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Urbanization poses many threats for many wildlife species. In addition to habitat loss and fragmentation, non-target wildlife species are vulnerable to poisoning by rodenticides, especially acutely toxic second generation anticoagulant rodenticides (SGARs). Although such poisonings are well documented for birds and mammals worldwide, the pathways by which these widely available compounds reach non-target wildlife have not been adequately studied, particularly in urban landscapes. Long-term studies of wild carnivores in and around Santa Monica Mountains National Recreation Area, a national park north of Los Angeles, have documented >85% exposure to anticoagulant rodenticides among bobcats, coyotes, and mountain lions. To investigate potential mechanisms of transfer of chemicals from residential users of rodenticides to non-target wildlife in the Santa Monica Mountains in Los Angeles County, California, we distributed surveys to residents in two study areas on the north (San Fernando Valley) and south (Bel Air-Hollywood Hills) slopes of these mountains. We assessed knowledge of residents about the environmental effects of rodenticides, and for information about individual application of chemicals. We asked for the same information from pest control operators (PCOs) in both study areas. Forty residents completed the survey in the San Fernando Valley area, and 20 residents completed the survey in Bel Air-Hollywood Hills. Despite the small number of total responses, we documented a number of important findings. Homeowners (as opposed to gardeners or PCOs) were the primary applicators of rodenticides, predominantly SGARs, and awareness of the hazards of secondary poisoning to wildlife was not consistent. Some residents reported improperly applying rodenticides (e.g., exceeding prescribed distances from structures), and in one instance a respondent reported observing dead animals outside after placing poison inside a structure. Improper application of SGARs that ignores label guidelines occurs in neighborhoods along the urban–wildland interface, thereby providing a transmission pathway for chemical rodenticides to reach native wildlife. Moreover, the responses suggest that even on-label use (e.g. placing poisons inside) can create risk for non-target wildlife.

Keywords
Anticoagulant, non-target species, urban carnivores, secondary poisoning, second generation anticoagulant rodenticides

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INTRODUCTION

Rodent control is a widespread activity in the U.S. Of the $90 million per year that residents spend on rodent control products, 90% of those products are in the dry bait category, such as anticoagulants (U.S. Environmental Protection Agency 2006). Genetic resistance to the first-generation anticoagulant rodenticides (e.g., warfarin) has led to development of a second generation of anticoagulant pesticides that are used against small mammal pests of households and agricultural crops (i.e., Norway and black rats, *Rattus norvegicus* and *R. rattus*, and house mice, *Mus musculus*) (Hadler and Buckle 1992). Second-generation anticoagulant rodenticides (SGARs; e.g., brodifacoum, bromadiolone, difethialone, difenacoum, and flocoumafen) are faster acting, more toxic, and more persistent in the environment than their first generation predecessors (Hadler and Buckle 1992; Whisson 1996). Although successful at controlling rodent pests, SGARs globally also contribute to non-target species mortality, such as in New Zealand (Alterio 1996), France (Lambert et al. 2007; Berny and Gaillet 2008), Britain (McDonald et al. 1998; Shore et al. 2003), and Canada (Thomas et al. 2011). In the US, many non-target species have been poisoned by SGARs (Stone et al. 1999; Way et al. 2006; Riley et al. 2007; Uzal et al. 2007; U.S. Environmental Protection Agency 2008; Albert et al. 2010).

Rodents that ingest SGARs may display behaviors that facilitate the ability of predators to capture them (Cox and Smith 1990). Internal hemorrhage greatly affects limb movement, thereby increasing lethargy and decreasing mobility of poisoned rodents. Cerebral hemorrhages can interrupt thigmotaxis, a behavioral mechanism that would normally lead an animal to maximize use of available cover (Cox and Smith 1990; Brakes and Smith 2005). Therefore, we might expect poisoned rodents to be at greater risk of being captured as prey than healthy animals. In turn, opportunistic predators may be at a particular risk because they seek prey that can be caught easily. Consumption of either prey or carcasses contaminated with rodenticides may lead to poisoning of a predator (Brakes and Smith 2005; Rattner et al. 2011). SGARs can even affect wildlife as a result of consuming contaminated invertebrates, contaminated soil, or baits that have been removed from bait stations by rodents (Dowding et al. 2010). Even if products are used inside buildings, poisoned rodents may travel outside where predators could catch them (Stone et al. 1999).

Non-target species that have been documented as being exposed to SGARs in the United States and Canada include barn owl, barred owl, and great horned owl (Albert et al. 2010), gray squirrel, raccoon, white-tailed deer, and red-tailed hawk (Stone et al. 1999), bobcat, coyote and mountain lion (Way et al. 2006; Riley et al. 2007; Uzal et al. 2007), and red fox, striped skunk, and raccoon (U.S. Environmental Protection Agency 2008). In New York State during a 27-year period brodifacoum was involved in 84% of the poisoning cases evaluated (Stone et al. 1999). In one instance, the source of the exposure was determined to be brodifacoum applied in barns and sheds where an owl subsequently was found nearly dead from exsanguination caused by a small laceration on a toe (Stone et al. 1999). This example documents that even though rodenticides were used inside buildings, poisoned rodents traveled outside where predators could catch them. Secondary poisoning — where a non-target species consumes a poisoned target species — caused by these compounds has also been linked to increased disease prevalence, specifically increased susceptibility to parasitic mange in bobcats (Riley et al. 2007).

Urban carnivores are predisposed to secondary poisoning because of habitat use in proximity to residential neighborhoods where these poisons are used (Riley et al. 2003; Gehrt and Riley 2010). In fact, besides road kills, poisoning by rodenticides has been identified as a cause of mortality for urban coyote (*Canis latrans*; Gehrt and Riley 2010), bobcat (*Lynx rufus*; Riley et al. 2010), San Joaquin kit fox (*Vulpes macrotis*; Cypher 2010), and mountain lion (*Puma concolor*; Beier et al. 2010). Others suspect that SGARs may be used to intentionally poison wildlife (Way et al. 2006). The prevalence and severe consequences of SGAR intoxication warrant further investigation.

Use of rodenticides in the agricultural conditions in Europe has been investigated through user surveys (Tosh et al. 2011). These results indicated that users were generally aware of the effects on non-target species, but did not always follow all best practices for application (Tosh et al. 2011). In contrast, few residential users in a previous study in California were aware of non-target species impacts (Morzillo and Mertig 2011a). The application practices of residential users on the urban–wildland interface are not well described, which motivated this study.

We investigated rodent control in a region where secondary poisoning of carnivores has occurred (Riley et al. 2007; Gehrt and Riley 2010). Our objective was to determine potential starting points of pathways through which rodenticides applied at single-family residences eventually could reach non-target wildlife. In other words, we asked, where might anticoagulant rodenticides enter the “natural” environment? Besides describing rodenticide use, we sought to confirm that one SGAR pathway to non-target species is through improper applications by homeowners. SGAR label instructions specify that the baits be applied “inside and along the outside walls of buildings” (U.S. Environmental Protection Agency 1998). We also assessed user knowledge of non-target impacts and compared use of rodent control methods by residents with those of licensed Pest Control Operators (PCOs).

METHODS

This research was a senior-level student-directed project as part of the Environmental Science Practicum at the University of California, Los Angeles (UCLA). There, seniors pursue research projects for an off-campus client, in this instance, the National Park Service at Santa Monica Mountains National Recreation Area (SMMNRA). For purposes of student training, the class was separated into two groups, each with its own study area adjacent to SMMNRA.

Study Areas

Each study area represents an area of urban–wildland interface where residential neighborhoods overlap with habitat of native wildlife, including mountain lions, bobcats, and coyotes. Extensive exposure to anticoagulant rodenticides has been reported within and surrounding SMMNRA (Riley et al. 2003; Riley et al. 2007; Gehrt and Riley 2010). Morzillo and Mertig (2011a, b) evaluated factors affecting use of chemical rodenticides by homeowners in an area adjacent to the western boundary of the current study area.

San Fernando Valley (SFV). This study area contained low- to medium-density residential development, as well as some commercial development and golf courses (Figure 1).

The 101 and 405 Freeways border the study area on the north and east. We further defined the northern boundary of the study area as Ventura Boulevard because it marks the northern (inland) extent of the Santa Monica Mountains.

Bel Air-Hollywood Hills (BA-HH). This study area included the coastal slope of the Santa Monica Mountains south of the 405 Freeway and the 101 Freeway intersection (Figure 1). This area is characterized by highly fragmented open space interspersed with residential development in canyons (Beverly Glen, Benedict, Coldwater, Laurel) and on ridgelines (e.g., Bel Air, Beverly Hills, and Hollywood Hills). Open space lies to the west and Griffith Park (largest natural park in the city of Los Angeles; 1,744 ha) is found to the east. This area is almost exclusively low-density residential with many large homes.

