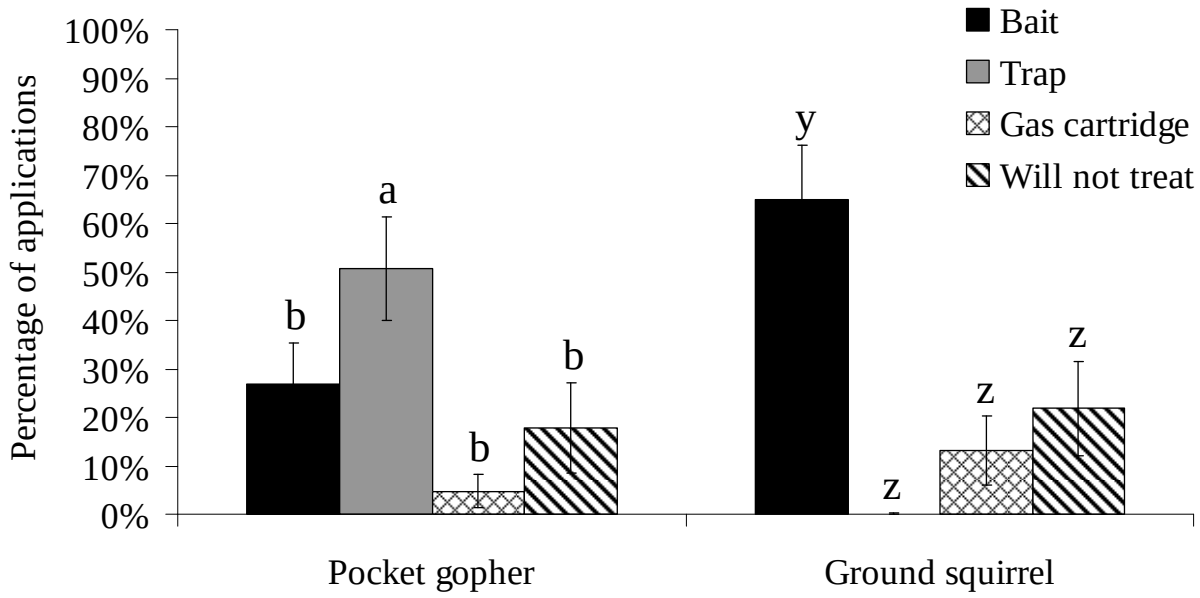

Figure 4. Average percentage of applications and associated standard errors for alternative pocket gopher and ground squirrel control techniques that agricultural survey respondents anticipate using in areas where aluminum phosphide can no longer be used. Significant differences for each species are denoted by different letters.

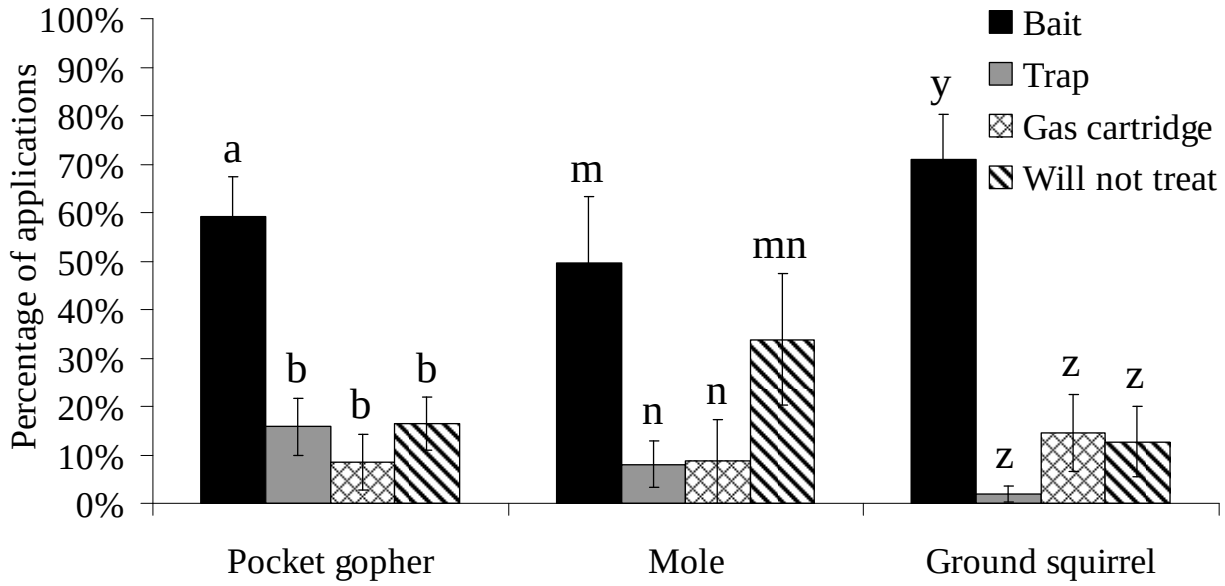

Figure 5. Average percentage of applications and associated standard errors for alternative pocket gopher, mole, and ground squirrel control techniques that residential survey respondents anticipate using in areas where aluminum phosphide can no longer be used. Significant differences for each species are denoted by different letters.

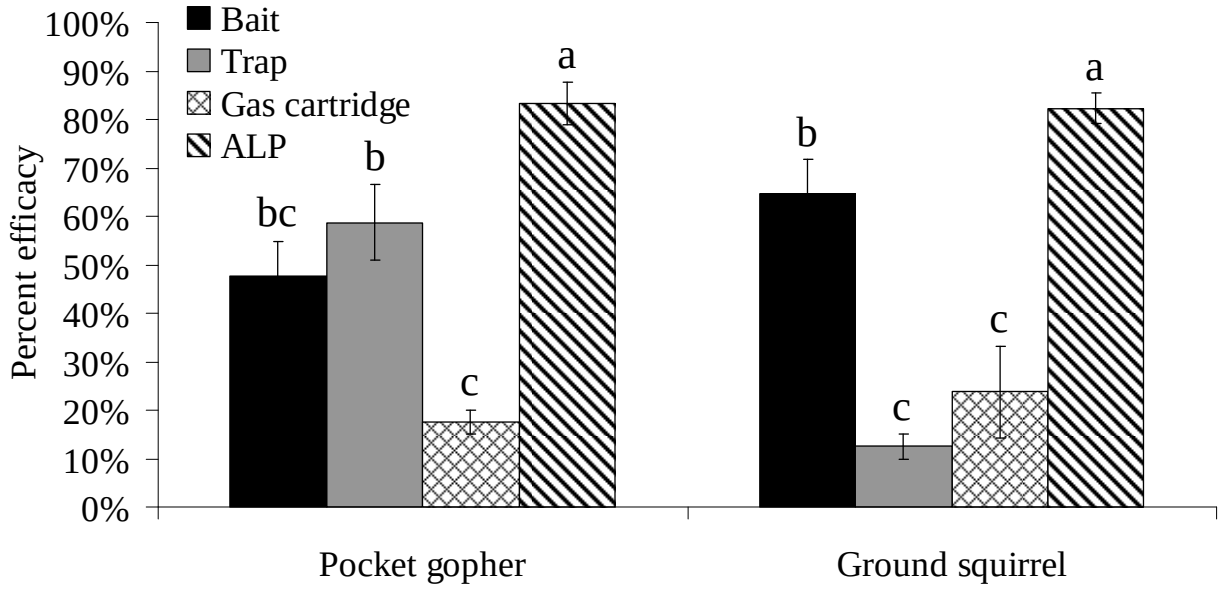

Figure 6. Average percent efficacy and associated standard errors for pocket gopher and ground squirrel control methods as estimated by agricultural survey respondents. Significant differences for each species are denoted by different letters.

