The Importance of Aluminum Phosphide for Burrowing Pest Control in California

Roger A. Baldwin
University of California Kearney Agricultural Research & Extension Center, Parlier, California

Abstract: Aluminum phosphide (ALP) is used extensively for burrowing mammal control. However, recent changes have been made to the ALP label that could substantially limit its utility for burrowing mammal control in the future. As such, I developed surveys to help quantify the impact that these changes are likely to have on ALP usage and vertebrate Integrated Pest Management 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. I found that 49,005 lbs of active ingredient (AI) of ALP was used for burrowing mammal control in 2010, with most applications occurring in residential areas, applied primarily by licensed Pest Control Operators who specialize in vertebrate IPM. Most applications were applied to control pocket gophers, while ground squirrel and mole burrow systems were also treated. 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. The impact of restrictions in residential areas may be even more extreme, with estimated reductions in ALP applications ranging from 70-98%. Alternative control methods were typically considered less efficacious than ALP. Furthermore, 13-34% of respondents indicated that they would no longer control these pests in areas where they could not use ALP. Insufficient or ineffective management programs targeted at these pests could result in increased economic damage, greater human health and safety concerns, and increased environmental degradation. Even though ALP has a safe track record in California, ALP users were 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 relaxing some of the current restrictions. Because of the extreme importance of burrowing mammal 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 ALP. Otherwise, it is quite possible that the estimated 85% reduction in future ALP applications for burrowing mammal control could result in far greater negative consequences than the benefits gained from the new regulations.

Key Words: aluminum phosphide, burrow fumigant, ground squirrel, mole, pocket gopher, regulation, *Scapanus* spp., *Spermophilus* spp., *Thomomys* spp.

Proc. 25th Vertebr. Pest Conf. (R. M. Timm, Ed.)
Published at Univ. of Calif., Davis. 2012. Pp. 151-159.

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). Damage caused by pocket gophers is similar (Marsh 1998, Salmon and Baldwin 2009). A variety of techniques are often used to control these pests including habitat modification, trapping, baiting, burrow fumigation, and others. Each technique has its strengths and weaknesses, and as such, each can be a valuable component of an Integrated Pest Management (IPM) program. 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).

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 nationwide, 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 enacted substantially stricter regulations on ALP. These new regulations have substantial ramifications for burrowing mammal control and include: 1) a strict prohibition of ALP applications in all areas except agricultural areas, orchards, non-crop areas, golf courses, athletic fields, parks, and other non-residential institutional or industrial sites, 2) an increase from 15 to 100 feet in buffer zones around buildings occupied by humans and domestic animals where ALP applications are excluded, and 3) extensive posting restrictions where ALP applications are allowed (see Baldwin 2012 for greater detail).

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 PURs 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 the proportion of applications made in residential/urban (hereafter residential) or agricultural areas. For this, I considered all application site names that were listed as landscape maintenance, rights-of-way, turf/sod, uncultivated non agriculture, and vertebrate control as residential use. All other site names were included in the agricultural use category.

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 and residential 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 factors covered in the surveys included questions on the following topics:

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 percent 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 mammal. 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

Use of ALP in 2010 totaled 106,380 lbs of AI. Of this, 49,005 lbs (46%) were used for burrowing mammal control; 81% (39,711 lbs) was applied in residential areas, while 19% (9,294 lbs) was used for agricultural purposes. 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 negative 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 rates 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 (Figure 1).

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 impact on ALP applications in residential areas where ALP can still be utilized

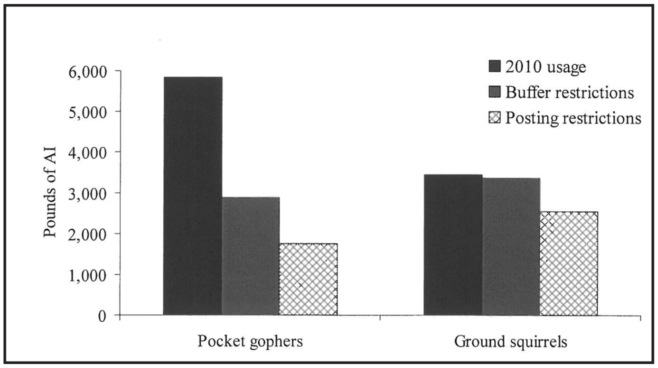

Figure 1. Pounds of active ingredient (AI) of aluminum phosphide (ALP) used in 2010 before new restrictions were enacted, the anticipated reduction in ALP applications due to buffer restrictions, and the additional anticipated reduction in applications due to posting restrictions for both pocket gophers and ground squirrels in agricultural areas.