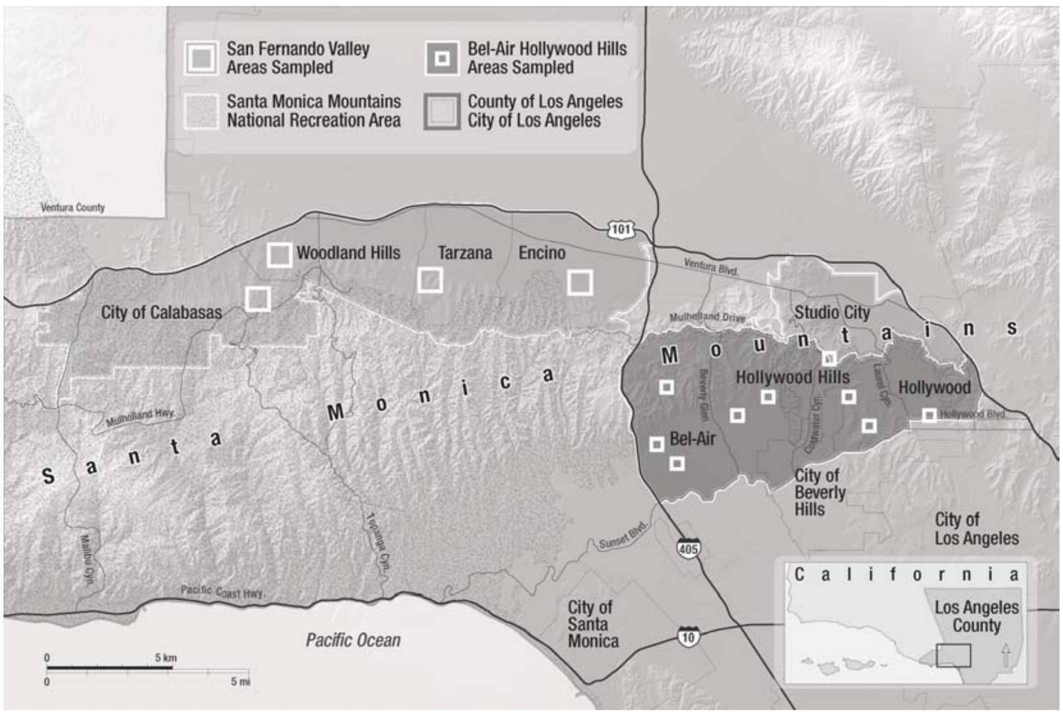

Figure 1. Study areas in San Fernando Valley and Bel-Air to Hollywood Hills. Fliers were distributed to residences indicated by squares.

Survey Design

We developed a series of questions to collect information about rodenticide use, application, and knowledge about related environmental effects (see Appendix A). We employed our survey using an online questionnaire. This method was used because of its low-cost advantage, as well as ease of accessibility, delivery, and response times (e.g., Couper 2009; Poole and Loomis 2009). We acknowledge that several concerns, such as coverage error and potential for response inconsistencies have been linked to use of internet questionnaires (e.g., Couper 2009; Poole and Loomis 2009).

The first part of the survey included an introduction to inform participants of the purpose of the survey, consent information, a description about how the data would be used, and an estimate of the time it would take to complete the survey (Warwick and Lininger 1975). The next several sections investigated if rodenticides were used, products used, target species, application process, and awareness of non-target effects. To ensure recall of the type of rodenticide used, we provided a list of brand names with photographs. Respondents therefore had both the names of the products and a visual reminder of the color and design of the packaging to make their choices about use of chemical rodenticides. We also asked general demographic questions including income, property size, education, age, and ethnicity. All questions in the survey except date of birth were closed questions. Each question was contained on its own webpage to avoid confusion. Finally, the survey ended with a "thank you" for the participants and an invitation to enter into a random drawing for a $50 gift card. The UCLA Institutional Review Board granted the use of human subjects (IRB Exempt Protocol #10-065).

Recruitment of Participants

In March 2010, we contacted Home Owners Associations (HOAs) and Residents Associations for assistance with recruiting resident participants for the online survey. In SFV, two associations agreed to participate; one announced the study using a digital flier, and the other in a digital newsletter. For associations where no residents responded to the electronic solicitation, we also distributed fliers door-to-door (see Appendix B). All recruited participants were limited to occupants of single-family residences.

We placed fliers either on the door handle or on the doormat, with the UCLA seal and title of the project clearly visible. When homeowners were present, we briefly explained the project and invited them to participate. Fliers were placed near the gate or the security keypad of gated properties.

In SFV, we focused on the areas closest to SMMNRA (Riley et al. 2006). This area included areas within Encino, Woodland Hills, Calabasas, and Tarzana. For each of the areas, we randomly selected grids from the Thomas Guide Map, 2007 Edition; each grid contained 250–350 homes. In BA-HH, we used Google Earth to create a quarter-mile-square grid within this study area. We used a random number generator to select nine grid cells within BA-HH (Figure 1). If a selected area lacked residential areas, we used the random number generator to select replacement areas until we had 9 suitable areas. We then walked door-to-door and distributed fliers. In SFV, we delivered 1,200 fliers. In BA-HH we delivered 460 fliers. The difference in the number of fliers is attributed to variation in building density.

Pest Control Operator Interviews

We interviewed managers of pest control operators (PCO) to obtain information about the types of chemicals used, techniques used to apply chemicals, distribution of these chemicals (i.e., where and when they were used), as well as the primary reasons that homeowners retained their services (see Appendix C). We used a phone directory to compile a list of PCOs for each study area and randomly selected companies to sample. We also initiated contacts to any PCO reported by respondents to the online survey.

RESULTS

Survey of Residents

In SFV, 53 people completed online survey; 13 of these responses did not qualify for further analysis. In BA-HH, we received response from 21 residents; one of these responses did not qualify for further analysis. The age of respondents between the two areas did not differ (Student's T test, $p < 0.80$; average age = 55) nor did their ethnicity (Chi-square, $p < 0.27$; overall 95.5% white) or education level (Chi-square, $p < 0.83$; overall 87.9% with bachelor's degree or more).

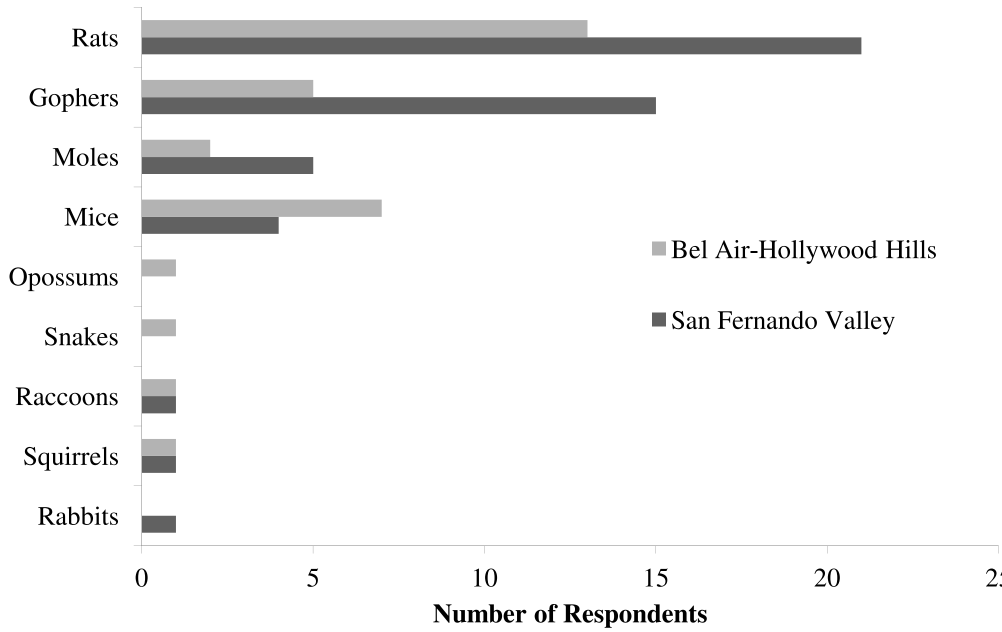

Figure 2. Target species for homeowner rodent control for two study areas in urban–wildland interface areas of the Santa Monica Mountains, Los Angeles County. Respondents could select more than one target species. Several responses were volunteered (raccoons, snakes and rabbits).

In SFV, 65% of respondents used some form of rodent control on their property within the last year, as did 75% in BA-HH. Rats were the most commonly cited target species in both locations, followed by mice and gophers in BA-HH, and gophers and moles in the SFV (Figure 2). Despite the greater proportion of respondents targeting gophers in SFV, the profile of target species was not significantly different between the two areas (Pearson's Chi-square, $p < 0.37$).

Most households applied rodent control themselves in both SFV (62.5%, 25 of 40) and BA-HH (60%, 9 of 15). Gardeners also applied rodent controls (SFV = 17.5%; BA-HH = 6.6%). In BA-HH area, 28% of respondents hired a pest control company but also applied chemicals themselves.