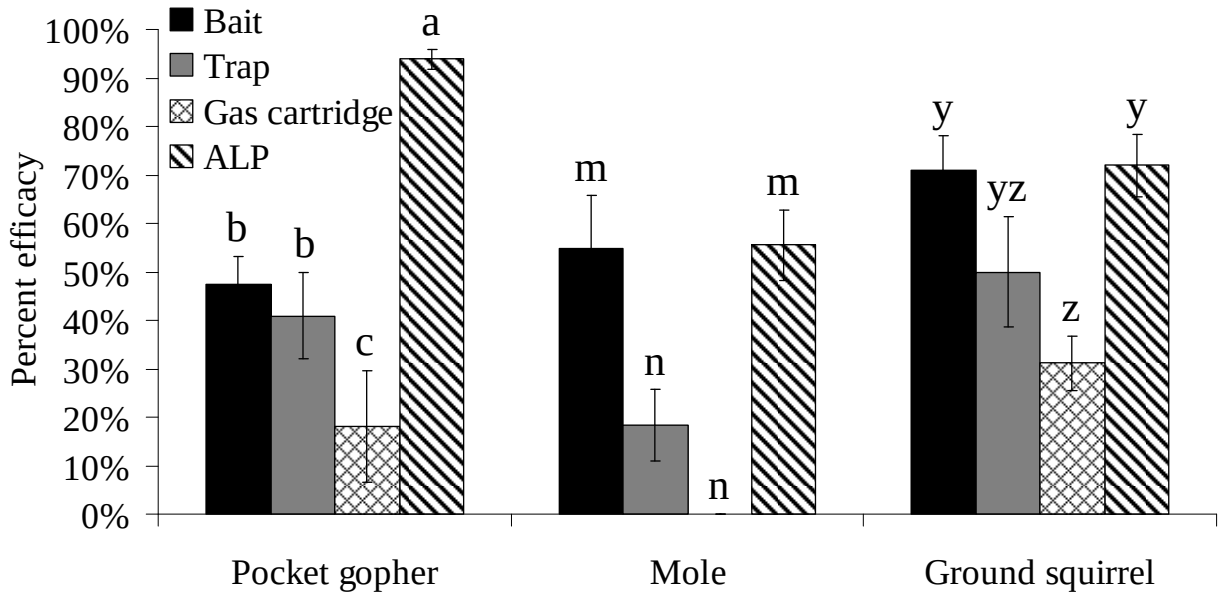

Figure 7. Average percent efficacy and associated standard errors for pocket gopher, mole, and ground squirrel control methods as estimated by residential survey respondents. Significant differences for each species are denoted by different letters.

Overall, potential options to mitigate the new restrictions on ALP use for burrowing mammals were positively received. For agricultural areas, 100% of respondents (exact binomial test, $P < 0.001$) indicated that they would be willing to receive training for a special certification category if restrictions were reduced to allow the user to apply ALP for burrowing mammal control in areas up to 25 feet from any occupied structure and if posting restrictions were removed (Fig. 8). Acceptance of mitigation alternatives in residential areas ranged from 22–87% (Fig. 8). Greatest acceptance (87%; exact binomial test, $P < 0.001$) was for the implementation of a special certification category for aluminum phosphide. A second alternative that would increase the buffer to 25 feet *for pocket gophers only* while eliminating the residential application exclusion received almost the same level of support (85%; exact binomial test, $P < 0.001$; Fig. 8). The presence of a 100-foot buffer was clearly deemed too restrictive (22% acceptance; exact binomial test, $P = 0.011$) to allow much of an increase in residential areas where ALP cannot currently be applied (Fig. 8).

DISCUSSION

Aluminum phosphide has historically been used extensively for burrowing mammal control as evidenced by the 49,005 lbs of AI applied for these species in 2010. The majority of ALP was applied in residential areas (81%), with most applications focused on residential yards (Fig. 1). Such areas require effective control of burrowing mammals to reduce tripping hazards to residents or others. In fact, survey respondents indicated that 52% of all applications of ALP made in residential areas were to reduce the potential for injury associated with tripping over mounds or stepping in burrows. Numerous school and park districts engage in pocket gopher control to avoid lawsuits from such injuries. Some of these species also carry diseases of concern. In particular, ground squirrels are known reservoirs of bubonic plague (Yensen and Sherman 2003). Burrow fumigation with ALP allows applicators to kill both the host and carrier (fleas); most other control methods (trapping, shooting, etc.) only kill the reservoir species allowing the carrier to attach to another living organism (e.g., human, pet, etc.) thereby increasing the probability of disease transmission to humans. Burrowing mammals can also cause extensive physical damage to lawns, gardens, flower beds, cut and fill slopes, dams, dikes, and building infrastructure. Certainly, effective control of pests such as pocket gophers and ground squirrels is needed in such residential areas, and ALP appears to be an effective tool to combat these pests.

Aluminum phosphide was also an important management tool in agricultural areas with 9,294 lbs of AI used in these areas in 2010. Most applications in agricultural areas focused on nut crops, wine grapes, and alfalfa (Table 1). Not surprisingly, pocket gophers and ground squirrels have been implicated for substantial losses in profits associated with these crops (pocket gophers: nuts = 6.1%, grapes = 6.7%, alfalfa = 8.8%; ground squirrels: nuts = 8.7%, grapes = 4.6%, alfalfa = 5.5%—Baldwin et al. 2011). In fact, one estimate for ground squirrel damage to almonds was between $20–28 million in 1998 (Marsh 1998a). This value would likely be much higher today. Damage caused by pocket gophers and ground squirrels can vary but includes direct consumption of crops, girdling of tree trunks and vines, consumption of root systems, and damage to irrigation tubing. Their burrow systems and mounds also result in the loss of irrigation water, increased soil erosion from water channeling down burrow systems, and by serving as potential hazards to both farm laborers and farm equipment (Marsh 1994, O'Connell