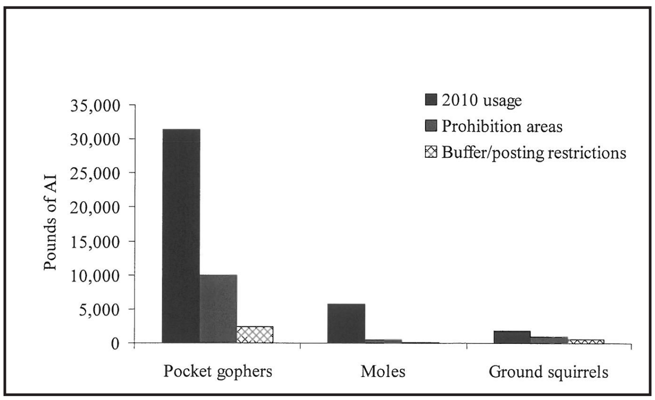

Figure 2. Pounds of active ingredient (AI) of aluminum phosphide (ALP) used in 2010 before new restrictions were enacted, the anticipated reduction in ALP applications due to the prohibition of applications in many residential areas (see text for description), and the additional anticipated reduction in applications due to increased buffer and posting restrictions for pocket gophers, moles, and ground squirrels in residential areas.

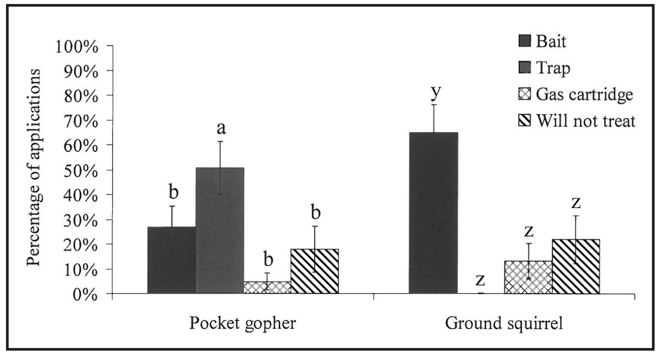

Figure 3. Average percentage of applications and associated standard errors for alternative pocket gopher and ground squirrel control techniques that agricultural survey respondents anticipate using in areas where aluminum phosphide can no longer be used. Significant differences for each species are denoted by different letters.

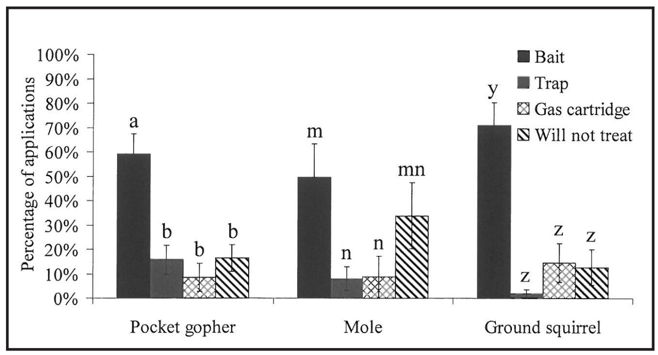

Figure 4. Average percentage of applications and associated standard errors for alternative pocket gopher, mole, and ground squirrel control techniques that residential survey respondents anticipate using in areas where aluminum phosphide can no longer be used. Significant differences for each species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

($\bar{x}$ 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]). Combined, 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 (Figure 2).

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: $H_3 = 19.6$, $P < 0.001$). Survey data 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; Figure 3). 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 alternative for pocket gopher ($\bar{x} = 59\%$, SE = 8), mole ($\bar{x} = 50\%$, SE = 14), and ground squirrel control ($\bar{x} = 71\%$, SE = 9; Figure 4). A 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; Figures 3-4) in these areas.

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 the most effective management tool for both pocket gophers ($\bar{x} = 83\%$, SE = 4) and ground squirrels ($\bar{x} = 82\%$, SE = 3;

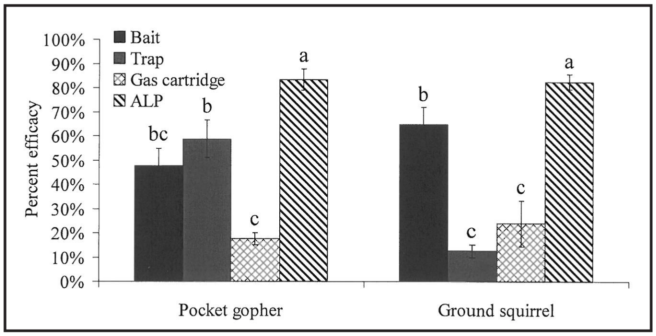

Figure 5. Average percent efficacy and associated standard errors for pocket gopher and ground squirrel control methods as estimated by agricultural survey respondents. Significant differences for each species are denoted by different letters.