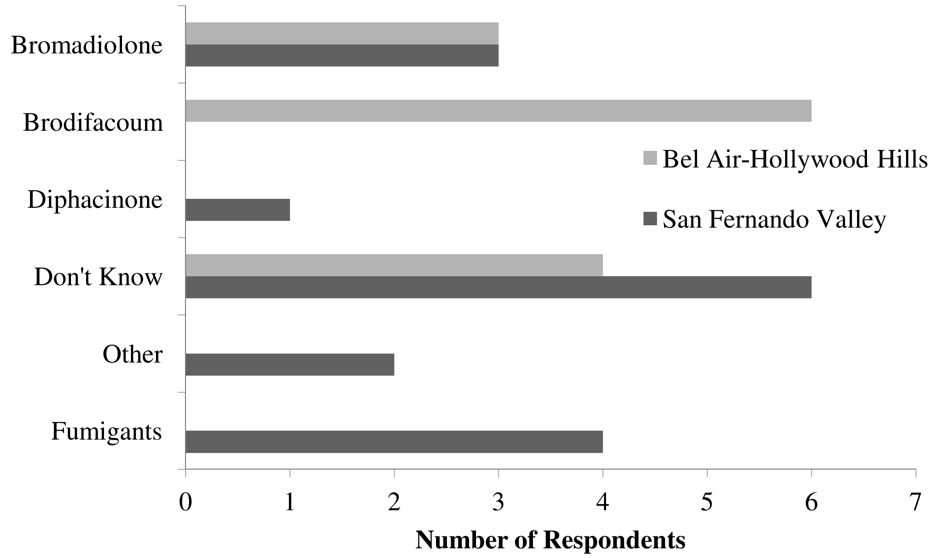

Figure 3. Types of chemical rodenticide used on residential properties in two study areas in urban–wildland interface areas of the Santa Monica Mountains, Los Angeles County. Respondents were able to select multiple answers. Active ingredients from brand name products are listed.

The most commonly reported chemicals in SFV were fumigants, whereas SGARs (active ingredient brodifacoum) were most common in BA-HH (Figure 3). For both areas together, respondents who used anticoagulant rodenticides either could not recall a specific brand name, or if they did, 12 of 13 products uses reported were second-generation (i.e., brodifacoum or bromadiolone). The profile of rodenticides used in the two areas differed substantially (Pearson's Chi-square, $p < 0.09$), with the fumigants being used in SFV and not in BA-HH.

In both locations, households that indicated use of anticoagulants, respondent application of it ranged from monthly to twice per year or variably. From the categories provided on the survey, 10 SFV and 5 BA-HH respondents reported placing SGARs outside away from walls up to 300 and 100 feet away from buildings respectively (Figure 4). Homeowners observed dead rodents (target species) outside after chemical application in both study areas. The median distance category was 1–10 feet for both SFV and BA-HH, and ranged upwards to 30–100 feet away. Of the respondents who placed SGARs outdoors, four observed dead animals outdoors. One homeowner placed a product only *inside* his garage and subsequently found dead animals both inside and outside of the structure.

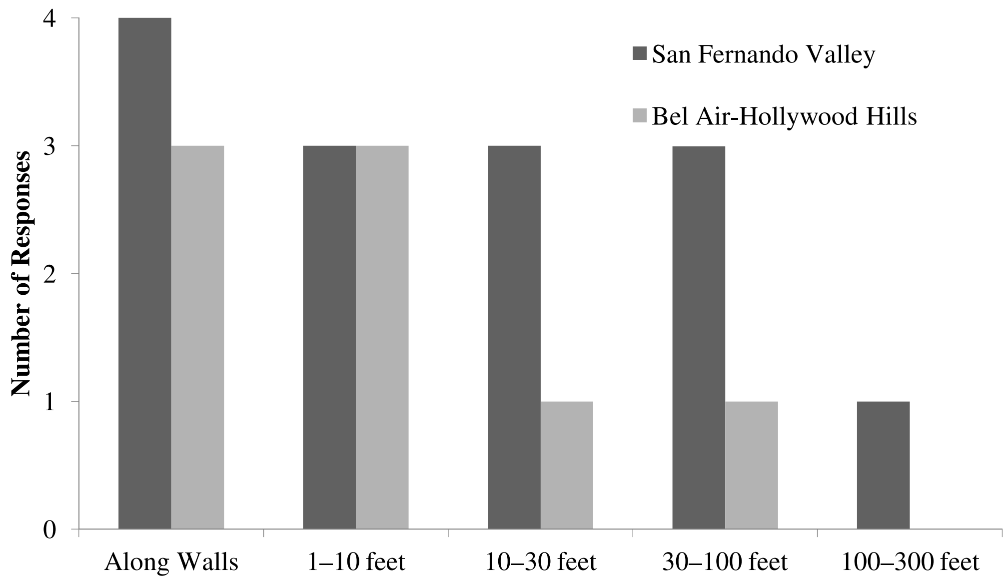

Figure 4. Distribution of anticoagulant rodenticide application outdoors on residential properties in two study areas in urban–wildland interface areas of the Santa Monica Mountains, Los Angeles County. Respondents were able to select multiple answers.

In SFV, 66% of participants (4 of 6) admitted knowing that chemicals used in rodent control, as well as anticoagulants, might be affecting local wildlife. In BA-HH, 35% homeowners (7 of 20) knew about effects of SGARs on wildlife. Five people did not know and 8 people did not answer the question.

Surveys of Pest Control Operators (PCOs)

Five of 23 PCOs contacted in SFV responded to our survey. All 5 PCOs stated that they primarily control mice and rats, and use snap traps. Four also responded that they use chemical baits, and 2 used exclusion techniques. For those that used chemicals, 3 used SGARs and 2 used available first generation anticoagulants.

All PCOs stated that the main reason they are contacted is because of indoor rodents; two of those PCOs also stated as many calls about rodents in outdoor landscaping. All 5 companies inform homeowners about products used; 2 companies inform homeowners about locations of traps or bait. All PCOs reported placing rodenticides within 1 foot of fences and buildings, while one each reported placement up to 60 feet from buildings.

Only 2 of 37 (5.4%) PCOs from the BA-HH area responded. Neither company used chemicals; both used snap traps and exclusion techniques.

DISCUSSION

Homeowners reported applying rodenticides in ways that are prohibited by package instructions. Thus, this is a probable pathway for transfer of SGARs to other wildlife. Because our study areas are known to have nearby carnivore populations, we can speculate that wildlife may encounter the poison directly, and, more importantly, can encounter as contaminated prey animals, alive or dead.

The two compounds (brodifacoum, bromadiolone) most frequently detected by Riley et al. (2007) in mammalian carnivores were the same most frequently reported as used by respondents in our survey (Figure 3). Similarly, bromadiolone and brodifacoum were the two most common compounds found in more than 100 mountain lions tested from around the state of California (R. H. Poppenga, personal communication, December 8, 2010). Respondents also reported use of the first-generation anticoagulant poison diphacinone, but this chemical is also highly toxic to birds and mammals (Rattner et al. 2011).

Entire housing developments in our study area may contribute to secondary poisoning through systematic use of SGARs. One homeowner noted on their returned survey that her HOA had applied numerous bait stations containing difethialone around homes for many years, but has since changed to a more environmentally friendly method.

We speculate that homeowners with pets may be more wary of using chemical rodenticides; one homeowner stated that "[We] used the poisons before but not anymore because of the cat and also the hawks." This was consistent with Morzillo and Mertig's (2011a) suggestion that concern about rodenticides affecting wildlife was the most significant predictor of the potential for residents to change their pest control behavior.

Stricter U.S. Environmental Protection Agency regulations on pesticides took effect in June 2011 (U.S Environmental Protection Agency 2008). These regulations significantly reduce the availability of SGARs to homeowners by prohibiting their sales in grocery stores, drug stores, and hardware stores. They also specify that these products must be sold in a preloaded bait station or in bulk quantities. Such changes are intended to decrease the potential for exposure of non-target wildlife (U.S. Environmental Protection Agency 2008).

The EPA's mitigation measures contain an implicit assumption that homeowners are more likely than a pest control operator to misuse products, which is consistent with our data (even with our small sample size). If residential users do not follow directions carefully when products are available, reducing availability of SGARs may be an effective action to reduce improper use and subsequent effects on wildlife. It may be beneficial to re-survey homeowners after the effective date of new restrictions to determine if rodent control practices have changed and whether these restrictions are an effective way to reduce homeowner use of SGARs. Licensed applicators may account for a great deal of use of these chemicals, and the use of their services may increase with decreased availability of products to homeowners. Currently, 58% of residents near our study area report self-applying rodent control products (Morzillo and Mertig 2011b), so the EPA rule change may have a substantial effect.

The geography of our study sites limited our ability to distribute fliers easily, and may have contributed to low response rate. Some locations were gated or depositing fliers was not allowed. The homeowner or upkeep staff may not have seen the flier or interpreted it as junk mail. Therefore, our challenges revealed a difficulty with trying to recruit participants living in affluent areas by media other than mail or telephone.