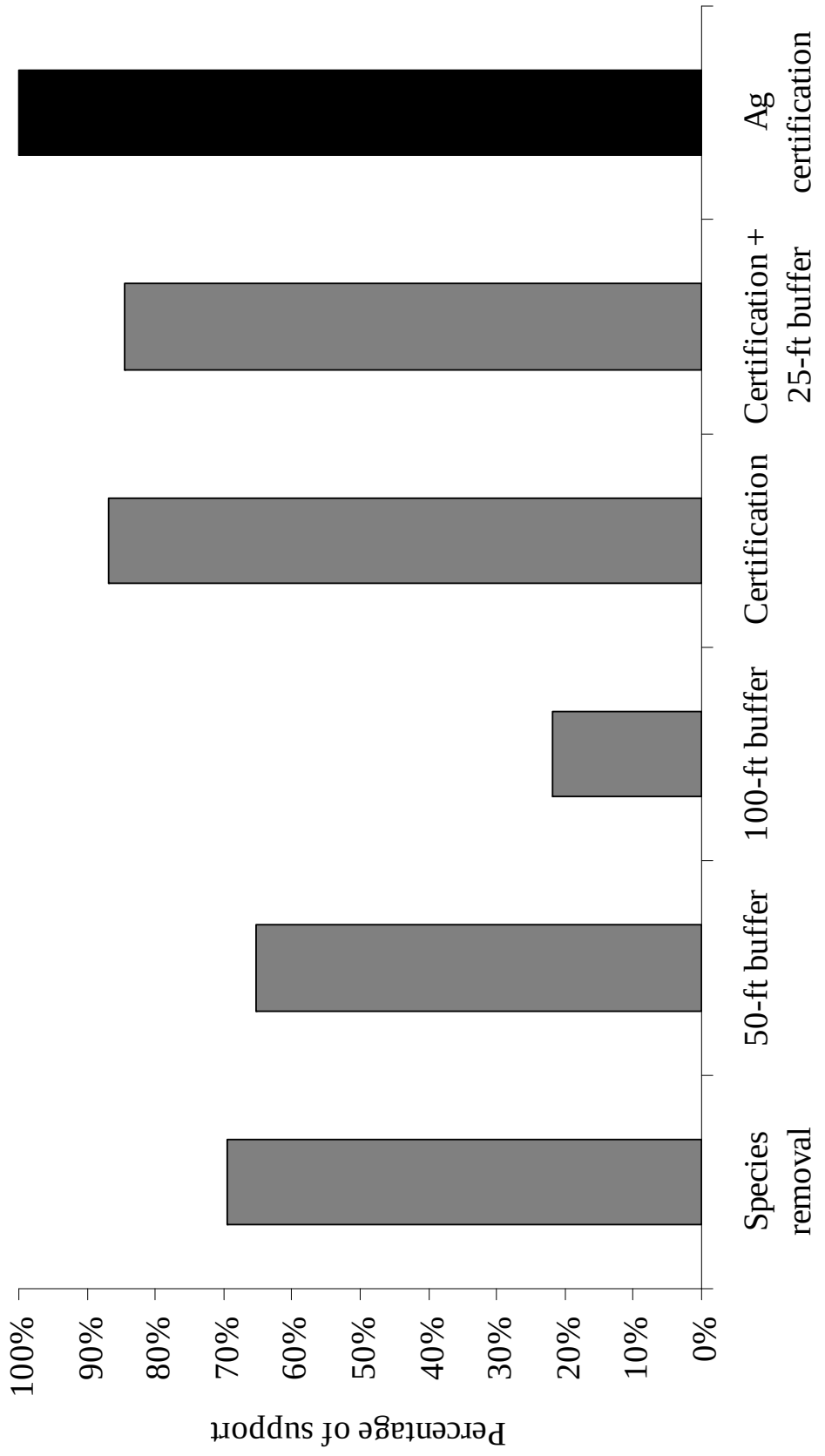

Figure 8. Percent support for proposed mitigation alternatives for residential (represented by gray bars) and agricultural (represented by black bar) respondents. The definitions for the mitigation alternatives are provided in the Methods section. The residential options correspond to the following: species removal = option 1, 50-ft buffer = option 2, 100-ft buffer = option 3, certification = option 4, and certification + 25-ft buffer = option 5. Only one option was provided for agricultural respondents. The 100-ft buffer, Certification, Certification + 25-ft buffer, and Ag certification categories differed significantly from the expected proportion of 0.5. The other categories did not differ significantly from a proportion of 0.5.

1994, Marsh 1998b, Salmon and Baldwin 2009). Burrow fumigation with ALP allows growers and Pest Control Advisers and Operators to target burrow systems of these pests and appears to be a highly effective technique for pocket gopher and ground squirrel control (e.g., pocket gopher = 90–100%—Baker 2004; ground squirrel = 97–100%—Salmon et al. 1982, Baldwin and Holtz 2010).

Of the burrowing pests assessed, pocket gophers received the bulk of ALP applications (agricultural areas = 63% of applications, residential areas = 79%), although mole (residential areas = 14% of applications) and ground squirrel burrows (agricultural areas = 37% of applications, residential areas = 5%) were also treated with ALP (Figs. 2 and 3). The greater usage of ALP for pocket gopher control is likely due in large part to the great disparity in perceived efficacy between ALP and other control alternatives (Figs. 6 and 7). This is particularly true for residential users, where ALP is considered twice as efficacious as the next most efficacious approach (Fig. 7). In contrast, baiting is often considered as efficacious or almost as efficacious as ALP burrow fumigation for ground squirrels and moles and is likely the reason why we do not see a large disparity for these two species (Figs. 6 and 7).

Although a historically important control option, it appears that burrow fumigation with ALP will dramatically decrease in the future due to greater restrictions recently imposed on its use for burrowing mammals. This impact will be felt most strongly in residential areas where I estimate a 90%, 98%, and 70% drop in applications for pocket gophers, moles, and ground squirrels, respectively. The greatest loss will be in areas where users no longer are allowed to apply ALP regardless of the distance from structures and new posting restrictions (Fig. 3). This is not surprising given that most applications have historically occurred in these areas (Fig. 1). However, further losses are expected due to expanded buffer and posting restrictions. The impact of the increased size of buffers on ALP usage is obvious; the less area you can treat, the lower the total usage will be. The impact of new posting restrictions is less obvious and more difficult to quantify. This impact will likely arise due to the general publics' fear of chemicals (i.e., chemophobia; Stroup 1990) and subsequent negative feedback associated with this fear. Such fears are often unwarranted (Stroup 1990), which is likely the case with ALP given the extremely low levels of phosphine gas measured above ground after application (Baker and Krieger 2002). Proper education on the hazards associated with these applications may alleviate these fears to some extent but such education will not be practical in most situations given budget limitations. As a consequence, the fear associated with ALP applications, even if unwarranted, will likely increase negative feedback to the point where applications of ALP may no longer be practical. As such, new posting restrictions will likely serve as a strong barrier to the application of ALP in areas where it is not otherwise prohibited.

Similar impacts for pocket gophers (cumulative reduction in applications = 70%) are expected by agricultural users as well, although the impact is likely to be less severe for ground squirrels (cumulative reduction in applications = 26%). Apparently, many agricultural applications for pocket gophers have historically occurred in close proximity to occupied structures (Fig. 2); few applications occurred in these areas for ground squirrels, as posting restrictions had a greater impact on this species (Fig. 2). Interestingly, although most ALP applications in agricultural areas have historically been for pocket gopher control, this may not be the case in the future (Fig.

2). This could be a real problem for pocket gopher control in the future given the perceived lack of efficacy associated with alternative control options (Fig. 6).