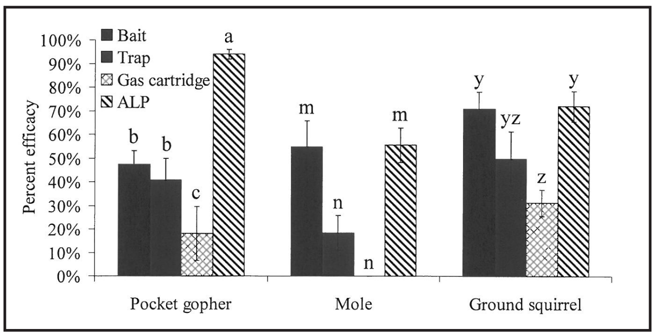

Figure 6. Average percent efficacy and associated standard errors for pocket gopher, mole, and ground squirrel control methods as estimated by residential survey respondents. Significant differences for each species are denoted by different letters.

Figure 5). Trapping ($\bar{x}$ = 59%, SE = 8) was considered the most effective alternative for pocket gopher control, while baiting was considered the most effective alternative for ground squirrels ($\bar{x}$ = 65%, SE = 7; Figure 5). 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 (Figure 6). 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; Figure 6).

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.

Overall, potential options to mitigate the new restrictions on ALP 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

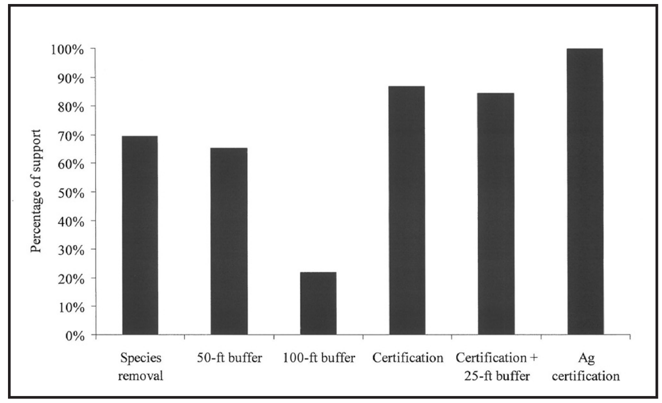

Figure 7. Percent support for proposed mitigation alternatives for residential (represented by gray bars) and agricultural (represented by black bar) respondents. The definitions for the mitigation alternatives are provided in the Methods section. The residential options correspond to the following: 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.

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 (Figure 7). Acceptance of mitigation alternatives in residential areas ranged from 22–87% (Figure 7). 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, $P < 0.001$; Figure 7).

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 (Baldwin 2012). 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, flood control 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. Damage caused by pocket gophers and ground squirrels is often extensive yet variable 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 1994, Marsh 1998, Salmon and Baldwin 2009). Burrow fumigation with ALP allows growers and Pest Control Operators (PCOs) 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, although mole and ground squirrel burrows were also treated with ALP (Figures 1-2). 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 (Figures 5-6). 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 (Figures 5-6).

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 (Figure 2). This is not surprising, given that most applications have historically occurred in these areas (Baldwin 2012). 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 public's 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). Nonetheless, 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 are expected by agricultural users as well, although the impact is likely to be less severe for ground squirrels. Many agricultural applications for pocket gophers have historically occurred in close proximity to occupied structures (Figure 1); few applications occurred in these areas for ground squirrels, as posting restrictions had a greater impact on this species (Figure 1). This could be a real problem for pocket gopher control in the future, given the perceived lack of efficacy associated with alternative control options (Figure 5).

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 (Figure 4). This may be less of a concern when controlling mole and ground squirrel populations, as efficacy is considered equivalent between baiting and ALP (Figure 6). However, it could be a real concern for pocket gopher control, as ALP is considered by far the most efficacious control option (Figure 6). 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. 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., Tickes et al. 1982, Proulx 1998; Figure 6) could require greater numbers of applications, which would result in either greater cost to the resident or less revenue for the Pest Control professional. These economic impacts have substantial ramifications not only for Pest Control companies and homeowners, but they also impact 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 (Figure 3). 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 (Figure 3). 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 Coop. Extension, unpubl. 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 (Figure 3). Furthermore, respondents indicated that they would not treat pocket gophers or ground squirrels in a relatively large proportion of sites (Figure 3). 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 (Figure 4). 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. Given the known reproductive capabilities of pocket gophers (1-3 litters per year, 5-6 young per litter; Salmon and Baldwin 2009) and ground squirrels (1 litter per year, 7-8 young per litter; Marsh 1994), this could result in very substantial gains in population size in a very short period of time. As such, 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. For example, treating ground squirrel burrows with ALP in the springtime eliminates ground squirrels before young are born each year (Marsh 1994). Following this approach, toxic baits could then be used in much smaller amounts later in the year to eliminate remaining ground squirrels. This approach could require less effort and toxicant to control this pest, thereby maximizing efficacy and cost effectiveness while reducing environmental hazards.