Some potential biases were unavoidable. First, the title and purpose of the survey may have caused participants to make assumptions about what responses were expected by surveyors. Second, those who are not using rodent control may have felt it unnecessary to participate. Conversely, the UCLA Institute of the Environment as the research group may have led participants choose “environmentally friendly” answers, or to not respond in general. The probability of response may also have been affected by unwillingness to report behavior that might be construed as being irresponsible or illegal and those who have a low level of environmental awareness or interest may not respond either, although eligibility to win a gift certificate was provided as incentive for participation to offset this tendency. Nevertheless, the results do show that off-label use of SGARs does occur, which justifies further investigation.

Future studies should attempt to obtain a greater response rate from both homeowners and PCOs. Regardless, this research yielded: (1) the finding that off-label use was common among respondents, while our very small sample of PCOs reported following guidelines, and (2) information about logistics of surveying by an online questionnaire with participants solicited by fliers delivered to their homes. Although Morzillo and Mertig (2011a, b) had previously investigated what type of chemical products were used and where products were applied, they did not report on whether compounds were first- or second-generation ARs or how exactly residents applied the chemicals. Further research using mailed surveys and multiple follow-up techniques could be used to confirm and generalize the results of our findings and should be expanded to further explore the influence of attitudes about wildlife and potential non-target poisoning (e.g., pets) on SGAR use. Such an approach could also track the effects of the EPA’s rule change. It would also be useful to add questions about where residents buy their rodent-control products and inquire about the factors that influence the choice of product. Our results have provided preliminary results that could aid in developing such expanded survey instruments.

To mitigate poisonings now, we recommend outreach programs discussing the potential effects chemical products on wildlife. Near our study area, Morzillo and Schwartz (2011) found relationships between rodent control and resident proximity to natural areas. Thus, for example, property owners next to natural areas and who control rodents also might be gently reminded to review product application directions. Awareness or outreach may solve the problem. Yet, at least two respondents who claimed to know about the adverse effects of SGARs on wildlife also reported using them, so regulation will still be key to any approaches to reduce exposure of non-target species to SGARs.

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APPENDICES

Appendix A: Survey Questionnaire

1. Information sheet for consent to participate in a research study. By reading and accepting this questionnaire, I am agreeing to participate in this study.
   - _ Yes, I agree to participate in this study.
   - _ No, I do not agree to participate in this study.

2. Do you currently live in [survey area]?
   - _ Yes
   - _ No

3. Do you live in a single-family residence?
   - _ Yes
   - _ No

4. Do you live south of Ventura Boulevard?
   - _ Yes
   - _ No

5. Has any form of rodent control been used on your property in the past year?
   - _ Yes
   - _ No

6. What animals are/were you trying to control for? (check all that apply)
   - _ Mice
   - _ Rats
   - _ Gophers
   - _ Moles
   - _ Squirrels
   - _ Opossums
   - _ Raccoons
   - _ Skunks
   - _ Other _________

7. What caused your household to begin controlling these animals on your property? (check all that apply)
   - _ Observed animals indoors
   - _ Observed animals outdoors
   - _ Damage observed to own structures
   - _ Damage observed to neighbor’s structures
   - _ Damage observed to own landscaping (including garden, lawn, etc.)
   - _ Damage observed to neighbor’s landscaping (including garden, lawn, and etc.)
   - _ Preventative use
   - _ Part of routine treatment by hired company
   - _ Other _________

8. Who applied the rodent control? (check all that apply)
   - _ Member of household
   - _ Pest control company

- _ Gardener/landscape company
- _ Not sure
- _ Other _________

9. If you answered with Pest Control company, please specify which company:
- _ Don't remember
- _ Please specify: _________

10. If you answered with Pest Control company above, did they provide you with information about the products they applied?
- _ Yes
- _ No
- _ Not sure
- _ Not applicable

11. Which, if any, of the following non-chemical rodent control methods have been used on your property in the past year: (check all that apply)
- _ Snap traps
- _ Glue boards
- _ Live traps
- _ Shooting
- _ Electricity (i.e. rat zapper)
- _ Ultrasound deterrents
- _ Preventative methods (e.g. securing access points, cutting vegetation)
- _ Don't know
- _ None

12. [Brand images] Which, if any, of the following brands of chemical rodent control methods have been used on your property in the past year: (check all that apply)
- _ d-con
- _ Tomcat Liquid
- _ Tomcat Bait Stations
- _ Tomcat Quickstrike
- _ Tomcat Pellets, Blocks, and Trays
- _ Moletox
- _ Wilco Baits
- _ Victor Fast-Kill
- _ Victor Multi-Kill
- _ Ratol
- _ FirstStrike
- _ Rodetrol
- _ Other fumigants (e.g. gas canisters)
- _ Other nerve agent (e.g. Bromethalin)
- _ Zinc phospide
- _ Don't know
- _ None
- _ Other

13. If chemical rodent control is applied on your property, how often is it applied?
- _ Approximately every month or more often

- _ Approximately every other month (6 times per year)
- _ Approximately every four months (3 times per year)
- _ Approximately twice a year
- _ Approximately once a year or less often
- _ Other _________

14. If chemical rodent control is applies on your property, in what locations INSIDE of structures is it used? (check all that apply)

- _ Basement
- _ Crawlspace
- _ Attic
- _ Another location within home
- _ Garage
- _ Outbuilding
- _ Not applied
- _ Other _________

15. If chemical rodent control is applied on your property, in what locations OUTSIDE structures is it used? (check all that apply)

- _ Along walls of any building (within 1 foot)
- _ Between 1 and 10 feet from any building
- _ Between 10 and 30 feet from any building
- _ Between 30 and 100 feet from any building
- _ Between 100 and 300 feet from any building
- _ More than 300 feet from any building
- _ Not applied outside

16. Has anyone in your household found dead animals at the following locations INSIDE structures after chemical rodent control methods have been applied? (check all that apply)

- _ Basement
- _ Crawlspace
- _ Attic
- _ Another location within home
- _ Garage
- _ Outbuilding
- _ Not applied
- _ Other _______

17. Has anyone in your household found dead animals at the following locations OUTSIDE structures after chemical rodent control methods have been applied? (check all that apply)

- _ Along walls of any building (within 1 foot)
- _ Between 1 and 10 feet from any building
- _ Between 10 and 30 feet from any building
- _ Between 30 and 100 feet from any building
- _ Between 100 and 300 feet from any building
- _ More than 300 feet from any building
- _ Not applied outside

18. Are you aware that chemicals used for residential rodent control may be affecting wildlife in your area?

- Yes
- No

19. Does your household have a pest with access to the outside?
    - Yes
    - No

20. Does anyone under 18 years old live in your household?
    - Yes
    - No

21. How large is your property?
    - Less than 5,000 square feet (0.1. acre)
    - 5,001–7,000 square feet (0.11–0.16 acre)
    - 7,001–10,000 square feet (0.17–0.23 acre)
    - 10,001–21,779 square feet (0.24–0.49 acre)
    - 0.5–1 acre
    - More than 1 acre

22. What is your annual household income?
    - Less than $50,000
    - $50,000 to $75,000
    - $75,001 to $100,000
    - $100,001 to $150,000
    - $150,001 to $200,000
    - $200,001 to $300,000
    - More than $300,000

23. What is the highest level of education you have completed?
    - Less than high school
    - High school or FED
    - Vocation or trade school
    - Some college
    - Associate's (2 year) degree
    - Bachelor's (4 years) degree
    - Graduate or professional degree

24. Please specify your year of birth.

25. What is your ethnic background?
    - White/Caucasian
    - Black/African American
    - Asian/Pacific Islander
    - Hispanic/Latino
    - Other _______

Thank you for your participation!

If you wish to be entered into a drawing for a $50 Best Buy Gift Card, please email your contact information to [student email]. Your email will not be associated with your responses to the survey and we won't share your email with anyone or send you messages.

Appendix B: Door-to-door Recruitment Flier

UCLA Institute of the Environment Senior Environmental Science Practicum

Methods of Rodent Control in Residential Areas Surrounding the Santa Monica Mountains

The purpose of the survey is to study the reasons for and the use of rodent control methods around the Santa Monica Mountains. The survey is expected to last only 5 – 10 minutes, and your participation is completely voluntary. You may exit at anytime without any consequences, and all data collected in this survey will be kept confidential.

Upon completion of the survey, you will have the option to email us to enter yourself in a drawing to win a $50 Best Buy gift card.

The link for the survey is as follows: **[*website*].**
You will be directed to a UCLA Institute of the Environment Website. Please click on Rodenticide Usage Study to participate in the survey. The deadline to participate in the survey is [*date*]

If you have any questions, feel free to contact [*name*] at [*email*], or Dr. Travis Longcore, our faculty advisor, at longcore@ucla.edu. Thank you for your time.

Appendix C: Pest Control Company Interview Questionnaire

1. What areas does your company currently service?

2. How does your company control for rodents?
   2a. If you use chemical rodent control, which chemicals does your company use?
   2b. If you use physical rodent control, which methods does your company use?