Given the loss of ALP for burrow fumigation in many areas, applicators will need to utilize alternative tools to control burrowing pests in these areas. The use of rodenticide baits will be the primary tool used to control these pests in residential areas (Fig. 5). This may be less of a concern when controlling mole and ground squirrel populations, as efficacy is considered equivalent between baiting and ALP (Fig. 7). However, it could be a real cause for concern for pocket gopher control, as ALP is considered by far the most efficacious control option (Fig. 7). Lower levels of control will result in either greater numbers of these pests or greater effort required to control these pests. This could result in increased applications of toxic baits (e.g., strychnine, anticoagulants) which could increase secondary toxicity hazards. Such non-target concerns can be particularly important to businesses, home-owners, and applicators, as 27% of respondents indicated in the comments section of the survey (see Appendix II) that this was a concern when switching to baits. These secondary hazards are not present with ALP, as the killing agent is a gas (phosphine). After death, the phosphine gas quickly dissipates from the body which eliminates secondary toxicity concerns. It should be pointed out that although these baits can be a substantial cause for concern when applied in areas occupied by pets, they typically pose relatively little risk to wildlife populations when applied appropriately. However, an increased reliance on less effective baits may result in increased levels of inappropriate use of rodenticides which could have substantial negative impacts on humans, pets, and the environment. Even if applied appropriately, the fact that baiting often does not attain the desired level of control for pocket gophers (e.g., strychnine = 0–36%, zinc phosphide = 5–45%, diphacinone = 0–10%—Tickes et al. 1982, Proulx 1998; Fig. 7) would require greater numbers of applications which would result in either greater cost to the resident or less revenue for the Pest Control professional. In fact, 8% of residential respondents indicated that they will likely go out of business if the current ALP label changes stand, while 23% of residential respondents indicated that new restrictions were likely to have a negative impact on their profitability or would increase costs for customers. These responses were provided in the comments section at the end of the survey (see Appendix II). The fact that they were unsolicited responses reinforces the potential negative economic impact that these new regulations may have on these businesses. These economic impacts have substantial ramifications not only for the individuals directly involved with the company, but also with the local economy (Shwiff et al. 2009).

As with residential areas, baiting appears to be the preferred alternative for ground squirrel control in agricultural areas (Fig. 4). This is not surprising given the relatively high efficacy and low cost associated with this approach for ground squirrel control (Salmon et al. 2000, 2007). Interestingly though, trapping was considered the primary tool that will be used for pocket gopher control in agricultural areas where ALP can no longer be used (Fig. 4). Reasons for this are unclear given the perceived greater cost and effort required to trap than to bait (Marsh 1992, Engeman and Witmer 2000). However, recent projects have shown that trapping can be substantially more efficacious than baiting and less costly than once believed (R. Baldwin, University of California Cooperative Extension, unpublished data). Additionally, 1.8% strychnine-treated milo grain, which is the pocket gopher bait preferred by most applicators, has become quite difficult to obtain due to strychnine shortages in the U.S. (B. Hazen, Wilco

Distributors, Inc., pers. comm., 2012). The combination of these two factors may have increased the desirability of some growers to use trapping in place of baiting.

Regardless of the preferred alternative method, ALP was still considered the most efficacious control method by agricultural respondents (Fig. 4). Furthermore, respondents indicated that they would not treat pocket gophers or ground squirrels in a relatively large proportion of sites (Fig. 4). This is cause for concern as that would result in increased pocket gopher and ground squirrel populations throughout much of California agriculture. This same trend was observed in residential areas as well (Fig. 5). This lack of effective control is compounded by the large proportion of areas where less effective control methods will be used in lieu of ALP. This potential concern is clearly illustrated by the following example. For this example, let us assume that 3 ALP tablets (0.0066 lbs each) are applied per pocket gopher burrow system (label specifies 2–4). If the percent of AI = 0.57%, then there is 0.0113 lbs of AI applied per burrow system. Given that 4,082.6 lbs of AI of ALP were applied for pocket gopher control in agricultural areas where ALP will no longer be used, this results in 360,975 ALP applications in 2010 that will not occur in the future. Assuming single occupancy of pocket gopher tunnel systems (which may be an underestimate given some burrows occupied by females with young) and an overall efficacy of 83.3% for ALP (Fig. 6), this would historically result in the removal of 300,692 pocket gophers. Now if we assume that the proportion of sites that will be treated with alternative methods of control (as well as sites that will no longer be treated) is the same as that represented in Fig. 4, and that these control methods have efficacy values represented in Fig. 6, then this would result in 156,673 pocket gophers removed (only 52% of total removed from the same number of ALP applications) from these same areas. This is a substantial reduction (144,019 fewer pocket gophers) in the number of pocket gophers removed when using alternative control methods. Given the known reproductive capabilities of pocket gophers (1–3 litters per year, 5–6 young per litter; Salmon and Baldwin 2009), this could result in very substantial gains in population size in a very short period of time. Similar and even more extreme values could be calculated for other species in both agricultural and residential areas. These values are certainly not meant to be an exact reflection of the current and future status of burrowing mammals in California, but rather are provided to illustrate the impact that new ALP restrictions might have on these pest populations given the values obtained from this study. Regardless, it could be argued that the impact that these dramatically larger pest populations have on economic concerns, the environment, and human health and safety may far outweigh any potential risks associated with ALP.

It should also be pointed out that burrow fumigation with ALP is a very important part of an IPM program for controlling burrowing mammals (Baldwin and Salmon 2011). The premise of IPM is to utilize multiple techniques to provide more effective long-term control of pest populations while minimizing impacts to humans and the environment. The California ground squirrel provides the perfect example to illustrate the importance of ALP to an IPM program. One way to minimize impacts to humans and the environment is to target ground squirrel populations when they are at their lowest. This is usually right before a pulse in reproduction which is in early spring for ground squirrels. With ALP, relatively high soil moisture is required for the fumigant to work (Salmon et al. 1982, Baker 1992). Early spring is an excellent time to use this burrow fumigant in California given the Mediterranean climate present throughout much of the state. This allows the applicator to remove ground squirrels before they have an opportunity to

reproduce thereby requiring less effort and toxicant to control this pest (Marsh 1994). The elimination of ALP applications in many areas removes this useful tool and requires the applicator to rely more heavily on rodenticide baits to control ground squirrels in these areas.

This reliance on baits has several negative ramifications. First, baits are not typically very effective during spring as squirrels are primarily consuming green vegetation during this season. The rodenticide carriers that are used for ground squirrel control are either seed or pelletized baits, so poor bait acceptance is usually observed until ground squirrels switch over to seed-based foods in summer (Marsh 1994). By this time, the next generation of squirrels has been born and is actively foraging above ground. This means more toxicant will be required to effectively control the population, which subsequently increases potential exposure of these rodenticides to non-target species.

Even when applied appropriately and non-target concerns are minimized, there can be problems with efficacy associated with rodenticides in certain areas. For example, ground squirrels strongly prefer many nuts (e.g., almonds, pistachios, etc.) to grain-based baits. If ground squirrels are feeding primarily on these nuts, they likely will not consume the bait (O'Connell 1994). Therefore, if an individual has to rely on baits to control ground squirrels, they may not be very successful in these areas as baiting is not effective in spring (because they are consuming green vegetation at that time), and are not effective in the summer given the presence of a preferred food source (i.e., nuts).