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 PCOs, PCAs, growers, governmental agencies, homeowners, etc., for controlling these pests. Residential respondents were 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 (Figure 7). 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 (Figure 7).

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 safe track record in the U.S. when applied according to the label, as the author is unaware of any fully compliant applications of ALP for burrowing mammals that 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 then seems logical that greater education provided through a mandatory certification program on ALP usage for burrowing mammals would further reduce the extraordinarily minimal risk (e.g., no fatalities in California from millions of applications since 2000; Baldwin 2012) 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 (2004) 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 (Figures 1-2), 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., Figure 2). A reconsideration of this posting restriction may be warranted if built into the proposed burrowing mammal certified applicator category.

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 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 PURs. Lastly, I would like to thank all survey participants for volunteering their 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 Inc.; 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. Proc. Vertebr. Pest Conf. 15:312-321.

Baker, R. O. 2004. Field efficacy of Fumitoxin® (55% aluminum phosphide) tablets for controlling valley pocket gopher. Proc. Vertebr. Pest Conf. 21:253-257.

Baker, R. O., and R. Krieger. 2002. Phosphine exposure to applicators and bystanders from rodent burrow treatment with aluminum phosphide. Proc. Vertebr. Pest Conf. 20:267-276.

Baldwin, R. A. 2012. Identifying the level of use of aluminum phosphide for controlling burrowing pests in California. University of California, Davis. Final Report to CDFA.

Baldwin, R. A., and B. A. Holtz. 2010. Fumigation of California ground squirrels revisited: are fumigants an effective method for controlling ground squirrels? Proc. Vertebr. Pest Conf. 24:129-132.

Baldwin, R. A., and N. Quinn. 2012. The applicability of burrow fumigants for controlling Belding's ground squirrels in alfalfa. Proc. Vertebr. Pest Conf. 25:160-163.

Baldwin, R. A., and T. P. Salmon. 2011. The facts about rodenticides. The Wildl. Prof. 5:50-53.

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

Marsh, R. E. 1992. Reflections on current (1992) pocket gopher control in California. Proc. Vertebr. Pest Conf. 15:289-295.

Marsh, R. E. 1994. Current (1994) ground squirrel control practices in California. Proc. Vertebr. Pest Conf. 16:61-65.

Marsh, R. E. 1998. One hundred years of pocket gopher traps and trapping. Proc. Vertebr. Pest Conf. 18:221-226.

McDonald, J. H. 2009. Handbook of Biological Statistics, 2nd Ed. Sparky House Publishing, Baltimore, MD.

O'Connell, R. A. 1994. Trapping ground squirrels as a control method. Proc. Vertebr. Pest Conf. 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 Prot. 17:135-138.

Salmon, T. P., and R. A. Baldwin. 2009. Pest Notes: Pocket gophers. Publication 7433, Statewide Integrated Pest Management Program, Div. of Agricultural and Natural Resources, Univ. of California. 5 pp.

Salmon, T. P., W. P. Gorenzel, and W. J. Bentley. 1982. Aluminum phosphide (Phostoxin) as a burrow fumigant for ground squirrel control. Proc. Vertebr. Pest Conf. 10:143-146.

Salmon, T. P., and R. H. Schmidt. 1984. An introductory overview to California ground squirrel control. Proc. Vertebr. Pest Conf. 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*). Wildl. Res. 34:14-18.

Salmon, T. P., D. A. Whisson, and W. P. Gorenzel. 2000. Use of zinc phosphide for California ground squirrel control. Proc. Vertebr. Pest Conf. 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. 35 pp.

Stroup, R. L. 1990. Chemophobia and activist environmental antidotes: Is the cure more deadly than the disease? Pp. 193-213 *in*: W. Block (Ed.), Economics and the Environment: A Reconciliation. The Fraser Institute, Vancouver, BC, Canada.

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*). Proc. Vertebr. Pest Conf. 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). Pp. 211-231 *in*: G. A. Feldhamer, B. C. Thompson, and J. A. Chapman (Eds.), Wild Mammals of North America: Biology, Management, and Conservation, Second Ed. The Johns Hopkins University Press, Baltimore, MD.

Zar, J. H. 1999. Biostatistical Analysis. Prentice-Hall, Inc., Upper Saddle River, NJ.