3. Does your company control for _____?
   - _ Mice
   - _ Rats
   - _ Gophers
   - _ Moles
   - _ Squirrels
   - _ Opossums
   - _ Raccoons
   - _ Skunks
   - _ Other _________

4. Do your customers tell your company why they need rodent control?
   - _ If so, what are the main reasons you hear?

5. What information does your company provide to customers regarding rodent control?

6. How often do you apply/reapply rodenticides at an average household?

7. Does your company apply rodent control inside structures?
   - _ If so, where? (Garage, basement, crawl space, attic, etc.)

8. Does your company apply rodent control outside structures?
   - _ If so, at what distances from buildings?

About

ONE VOICE SINCE 1898

For more than 125 years, the California Grocers Association has served as the voice of the state's grocery community. A nonprofit, statewide trade association, CGA's membership is comprised of over 300 retailers operating more than 6,000 brick-and-mortar stores, and approximately 150 grocery supply companies.

The Association is recognized as the leading resource in the areas of government and industry relations for California's food industry and its customers while also providing continuing education opportunities for industry employees and their children.

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CGA serves as the waypoint for California's grocery industry. With more than 400 member companies our community includes most of the state's grocery retailers and a number of their suppliers.

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CONTACT US

Northern spotted owl | Dave Roelofs, BLM

PESTICIDE EXPOSURES & MORTALITIES IN NON-TARGET WILDLIFE

CALIFORNIA DEPARTMENT OF FISH & WILDLIFE

2022 Annual Report
Wildlife Health Laboratory
31 July 2023

2022 SUMMARY OF PESTICIDE EXPOSURES & MORTALITIES IN NON-TARGET WILDLIFE

By Jaime Rudd, Krysta Rogers, & Nicholas Shirky

With contributions from Deana Clifford and Brandon Munk

PREPARED BY THE WILDLIFE HEALTH LABORAOTRY OF THE CALIFORNIA DEPARTMENT OF FISH & WILDLIFE

State of California
Natural Resources Agency

INTRODUCTION

It is the mission of the California Department of Fish and Wildlife (CDFW) to manage California's diverse fish, wildlife, and plant resources, and the habitats upon which they depend, for their ecological values and for their use and enjoyment by the public. As such, a memorandum of understanding was developed between the California Department of Pesticide Regulation (CDPR), the County Agriculture Commissioners (CAC), and the CDFW. The purpose of the memorandum is to ensure that pesticides registered in the state of California are used in a manner that protects non-target fish and wildlife resources, while recognizing the need for responsible pest control.

In partial fulfillment of the MOU, this 2022 annual report summarizes documented pesticide exposure and toxicosis in California's fish and wildlife for the respective authorities of CDPR, CAC, and CDFW. These data represent a minimum number of reports for tested animals that died within the reported calendar year and are subject to change as new information becomes available.

DATA COLLECTION & ANALYSIS

The Wildlife Health Laboratory (WHL, formerly the Wildlife Investigations Laboratory) was established in 1941 and is mandated by Fish and Game Code Section 1008 to investigate all diseases and problems relating to wildlife. The WHL has accomplished this goal through collaboration with the public and various organizations to record, collect, and submit wildlife mortalities of interest to the WHL for examination and further diagnostics as needed. The WHL continues communication with interested parties as new information is discovered to aid further cooperation in the goal of maintaining healthy wildlife populations throughout the state.

Programmatically the WHL is divided into three units which address health issues: 1) avian, 2) large game, 3) small and non-game species. The avian unit oversees nearly 600 avian species including non-game (e.g., songbirds, raptors, shorebirds, waders, and seabirds) and game species (e.g., doves, pigeons, quail, turkey, and waterfowl). The large game unit primarily oversees black bear, bighorn sheep, deer, elk, pronghorn, and wild pig with shared responsibility of small game such as tree squirrels, rabbits, and hares. In addition to sharing health surveillance responsibilities with the large game unit, the non-game unit also oversees native non-game mammals, fur bearers, reptiles, and amphibians. This includes a consortium of species such as California tiger salamander, Western Pond turtles, pika, riparian brush rabbits, skunks, raccoons, foxes, bobcats, mountain lions, and gray wolves.

Wildlife Submissions

Wildlife remains are submitted to the WHL in various ways, primarily by the public – either direct submissions of deceased wildlife to the WHL, submission of living or deceased wildlife to wildlife rehabilitation centers ("rehab"), notification of mortalities to CDFW staff and law enforcement, or other government agency reports (e.g., animal control, sheriff, state and federal Department of Agriculture, U.S. Fish and Wildlife Service, the Park Service, etc.). The WHL also collaborates with universities, non-governmental organizations (NGO), and other agencies on statewide population monitoring projects and provides diagnostic support by conducting postmortem examinations. The WHL contracts with the California Animal Health and Food Safety (CAHFS) Laboratory for further disease and toxicology testing.

Postmortem Examination

Postmortem examinations (necropsies) are performed on wildlife remains at the WHL or the CAHFS Laboratory. If remains cannot be examined within 48-hours of collection, they are stored in a -20°C freezer until an examination can be performed. Prior to necropsy, frozen carcasses are thawed for a few days at 4°C or room temperature until they are ready for necropsy. Sex, age class, body condition and, when possible, the cause of death is determined. In addition to necropsy, mortality investigations often include microscopic evaluation of tissues (histology) and ancillary disease and toxicology testing. Tissue samples are collected and placed in 10% formalin for histological evaluation and a complimentary set of tissues are archived in -20C° freezers until submitted to the CAHFS Laboratory for analysis.

Carcasses in advanced stages of decomposition and autolysis are necropsied but formalin tissues may not be collected or submitted since autolysis can obscure or destroy microscopic lesions. In these cases, necropsies are performed, and tissue samples are collected for toxicology testing to rule out pesticide exposure but not necessarily toxicosis.

Anticoagulant Rodenticides. Anticoagulant rodenticides are grouped into two categories: "first generation anticoagulant rodenticides" which include warfarin (war), coumachlor (cou), diphacinone (diph), and chlorophacinone (chl) and the more toxic "second generation anticoagulant rodenticides" which include brodifacoum (brd), bromadiolone (brm), difenacoum (dfn), and difethialone (dif).

Liver samples are submitted to the CAHFS Laboratory for testing.

Non-Anticoagulant Rodenticides & Other Pesticides. A number of acutely toxic compounds such as bromethalin, strychnine, zinc phosphide, cholecalciferol, organophosphates, and carbamates are also used to manage rodent and insect pests. Like anticoagulant rodenticides, these compounds, or their metabolites, have been documented in non-target wildlife as a form of mortality or exposure.

Appropriate tissue samples (e.g., gastrointestinal contents, adipose, brain, spinal cord, kidney, liver) for requested tests are also submitted to the CAHFS Laboratory for testing.

Exposure & Toxicosis

Pesticides, including anticoagulant rodenticides, are not always acutely fatal and there is a high degree of variability among species and individuals in their vulnerability. In the absence of a universal threshold residue value that could indicate anticoagulant rodenticide "toxicosis," we must also rely on antemortem and/or postmortem evidence of coagulopathy unrelated to another identifiable cause of hemorrhage (e.g., trauma, disease, infection).

Individuals are considered to have anticoagulant rodenticide "exposure" if their livers had detectable levels of one or more anticoagulant rodenticide residues (regardless of concentration, reported in parts per billion or ppb) and lack antemortem and/or postmortem evidence of coagulopathy.

For non-anticoagulant rodenticides, diagnosing toxicosis requires the detection of the compound in the appropriate tissue sample or gastrointestinal contents, and antemortem and/or postmortem evidence in the absence of another identifiable cause (e.g., disease, infection, trauma).

In some cases, rodenticide residues are detected in the tissue sample, but postmortem evidence could not confirm or exclude toxicosis due to advanced decomposition which precludes a definitive diagnosis. Therefore, these diagnoses are reported as "suspected" or "undetermined" toxicosis.

It is important to note that exposure in the absence of toxicosis should not be ignored[1]. The uncertainties about the magnitude and drivers of chronic exposure and/or sub-lethal levels of rodenticide exposure demonstrate the need for continued monitoring. Exposure to anticoagulant rodenticides may predispose wildlife to excessive hemorrhage following an otherwise non-lethal traumatic injury or increase sensitivity to additional exposure(s)[1].

AVIAN SUMMARY

According to CDFW records at the time of this report, the remains of 1,211 birds were submitted to the WHL for necropsy, and/or disease or toxicology testing in calendar year 2022. Note, the number of birds submitted to WHL in 2022 was roughly twice the average number of birds submitted in previous years. The primary reason for increased submissions during 2022 was the unprecedented outbreak of Eurasian highly pathogenic avian influenza H5N1 that affected a diversity of wild birds and poultry in California, elsewhere in the United States, and globally. The ability to conduct surveillance testing for other diseases and exposure to toxins was impacted by the demand for disease testing for highly pathogenic avian influenza H5N1. Further, highly pathogenic avian influenza viruses are designated as a United States Department of Food and Agriculture select agent and a reportable foreign animal disease. All tissues are required to be immediately disposed of following a confirmed detection to reduce the risk of disease spread, and thus no further testing could be performed.