Ultimately, when dealing with any form of pest control it is important to remember that the more control options that are available, the more effective you are likely to be (Salmon and Schmidt 1984, Engeman and Witmer 2000). For example, even though baiting can be highly effective for ground squirrel control in many settings, there will likely be a subset of that population that is bait shy (i.e., will not consume the bait). No matter how much bait you put out, the ground squirrel will not consume it. As such, an alternative form of control is needed to maximize efficacy. Burrow fumigation with ALP fills this void quite effectively. The loss of ALP from many IPM programs greatly reduces the ability of individuals involved in burrowing pest control to effectively control those species. As pointed out previously, this could have very substantial ramifications and may need to be considered more thoroughly.

Aluminum phosphide is clearly an important tool for burrowing mammal control in California, as well as throughout much of the U.S. As such, mitigation alternatives to the current ALP label would be highly desirable to PCA's, PCO's, growers, governmental agencies, home owners, etc., for controlling these pests. The mitigation options provided to residential respondents indicated mixed results. Most respondents felt that allowing ALP applications for pocket gophers within residential areas as long as they were at least 100 feet from any occupied structure would be too great of a restriction (Fig. 8); this would still serve to eliminate applications in almost all homeowner residences. However, they were much more receptive to the development of a special certification category for use of ALP in residential areas that allowed use in areas farther than 25 feet from occupied structures, even if it was only for pocket gophers (Fig. 8). Likewise, agricultural respondents unanimously indicated a willingness to complete a special certification category if it reduced this buffer to 25 feet and removed the posting restriction (Fig. 8).

The advent of such a certification category could provide an effective mitigation alternative to the recently imposed label restrictions, as a lack of adherence to the previous label restrictions appears to be the primary driving force behind the new restrictions. Historically, the use of ALP for burrow fumigation has had a relatively safe track record in the U.S. As far as the author knows, only 2 incidents of ALP application for burrow fumigation have resulted in fatalities since 2000. One incident caused the death of a 5-year old girl in South Dakota; the other led to the death of two young girls in Utah. Both of these incidents were due to the misapplication of ALP, and for both, ALP was applied too close to the home and the application rate greatly exceeded the label specifications (Tharp 2010, U.S. Department of Justice 2011). No fully compliant applications of ALP for burrowing mammals have resulted in any fatalities in the U.S. since 2000 and likely for a longer period of time than that. This suggests that previous restrictions for ALP were adequate when properly followed. It seems logical then that greater education provided through a mandatory certification program on ALP usage for burrowing mammals would be sufficient to substantially reduce the extraordinarily minimal risk (e.g., if we assume equivalent usage of ALP from 2000–2010 at 2010 levels, then there have been 0 fatalities out of approximately 47,663,000 applications for burrowing mammals in California during this time-period; method for calculation provided earlier in Discussion) already present for ALP applications. Nonetheless, both residential and agricultural respondents were willing to increase the buffer to 25 feet, which would further reduce the potential danger associated with ALP applications around existing structures.

The loss of applications in residential areas and increased buffers around structures represent two of the greatest changes to the ALP label. However, they are not the only changes, as a 48-hour posting restriction is now imposed as well. The reason for this posting is unclear as Baker and Krieger (2002) clearly showed that phosphine exposure from ALP applications for burrowing mammal control was well below the Permissible Exposure Limit (almost always below 10% of this limit). As such, new posting restrictions would appear to provide little benefit, but could substantially limit where ALP can be applied given chemophobia concerns (Figs. 2 and 3; see earlier Discussion for greater detail), which could have serious ramifications on burrowing pest control and their associated economic and human health and safety impacts. As with the buffer changes, agricultural respondents indicated a willingness to obtain a special certified applicator permit to use ALP for burrowing mammal control if it removed this posting restriction. Although they were not presented this option, residential respondents would likely benefit greatly from the removal of this restriction as well (i.e., Fig. 3). A reconsideration of this posting restriction may be warranted if built into the proposed burrowing mammal certified applicator category.

It should be noted that ALP applicators have always been required to be properly trained to use ALP. This training was to be based on the product label. However, there has never been any form of test and subsequent verification of receipt of this training, other than annual and new employee required worker safety training, making enforcement of this difficult. The proposed certification category presented in this discussion is intended to verify the applicators knowledge of ALP and would be required not only to apply, but also to purchase.

Although a certified applicator category may alleviate some of the safety concerns with ALP applications for burrowing mammals, State funding and resources may not be available to initiate

and oversee such a program (D. Duncan, CDPR, pers. comm., 2011). Given that ALP is a Federally Restricted material, perhaps federal funding could be provided for such a certification program. Alternatively, the manufacturers and distributors may be willing to provide the training for this certification program given its importance to their business. Or, perhaps more simply, an open dialogue could be established between the associated regulatory agencies, manufacturers, and consumers/applicators to develop an amicable solution to this issue. It is my concern that if mitigation steps are not taken to minimize the impact of new ALP regulations, we will see an increase in burrowing pest problems that will be accompanied by numerous economic, environmental, and human health and safety problems that are associated with these pest species. It is quite possible that the estimated 85% reduction in future ALP applications for burrowing mammal control in California could result in far greater negative consequences than that which is gained from the new regulations.

ACKNOWLEDGMENTS

I would like to thank R. Baker, D. Bulls, R. Timm, the Pesticide Applicators Professional Association, numerous University of California Cooperative Extension Farm Advisors, and any other individuals I might have forgotten for assistance in developing and distributing this survey. L. Wilhoit, D. Duncan, and M. Read provided valuable assistance in accessing the CDPR PUR's. Lastly, I would like to thank all survey participants for volunteering their valuable time to complete this survey. This project was funded by the Vertebrate Pest Control Research Advisory Committee; and numerous professional pest control companies, manufacturers, and distributors including Animal Damage Management, Inc.; California Agri-Control, Inc.; Cragoe Pest Services, Inc.; Kastle Kare Landscape Pest Control; Pestcon Systems, Inc.; Rodent Pest Technologies, Inc.; Target Specialty Products; Univar; Wildlife Control Service, Inc.; and Wildlife Pest Management, Inc.

LITERATURE CITED

Baker, R. O. 1992. Exposure of persons to phosphine gas from aluminum phosphide application to rodent burrows. Proceedings of the Vertebrate Pest Conference 15:312–321.

Baker, R. O. 2004. Field efficacy of Fumitoxin® (55% aluminum phosphide) tablets for controlling valley pocket gopher. Proceedings of the Vertebrate Pest Conference 21:253–257.

Baker, R. O., and R. Krieger. 2002. Phosphine exposure to applicators and bystanders from rodent burrow treatment with aluminum phosphide. Proceedings of the Vertebrate Pest Conference 20:267–276.

Baldwin, R. A., and B. A. Holtz. 2010. Fumigation of California ground squirrels revisited: are fumigants an effective method for controlling ground squirrels? Proceedings of the Vertebrate Pest Conference 24:129–132.

Baldwin, R. A., and N. Quinn. 2012. The applicability of burrow fumigants for controlling Belding's ground squirrels in alfalfa. Proceedings of the Vertebrate Pest Conference 25:*in press*.

Baldwin, R. A., and T. P. Salmon. 2011. The facts about rodenticides. The Wildlife Professional 5:50–53.

Baldwin, R. A., T. P. Salmon, R. H. Schmidt, and R. M. Timm. 2011. Vertebrate pest "research needs" assessment for California agricultural commodities. University of California, Davis. Final Report to CDFA.

Borchert, J. N., R. M. Davis, and R. M. Poché. 2009. Field efficacy of rodent bait containing the systemic insecticide imidacloprid against the fleas of California ground squirrels. Journal of Vector Ecology. 34:92–98.

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.

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

Marsh, R. E. 1994. Current (1994) ground squirrel control practices in California. Proceedings of the Vertebrate Pest Conference 16:61–65.

Marsh, R. E. 1998a. Historical review of ground squirrel crop damage in California. International Biodeterioration and Biodegradation 42:93–99.

Marsh, R. E. 1998b. One hundred years of pocket gopher traps and trapping. Proceedings of the Vertebrate Pest Conference 18:221–226.

McDonald, J. H. 2009. Handbook of Biological Statistics (2nd ed.). Sparky House Publishing, Baltimore, Maryland, USA.

O'Connell, R. A. 1994. Trapping ground squirrels as a control method. Proceedings of the Vertebrate Pest Conference 16:66–67.

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.

Proulx, G. 2002. Effectiveness of trapping to control northern pocket gophers in agricultural lands in Canada. Proceedings of the Vertebrate Pest Conference 20:26–31.

Salmon, T. P., and R. A. Baldwin. 2009. Pest Notes: Pocket gophers. University of California, Statewide Integrated Pest Management Program, Division of Agricultural and Natural Resources, Publication 7433.

Salmon, T. P., W. P. Gorenzel, and W. J. Bentley. 1982. Aluminum phosphide (Phostoxin) as a burrow fumigant for ground squirrel control. Proceedings of the Vertebrate Pest Conference 10:143–146.

Salmon, T. P., and R. H. Schmidt. 1984. An introductory overview to California ground squirrel control. Proceedings of the Vertebrate Pest Conference 11:32–37.

Salmon, T. P., D. A. Whisson, A. R. Berentsen, and W. P. Gorenzel. 2007. Comparison of 0.005% and 0.01% diphacinone and chlorophacinone baits for controlling California ground squirrels (*Spermophilus beecheyi*). Wildlife Research 34:14–18.

Salmon, T. P., D. A. Whisson, and W. P. Gorenzel. 2000. Use of zinc phosphide for California ground squirrel control. Proceedings of the Vertebrate Pest Conference 19:346–357.

Shwiff, S. A., K. Gebhardt, and K. N. Kirkpatrick. 2009. The economic impact of bird and rodent damage to California crops: an economic evaluation of the losses caused by bird and rodent damage and selected benefits of pest control expenditures. Report prepared for the California Department of Food and Agriculture, Vertebrate Pest Control Research Advisory Committee, 35pp.

Sterner, R. T. 2008. The IPM paradigm: vertebrates, economics, and uncertainty. Proceedings of the Vertebrate Pest Conference 23:194–200.

Stroup, R. L. 1990. Chemophobia and activist environmental antidotes: is the cure more deadly than the disease? Pages 193–213 *in* W. Block, editor. Economics and the environment: a reconciliation. The Fraser Institute, Vancouver, British Columbia, Canada.

Tharp, C. 2010. Suspected pesticide poisonings raise concern over individuals not reading and following the pesticide product label. Pesticide News, Montana State University Extension, 1 March, 2010. http://www.pesticides.montana.edu/News/Miscellaneous/agalertreadtheproductlabel.pdf

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.

U.S. Department of Justice. 2011. News release: Bugman Pest and Lawn, Inc. and Coleman Nocks plead guilty to unlawful use of pesticide. 11 October, 2011. http://www.epa.gov/compliance/resources/cases/criminal/highlights/2011/bugman-pest-coleman-nocks-10-11-11.pdf

Yensen, E., and P. W. Sherman. 2003. Ground squirrels (*Spermophilus* and *Ammospermophilus* species). Pages 211–231 *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, Maryland, USA.

Zar, J. H. 1999. Biostatistical analysis. Prentice-Hall, Inc., Upper Saddle River, New Jersey, USA.

APPENDIX I

INTRODUCTRY LETTER FOR QUESTIONNAIRE REGARDING AGRICULTURAL USE OF ALUMINUM PHOSPHIDE FOR BURROWING MAMMAL CONTROL

Recent changes in aluminum phosphide (ALP) labels have been implemented due to the gross misuse of this product that led to the death two young girls in Utah. These changes include the following:

1. Use is strictly prohibited around all residential areas, including single and multi-family residential properties, nursing homes, schools (except athletic fields, where use may continue), day care facilities, and hospitals.

2. The products must only be used outdoors for the control of burrowing pests, and are for the use on agricultural areas, orchards, non-crop areas (such as pasture and rangeland), golf courses, athletic fields, parks, and other non-residential institutional or industrial sites.

3. Products must not be applied in a burrow system that is within 100 feet of a building that is or may be occupied by people or domestic animals. This buffer zone for treatment around non-residential buildings that could be occupied by people or animals has been increased from 15 to 100 feet.

4. When this product is used in athletic fields or parks, the applicator must post a sign at entrances to the treatment site containing the signal word DANGER/PELIGRO, skull and crossbones, the words: DO NOT ENTER/NO ENTRE, FIELD NOT FOR USE, the name and EPA registration number of the fumigant, and a 24-hour emergency response number. Signs may be removed 2 days after the final treatment.

5. When this product is used out of doors in a site frequented by people, other than an athletic field or park (such as agricultural fields), the applicator shall post a sign at the application site containing the signal word DANGER/PELIGRO, skull and crossbones, the name and EPA registration number of the fumigant, and a 24-hour emergency response number. Signs may be removed 2 days after the final treatment.

Because of these changes, the attached questionnaire was designed to develop accurate facts on various methods, including ALP, for controlling burrowing mammals in California. The information will be provided to registrants, NPMA, EPA, and others to help develop use policies, labels, etc. My primary objectives are to:

1. Identify the level of use of ALP for various burrowing mammals in agricultural areas prior to the new ALP label restrictions.

2. Identify how new ALP label restrictions will alter use of a variety of control methods.

3. Identify the potential impact of the new ALP label restrictions on burrowing mammal populations.

4. See if there is support to further increase safety for residents and other public bystanders by requiring a new Certified Applicator Category for use of ALP fumigants for burrowing pest control IF such a category would ease restrictions set forth in the most recent ALP labels.

The data collected should provide a much clearer picture of use patterns and importance of several methods, including ALP, for controlling agricultural populations of burrowing pests in California.

Thank you for taking time to provide this important information! Feel free to contact me if you have any questions about this survey.

Roger A. Baldwin, Ph.D.
IPM Wildlife Pest Management Advisor
University of California, Kearney Agricultural Center
9240 South Riverbend Ave.
Parlier, CA 93648
Phone: 559-646-6583
E-mail: rbaldwin@uckac.edu

QUESTIONNAIRE REGARDING AGRICULTURAL USE OF ALUMINUM PHOSPHIDE FOR BURROWING MAMMAL CONTROL

Directions: Please answer each question to the best of your ability. Once completed, be sure to save the file. Then e-mail to rbaldwin@uckac.edu or, if you prefer, mail to: Roger Baldwin, UC Kearney Ag Center, 9240 South Riverbend Ave., Parlier, CA 93648.