Waterfowl and waterbirds (n = 563) accounted for the largest percentage of birds submitted, followed by raptors (n = 438). Birds were submitted for various reasons by wildlife rehabilitators, members of the public, non-profit organizations, universities, CDFW staff and law enforcement, and other agencies (Table 1). Wildlife rehabilitators made up the majority of submissions, followed by agencies and specifically, CDFW. However, it should be noted that the majority of these reports originated with a member of the public.

Table 1. Total number of wild bird remains submitted to the Wildlife Health Laboratory for necropsy in 2022 based on the primary submitter's affiliation. Many submissions that are non-public originated as a public report.

Submitter Affiliation	No. Birds Submitted
CDFW	198
NGO/Non-Profit	41
Other Government Agency / Military	71
Private Consultant / Energy	37
Public	38
Rehab / Zoo / Sanctuary	823
University Affiliate	3
Total	**1,211**

Anticoagulant Rodenticide Exposure & Toxicosis

Of necropsied birds, 34 were tested for anticoagulant rodenticide exposure. Tested birds represent 95% (55/58) of California counties (Table 2). All age classes and sexes were represented in submitted carcasses.

Raptors were the largest group to have anticoagulant rodenticide exposure to one or more analyte(s) and/or toxicosis (Table 3). Of the 88.2% of tested birds with detectable levels of anticoagulant rodenticides (30/34), 56.7% (17/30) were cases of anticoagulant rodenticide toxicosis.

More than half of the exposed raptors had two or more second generation anticoagulant rodenticides detected in the liver (Figure 1). Brodifacoum, bromadiolone, difethialone, and diphacinone were the most common analytes detected in liver samples (Figure 2). None of the birds sampled had detectable levels of exposure to warfarin, difenacoum, or coumachlor.

Other Pesticides

Other pesticide-related investigations involved five separate incidents of mortality including 1) a mourning dove in Sacramento County, 2) rock pigeons in Fresno County, 3) rock pigeons in San Mateo County, 4) a great horned owl in San Luis Obispo County, and 5) a red-tailed hawk in Sonoma County. Avitrol was detected in a rock pigeon submitted from Fresno and San Mateo counties where multiple pigeons were reported with seizures before death. Avitrol was also detected in a single mourning dove reported with seizures before death and submitted from Sacramento County. Strychnine was detected in a great horned owl from San Luis Obispo County and a red-tailed hawk from Sonoma County. The great horned owl had the remains of a songbird in its digestive tract and the red-tailed hawk had the remains of a mourning dove in its digestive tract. The ingested birds were the presumed source of secondary exposure for these raptors as their remains were admixed with strychnine bait in the raptors digestive tract.

American kestrel | Naser Mojtahed, USFWS

Table 2. Exposure prevalence and number of confirmed toxicosis cases of anticoagulant rodenticides in 34 tested wild birds submitted to the Wildlife Health Laboratory in 2022 by county. After postmortem examination, livers were submitted for toxicology testing to the California Animal Health and Food Safety Laboratory in Davis, CA.

County	No. Tested	No. Exposed	Percent Exposed	No. Confirmed Toxicosis
Contra Costa	1	1	100.0	1
Kern	1	1	100.0	1
Los Angeles	5	5	100.0	4
Marin	3	2	66.7	2
Mendocino	2	1	50.0	0
Napa	1	1	100.0	0
Sacramento	4	4	100.0	0
San Bernardino	2	2	100.0	1
San Diego	2	2	100.0	1
San Joaquin	1	1	100.0	0
San Luis Obispo	2	2	100.0	0
San Mateo	1	1	100.0	1
Santa Clara	3	3	100.0	2
Santa Cruz	1	1	100.0	1
Sonoma	2	1	50.0	1
Ventura	3	2	66.7	2
Total	**34**	**30**	**88.2**	**17**

Table 3. Exposure prevalence and number of confirmed toxicosis cases of anticoagulant rodenticides in 34 wild birds submitted to the Wildlife Health Laboratory in 2022 by species (common name). After a postmortem examination, livers were submitted for toxicology testing to the California Animal Health and Food Safety Laboratory in Davis, CA.

Bird Species	No. Tested	No. Exposed	Percent Exposed	No. Confirmed Toxicosis
American kestrel	1	0	0.0	0
Barn owl	5	5	100.0	2
Golden eagle	2	2	100.0	0
Great horned owl	16	14	87.5	12
Red-shouldered hawk	4	4	100.0	2
Red-tailed hawk	2	2	100.0	1
Swainson's hawk	1	1	100.0	0
Turkey vulture	3	2	66.7	0
Total	**34**	**30**	**88.2**	**17**

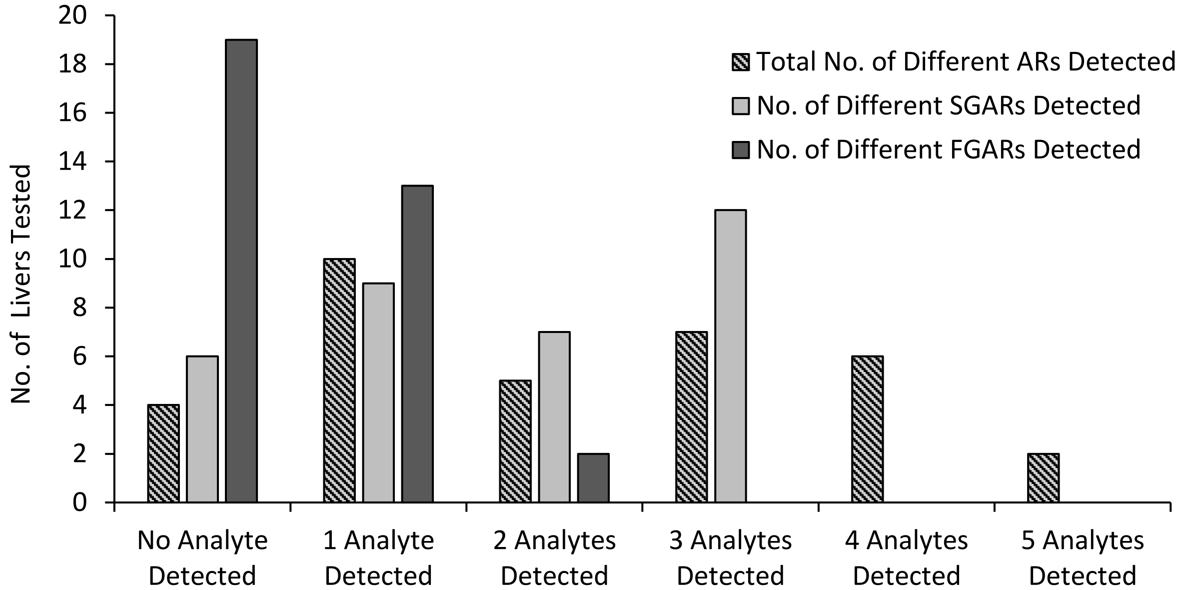


Figure 1. Number of anticoagulant rodenticide residues detected in the livers of 30 wild birds submitted to the Wildlife Health Laboratory for postmortem examination in 2022. After postmortem examination, livers were submitted for toxicology testing to the California Animal Health and Food Safety Laboratory in Davis, CA.

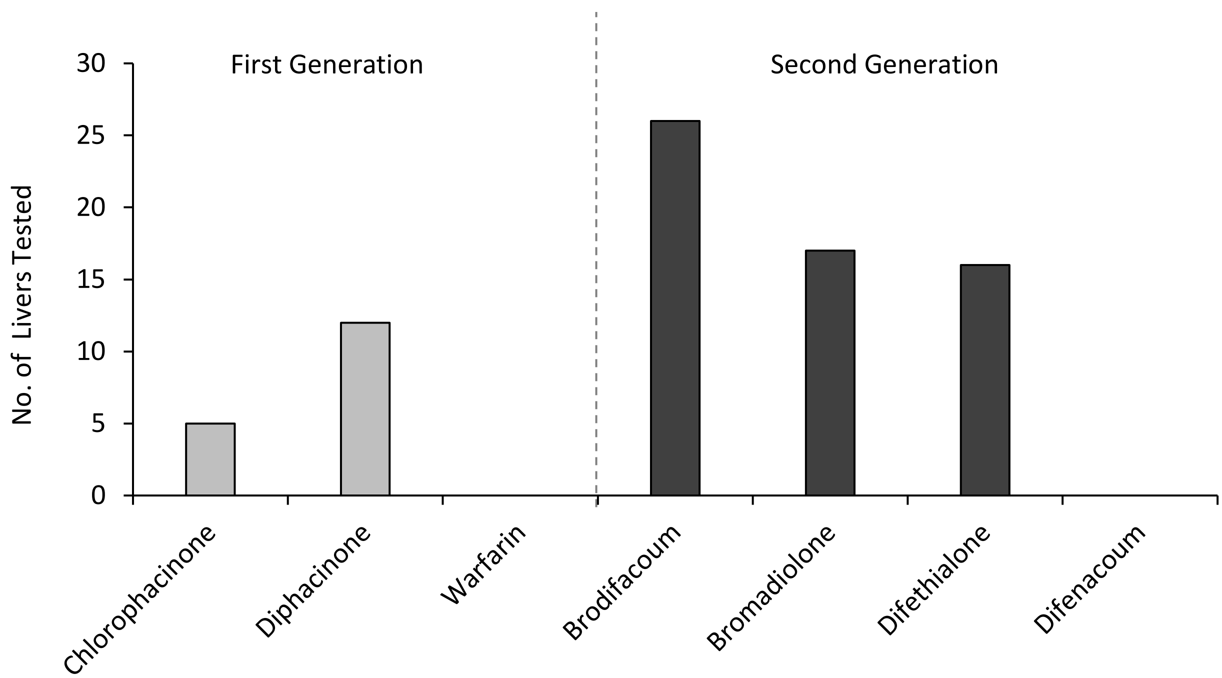


Figure 2. Anticoagulant rodenticide residues detected in the livers of 30 of the 34 tested wild birds submitted to the Wildlife Health Laboratory in 2022. Anticoagulant rodenticides were not detected in 4 of the tested bird livers. After postmortem examination, livers were submitted for toxicology testing to the California Animal Health and Food Safety Laboratory in Davis, CA.