1. Aluminum phosphide (ALP) for burrowing mammal control typically comes in tablet or pellet form. For each of these ALP forms, please provide the size (common flask sizes for tablets are 100, 333, and 500 tablets; common flask sizes for pellets are 1,660 and 2,500 pellets) and estimated number of ALP flasks you used annually for burrowing mammal control prior to the recent EPA mandated label changes. For example, if you used 3 500-count flasks of tablets per year before the recent EPA label changes, place 500 in the blank after flask size for tablets and 3 in the blank after number of flasks for tablets.

   For ALP **TABLETS**: flask size = _____ flask number = _____

   For ALP **PELLETS**: flask size = _____ flask number = _____

2. Estimate the percentage of your ALP applications that are for control of each of the below-listed pests (P. Gopher = pocket gopher, G. Squirrel = ground squirrel). For each pest that you do not use ALP as a control measure, place 0 in each corresponding blank. For example, let us assume you use ALP for ground squirrels and pocket gophers. Let us further assume that 80% of all of your ALP applications are for ground squirrels and 20% of all applications are for pocket gophers; you do not use ALP for any other burrowing mammals. Therefore, for ground squirrels you would place 80% in the corresponding blank, and for pocket gophers you would place 20% in the corresponding blank. All other blanks would receive a 0 with the resultant total of the row adding to 100%.

	P. Gopher	Mole	Vole	G. Squirrel	Rat
Percent of total ALP use by species:	_____	_____	_____	_____	_____

3. Estimate, by pest species, your percentage of ALP applications that occur within 100 feet (new label requirement) but greater than 15 feet (previous label requirement) from buildings. For each pest that you do not use ALP as a control measure, place 0 in each corresponding blank. For example, let us assume that 10% of all of your ALP applications for ground squirrel control occur within an area from 15–100 feet from a building. You would place 15% in the corresponding blank for ground squirrels. Keep in mind that you are estimating separately for each species, so the collective total of all species (e.g., sum of entire row) may exceed 100%.

	P. Gopher	Mole	Vole	G. Squirrel	Rat
Percent of ALP applications within buffer:	_____	_____	_____	_____	_____

4. Estimate your percent reduction in ALP applications given the new 48-hour posting requirement for sites frequented by people (e.g., fields/orchards/vineyards adjacent to roads, irrigation canals,

walkways, etc.; or treated fields frequented by farm laborers). Reasons for not applying ALP to these sites could range from concerns for negative publicity for using such pesticides to simply not being willing to go through the effort of posting such sites. If you do not anticipate any reduction in ALP usage from new posting requirements, place zero in the blank.

_____%

5. For each of the following species, what percentage of applications of each of the following control methods will you likely use in locations where you will no longer be able (e.g., within extended buffer zone) or willing (e.g., due to 48-hour posting requirements) to use ALP? If you will no longer treat a certain percentage of those areas for a given species, place that percentage in the "Will no longer treat" category for that species. For example, for control efforts in areas where you can no longer use ALP to remove gophers, if you anticipate using trapping 50% of the time, strychnine baiting 20% of the time, and no longer treating 30% of the areas where you previously used ALP, place 50, 20, and 30 in their respective blanks under P. Gopher (P. Gopher = pocket gopher, G. Squirrel = ground squirrel). All other blanks would receive a 0 with the resultant total of the column adding to 100%.

	P. Gopher	Mole	Vole	G. Squirrel	Rat
A. Gas or smoke cartridges	_____	_____	_____	_____	_____
B. Toxic bait	_____	_____	_____	_____	_____
C. Trapping	_____	_____	_____	_____	_____
D. Other* _____	_____	_____	_____	_____	_____
E. Will no longer treat	_____	_____	_____	_____	_____

* Please write the method in the blank next to "Other".

6. For each of the following species, in your estimation, what is the percent reduction in population size you typically observe for each of the following control methods (for example, your experience may have shown that trapping typically yields an 80% reduction in the number of pocket gophers in a population)? If you have not used a particular control method for a given species before, mark N/A in the appropriate space (P. Gopher = pocket gopher, G. Squirrel = ground squirrel).

	P. Gopher	Mole	Vole	G. Squirrel	Rat
A. ALP	_____	_____	_____	_____	_____
B. Gas or smoke cartridges	_____	_____	_____	_____	_____
C. Toxic bait	_____	_____	_____	_____	_____
D. Trapping	_____	_____	_____	_____	_____
E. Other* _____	_____	_____	_____	_____	_____

* Please write the method in the blank next to "Other".

7. Would you support a less stringent ALP product label, or amendment, that: 1.) allowed ALP use in agricultural areas within 100 feet but no closer than 25 feet to occupied structures, and 2.) eliminated the 48-hour posting requirement for agricultural areas? **Such use would only be allowable by applicators Certified in a new ALP Burrowing Mammal Certified Applicator Category.**

Yes____ No____

Additional Comments:

_____

_____

_____

_____

APPENDIX II

INTRODUCTRY LETTER FOR QUESTIONNAIRE REGARDING RESIDENTIAL USE OF ALUMINUM PHOSPHIDE FOR BURROWING MAMMAL CONTROL

Recent changes in aluminum phosphide (ALP) labels have been implemented due to the gross misuse of this product that led to the death two young girls in Utah. These changes include the following:

1. Use is strictly prohibited around all residential areas, including single and multi-family residential properties, nursing homes, schools (except athletic fields, where use may continue), day care facilities, and hospitals.

2. The products must only be used outdoors for the control of burrowing pests, and are for the use on agricultural areas, orchards, non-crop areas (such as pasture and rangeland), golf courses, athletic fields, parks, and other non-residential institutional or industrial sites.

3. Products must not be applied in a burrow system that is within 100 feet of a building that is or may be occupied by people or domestic animals. This buffer zone for treatment around non-residential buildings that could be occupied by people or animals has been increased from 15 to 100 feet.

4. When this product is used in athletic fields or parks, the applicator must post a sign at entrances to the treatment site containing the signal word DANGER/PELIGRO, skull and crossbones, the words: DO NOT ENTER/NO ENTRE, FIELD NOT FOR USE, the name and EPA registration number of the fumigant, and a 24-hour emergency response number. Signs may be removed 2 days after the final treatment.

5. When this product is used out of doors in a site frequented by people, other than an athletic field or park, the applicator shall post a sign at the application site containing the signal word DANGER/PELIGRO, skull and crossbones, the name and EPA registration number of the fumigant, and a 24-hour emergency response number. Signs may be removed 2 days after the final treatment.

Because of these changes, the attached questionnaire was designed by University of California and industry representatives to develop accurate facts on various methods, including ALP, for controlling burrowing mammals in California. The information will be provided to registrants, NPMA, EPA, and others to help develop use policies, labels, etc. Our primary objectives are to:

1. Identify the level of use of several control measures for various burrowing mammals in a variety of residential and other public use areas prior to the new ALP label restrictions.

2. Identify how new ALP label restrictions will alter use of these control methods.

3. Estimate the expected economic impact of new ALP label restrictions on burrowing pest control businesses.

4. Identify the potential impact of the new ALP label restrictions on burrowing mammal populations, as well as the potential impact this label might have on human health and safety.

5. Identify the need, or lack thereof, for this product on specific pests.

6. See if there is industry support to increase safety to bystanders by removing shallow burrowing pests, and those that have numerous hard-to-find open burrows (moles, voles, rats and mice), from the label except for agricultural and public health uses.

7. See if there is industry support to further increase safety for residents and other public bystanders by requiring a new Certified Applicator Category for use of ALP fumigants for burrowing pest control.

The data collected should provide a much clearer picture of use patterns and importance of several methods, including ALP, for controlling residential and urban populations of burrowing pests in California.

Thank you for taking time to provide this important information!

Roger A. Baldwin, Ph.D.
IPM Wildlife Pest Management Advisor
University of California, Kearney Agricultural Center
9240 South Riverbend Ave.
Parlier, CA 93648
Phone: 559-646-6583
E-mail: rbaldwin@uckac.edu

QUESTIONNAIRE REGARDING RESIDENTIAL USE OF ALUMINUM PHOSPHIDE FOR BURROWING MAMMAL CONTROL

Directions: Please answer each question to the best of your ability. Once completed, be sure to save the file. Then e-mail to rbaldwin@uckac.edu or, if you prefer, mail to: Roger Baldwin, UC Kearney Ag Center, 9240 South Riverbend Ave., Parlier, CA 93648.

1. What percent of your gross annual revenue AS IT PERTAINS TO BURROWING MAMMALS comes from control of the following pests? Be sure to consider only the part of your business that deals with burrowing mammals when providing these estimates.

   A. Pocket gophers _____
   B. Moles _____
   C. Voles _____
   D. Ground squirrels _____
   E. Rats _____

2. For each of the following pests, how many hours of labor per month does your business spend in a typical month using each of the following control methods for each of the listed mammals (P. Gopher = pocket gopher, G. Squirrel = ground squirrel)?

	P. Gopher	Mole	Vole	G. Squirrel	Rat
A. ALP	_____	_____	_____	_____	_____
B. Gas or smoke cartridges	_____	_____	_____	_____	_____
C. Toxic bait	_____	_____	_____	_____	_____
D. Trapping	_____	_____	_____	_____	_____

3. Aluminum phosphide (ALP) for burrowing mammal control typically comes in tablet or pellet form. For each of these ALP forms, please provide the size (common flask sizes for tablets are 100, 333, and 500 tablets; common flask sizes for pellets are 1,660 and 2,500 pellets) and estimated number ALP flasks your company used annually for burrowing mammal control prior to the recent EPA mandated label changes. For example, if you used 10 500-count flasks per year before the recent EPA label changes, place 500 in the blank after flask size for tablets and 10 in the blank after number of flasks for tablets.

   For ALP **TABLETS**: flask size = _____ flask number = _____

   For ALP **PELLETS**: flask size = _____ flask number = _____

4. It would greatly assist my efforts to quantify the economical impact of the new ALP restrictions if I had estimates of gross annual revenue from pest control companies. As such, I would like you to estimate your gross annual revenue EXCLUSIVELY from burrowing mammal (rodent and mole) control. However, if you would prefer not to provide this information, simply leave this blank unanswered.

   _____

5. State what percentage of your ALP applications are for control of each below-listed pest (P. Gopher = pocket gopher, G. Squirrel = ground squirrel) for each land-use category. For each pest that you use ALP as a control measure, the sum for each column must add to 100%. For each pest that you do not use ALP as a control measure, place 0 in each corresponding blank. For example, let us assume you use ALP only for pocket gophers. Let us further assume that 80% of all of your ALP applications for pocket gophers are in residential yards and 20% of all applications are in athletic fields and parks; you treat no other areas for pocket gophers. Therefore, for pocket gophers you would place 80% in the corresponding blank for residential areas and 20% in the corresponding blank for athletic fields/parks/etc. All other blanks in the pocket gopher column would receive a 0 with the resultant total of the column adding to 100%. All other blanks in all other columns would receive a 0 given that no effort was spent controlling these pests with ALP.

	P. Gopher	Mole	Vole	G. Squirrel	Rat
A. Residential yards	_____	_____	_____	_____	_____
B. School landscape/nursing homes/ day care's/hospitals	_____	_____	_____	_____	_____
C. Athletic fields/parks/golf courses/ cemeteries	_____	_____	_____	_____	_____
D. Institutional and commercial sites/ right of ways	_____	_____	_____	_____	_____

6. Estimate your anticipated percent reduction in ALP applications for ONLY sites included in Categories C and D listed in Questions 5 and 6 given the new restrictions requiring 100-foot buffers around all buildings and 48-hour posting of these sites. For example, if you previously made 100 applications per month to these sites, but now only make 40 such applications, then list 60%.

_____%

7. For each of the following species, what percent of applications for each of the following control methods will you likely use in locations where you will no longer be able or willing to use ALP? If you will no longer treat a certain percentage of those areas for a given species, place that percentage in the appropriate location (Will no longer treat) for that species. For example, for pocket gophers, if you will use trapping 50% of the time, strychnine baiting 20% of the time, and will no longer treat 30% of the areas where you used to use ALP, place 50, 20, and 30 in their respective blanks under P. Gopher (P. Gopher = pocket gopher, G. Squirrel = ground squirrel).

	P. Gopher	Mole	Vole	G. Squirrel	Rat
A. Gas or smoke cartridges	_____	_____	_____	_____	_____
B. Toxic bait	_____	_____	_____	_____	_____
C. Trapping	_____	_____	_____	_____	_____
D. Will no longer treat	_____	_____	_____	_____	_____

8. For each of the following species, in your estimation, what is the percent reduction in population size you typically observe for each of the following control methods (for example, your experience may have shown that trapping typically yields an 80% reduction in the number of pocket gophers in a population)? If you have not used a particular control method for a given species before, mark N/A in the appropriate space (P. Gopher = pocket gopher, G. Squirrel = ground squirrel).

	P. Gopher	Mole	Vole	G. Squirrel	Rat
A. ALP	_____	_____	_____	_____	_____
B. Gas or smoke cartridges	_____	_____	_____	_____	_____
C. Toxic bait	_____	_____	_____	_____	_____
D. Trapping	_____	_____	_____	_____	_____

9. What percent of your ALP applications were made to kill disease vectors such as fleas on burrowing mammals? _____%

10. What percent of your ALP applications were made to reduce risk of human injuries caused by burrowing mammal holes and mounds in public and private areas (for example, on athletic fields)? _____%

11. To increase public safety, do you support taking *moles, voles, rats* and *mice* off the ALP label for burrowing pests, EXCEPT for agricultural use or public health emergencies? Yes____ No____

12. Would you support use of ALP in residential and other areas if restricted to only pocket gophers with a **50-foot buffer** from occupied buildings? Yes____ No____

13. Would you support use of ALP in residential and other areas if restricted to only pocket gophers with a **100-foot buffer** from occupied buildings? Yes____ No____

14. Would you support a separate certification category for individuals applying ALP for burrowing mammals in residential areas or other areas frequented by people? Yes____ No____

15. Would you support a new ALP product label, or amendment, that allowed ALP use in residential and other public areas within 100 feet but no closer than 25 feet to occupied structures **for pocket gophers only**? Such use would only be allowable by applicators Certified in a new ALP Burrowing Mammal Certified Applicator Category. Yes____ No____

Additional Comments:

_____

_____

_____

_____