LARGE GAME SUMMARY

The remains and/or tissues of 68 large game mammals were submitted to the WHL for necropsy and/or toxicology testing in the year 2022.

Approximately 81% (55/68) of the large game carcasses were submitted by the CDFW and other agencies (Table 4). However, it should be noted that public reports represent the original source for most CDFW submissions.

Table 4. Total number of wild large game mammal tissues or remains submitted to the Wildlife Health Laboratory in 2022 based on the primary submitter's affiliation. Many submissions that are non-public originated as a public report.

Submitter Affiliation	No. Large Game Mammals Submitted
CDFW	55
Other Government Agency / Military	1
Private Consultant / Energy	1
Public	3
Rehab/Zoo/Sanctuary	8
Total	68

Anticoagulant rodenticides

Of necropsied large game mammals, 15 were tested for anticoagulant rodenticide exposure. Large game mammals were submitted from 11 of the 58 counties in California (Table 5). All age classes and sexes were represented in submitted carcasses.

Black bears accounted for the majority of large game mammals submitted with anticoagulant rodenticide exposure (Table 6). In total, 12 of the 15 (80%) large game mammals tested had exposure to one or more anticoagulant rodenticide and almost half of the tested animals (46.7%, 7/15) had exposure to two or more anticoagulant rodenticides regardless of first- or second generation (Figure 3). One sub-adult female from El Dorado County had exposure to five different anticoagulant rodenticides.

Diphacinone and brodifacoum were the most common analytes detected in tested liver samples (Figure 4). Coumachlor was not detected in any of the submitted liver samples.

None of the 12 exposures resulted in cases of anticoagulant rodenticide toxicosis.

Other Pesticide Exposure

Adipose from 14 black bears and one wild pig, and liver from one black bear from nine California counties were tested for exposure to the neurotoxic rodenticide, bromethalin (Table 7 and 8). Three of the tested black bears and the wild pig had detectable levels of bromethalin in the submitted samples. Of the four cases where bromethalin was detected, toxicosis was determined to be the cause of death in a young black bear from Kern County with a history of ataxia, circling, and incoordination. The bear was found deceased and submitted for postmortem examination and toxicology testing at the California Animal Health and Food Safety Lab in Tulare. Segmental mild vacuolation at the grey/white mater interface of the brain and chronic demyelination with Bungner's bands of motoric nerves fibers were observed of the cauda equina nerve roots in the lumbar and sacral region with no other associated pathogens or injuries.

Two bears from El Dorado County were tested for exposure to organophosphates; no detectable levels were found.

A general toxicology panel (GMCS/LCMS) was performed on a black-tailed deer from Nevada County. Caffein was detected in the submitted liver sample.

Acetylcholinesterase activity was measured as within normal limits for two bears from Los Angeles and El Dorado County, and black-tailed deer from Tehama County.

Samples of blue-colored adipose (fat), muscle, and brain from an adult female black bear taken under a hunting permit in Sierra County were submitted for rodenticide testing. The sample was screened for the presence of anticoagulant rodenticide residues, and diphacinone was detected in all three of the tested samples. Exposure to other anticoagulant rodenticides or other pesticides cannot be ruled out, however, because liver is the preferred sample for anticoagulant rodenticide testing.

Table 5. Exposure prevalence and number of confirmed toxicosis cases of anticoagulant rodenticides in 15 tested wild large game mammals submitted to the Wildlife Health Laboratory in 2022 by county. After postmortem examination, livers were submitted for toxicology testing to the California Animal Health and Food Safety Laboratory in Davis, CA.

County	No. Tested	No. Exposed	Percent Exposed	No. Confirmed Toxicosis
El Dorado	3	3	100.0	0
Humboldt	1	0	0	0
Kern	1	1	100.0	0
Los Angeles	1	1	100.0	0
Madera	1	1	100.0	0
Nevada	1	1	100.0	0
Placer	1	1	100.0	0
San Bernardino	2	2	100.0	0
Siskiyou	2	1	50.0	0
Tehama	1	0	0	0
Ventura	1	1	100.0	0
Total	**15**	**12**	**80.0**	**0**

Table 6. Exposure prevalence and number of confirmed toxicosis cases of anticoagulant rodenticides in 15 wild large game mammals submitted to the Wildlife Health Laboratory in 2022 by species. After a postmortem examination, livers were submitted for toxicology testing to the California Animal Health and Food Safety Laboratory in Davis, CA.

Large Game Species	No. Tested	No. Exposed	Percent Exposed	No. Confirmed Toxicosis
Black bear	13	11	84.6	0
Black tailed deer/ Mule deer	1	0	0	0
Wild pig	1	1	1	0
Total	**15**	**12**	**80.0**	**0**

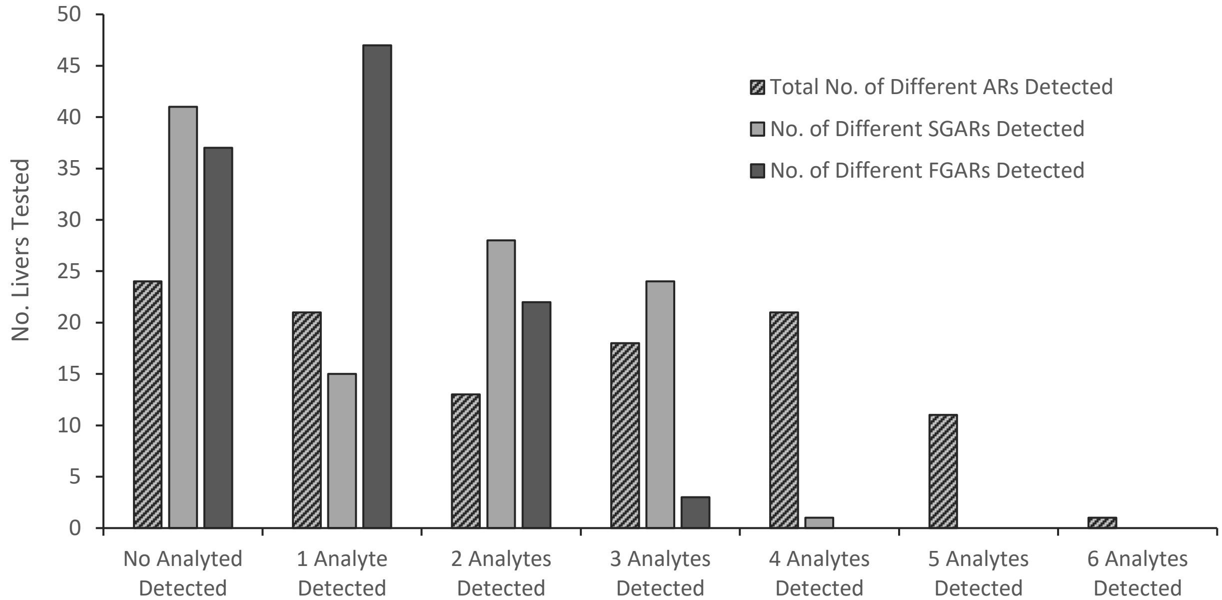


Figure 3. Number of anticoagulant rodenticide residues detected in the livers of 15 wild large game mammals submitted to the Wildlife Health Laboratory for postmortem examination in 2022. After postmortem examination, livers were submitted for toxicology testing to the California Animal Health and Food Safety Laboratory in Davis, CA.

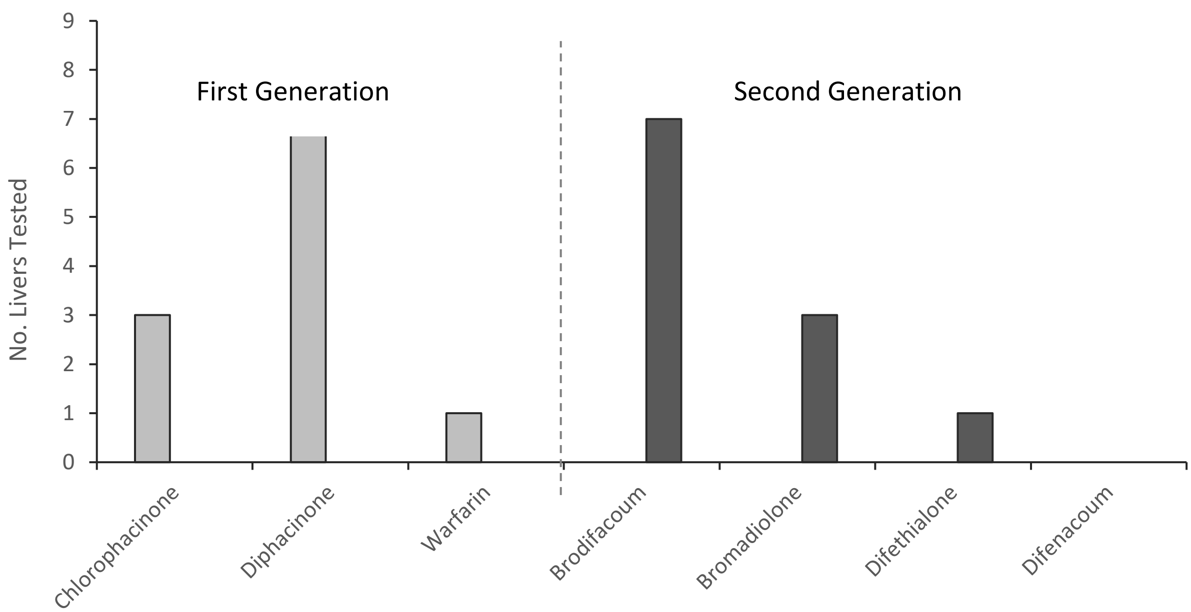


Figure 4. Anticoagulant rodenticide residues detected in the livers of 12 of the 15 tested wild large game mammals submitted to the Wildlife Health Laboratory in 2022. Anticoagulant rodenticides were not detected in 3 of the tested large game mammal livers. After postmortem examination, livers were submitted for toxicology testing to the California Animal Health and Food Safety Laboratory in Davis, CA.

Table 7. Bromethalin exposure in wild large game mammals submitted to the Wildlife Health Laboratory in 2022 by county. Adipose or liver were submitted for toxicology testing to the California Animal Health and Food Safety Laboratory in Davis, CA.

County	No. Tested	No. Exposed	Percent Exposed	No. Confirmed Toxicosis
El Dorado	5	1	20.0	0
Kern	1	1	100.0	1
Los Angeles	1	0	0	0
Madera	1	1	100.0	0
Nevada	1	0	0	0
Placer	1	0	0	0
San Bernardino	2	1	50.0	0
Siskiyou	2	0	0	0
Ventura	1	0	0	0
Total	15	4	26.7	0

Table 8. Bromethalin exposure in wild large game mammals wildlife submitted to the Wildlife Health Laboratory in 2022 by species. Adipose or liver were submitted for toxicology testing to the California Animal Health and Food Safety Laboratory in Davis, CA.

Species	No. Tested	No. Exposed	Percent Exposed	No. Confirmed Toxicosis
Black bear	14	3	21.4	1
Wild pig	1	1	100.0	0
Total	**15**	**4**	**26.7**	**0**


American black bear | Eileen Hornbaker, USFWS

SMALL GAME & NON-GAME SUMMARY

The remains of 264 herptiles and mammals were submitted to the WHL for necropsy in 2022. This included samples and remains of animals primarily for specialized disease surveillance such as rabbit hemorrhagic disease virus (lagomorphs), snake fungal disease (snakes), and white-nose syndrome (bats).

Small game and non-game animals were submitted for various reasons by wildlife rehabilitators, members of the public, non-profit organizations, universities, CDFW staff and law enforcement, and other agencies. Wildlife rehabilitators made up 35% (92/264) of submissions, followed by CDFW (33%; Table 9). Toxicology testing was not performed on the herptiles. Therefore, the remainder of this section will address completed test results for mammals.

Table 9. Total number of wild small- and non-game mammal remains submitted to the Wildlife Health Laboratory in 2022 based on the primary submitter's affiliation. Many submissions that are non-public originated as a public report.

Submitter Affiliation	No. Small- and Non-Game Animals Submitted
Animal Control	9
CDFW	87
NGO/Non-Profit	3
Other	2
Other Government Agency	14
Private Biological Consultant	2
Public	21
Rehab/Zoo/Sanctuary	92
University Affiliate	34
Total	**264**

Anticoagulant Rodenticide Exposure & Toxicosis

Of necropsied mammals, 150 were tested for pesticide exposure but results are only available for 109 tested mammals at the time of this report. Sampled remains with final reports represent 38 of the 58 counties in California (Table 10). The remains for a juvenile mountain lion did not have a specified location. All age classes and sexes were represented.

Bobcats accounted for the largest percentage of mammal samples submitted to the WHL (Table 11). In total, 86 of the 109 (78.9%) mammals tested had exposure to one or more anticoagulant rodenticide and almost half of the tested animals had exposure to three or more anticoagulant rodenticides regardless of first- or second generation (Figure 5). One adult female bobcat from Orange County had exposure to six different anticoagulant rodenticides.

One of the 86 exposures (1.2%) resulted in a case of anticoagulant rodenticide toxicosis (Table 11). Anticoagulant rodenticide toxicosis was suspected in 3.5% (3/86) of tested animals with livers that had detectable residue exposure, however toxicosis could not be ruled in or out in due to advanced stages of decomposition, making gross and histological interpretation of the tissues difficult.

Brodifacoum, bromadiolone, and diphacinone were the most common analytes detected in liver samples (Figure 6). None of the tested samples had detectable levels of exposure to coumachlor.

Other Pesticide Exposure

One-hundred three wild non-game and small game mammals were tested for additional pesticides, including bromethalin, organophosphates and carbamates, neonicotinoids, pyrethroids, fipronil and fipronil sulfone.

Adipose or brain from 95 animals across 34 counties was tested for exposure to the neurotoxic rodenticide, bromethalin (Table 12). Twenty-two of the tested animals had exposure to bromethalin and 22.7% of those exposures resulted in mortality (2/22) or suspected mortality (3/22) (Tale 13). Advanced decomposition likely precluded the identification of any lesion(s) that may be associated with bromethalin toxicity in the long-tailed weasel with exposure. Further, it had a clinical history of depressed behavior with possible neurologic signs prior to death but these signs were not described in detail by the submitter. Thus, it is undetermined if exposure may have resulted in clinical signs and toxicosis.

A general toxicology panel (GMCS/LCMS) was performed on two raccoons from Sonoma and Tehama Counties. No toxic compounds were detected.

Vitamin D3 levels were tested in a mature adult female bobcat after tubular mineralization was observed in the vessels of her lungs and kidneys to rule out Vit-D3 toxicosis. Vitamin D3 levels were within normal limits and the mineralization observed is suspected to have been non-clinically significant.

Twelve North American river otters were tested for neonicontinoids, pythreins, fipronil and fipronil sulfone, and organophosphates, however final results are only available for five river otters at the time of this report. None of the toxic compounds were detected.

American badger | Tom Koerner, USFWS

Table 10. Exposure prevalence and number of confirmed toxicosis cases of anticoagulant rodenticides in the livers of 109 small game and non-game remains submitted to the Wildlife Health Laboratory for postmortem examination in 2022 by county. Livers were submitted for toxicology testing to the California Animal Health and Food Safety Laboratory in Davis, CA. In some cases, rodenticide residues were detected in the liver, but postmortem evidence could not confirm or exclude toxicosis due to advanced decomposition. Therefore, these diagnoses are reported as "undetermined" toxicosis.

County	No. tested	No. Exposed	Percent Exposed	No. Confirmed Toxicosis	No. Undetermined Toxicosis
Butte	1	1	100.0	0	0
Calaveras	2	1	50.0	0	0
Contra Costa	6	4	66.7	0	0
El Dorado	1	1	100.0	0	0
Fresno	1	0	0	0	0
Imperial	1	1	100.0	0	0
Inyo	1	1	100.0	0	0
Kern	8	7	87.5	0	0
Kings	1	1	100.0	0	0
Los Angeles	4	3	75.0	0	0
Mendocino	3	3	100.0	0	0
Merced	1	1	100.0	0	0
Modoc	1	0	0	0	0
Mono	7	6	85.7	0	0
Monterey	7	4	57.1	0	1
Napa	2	1	50.0	0	0
Nevada	3	3	100.0	0	0
Orange	6	6	100.0	0	0
Placer	2	2	100.0	0	0
Plumas	2	1	50.0	0	0
Riverside	2	2	100.0	0	0
Sacramento	3	3	100.0	0	1
San Benito	2	1	50.0	0	0
San Bernardino	2	2	100.0	0	0
San Diego	2	2	100.0	0	0
San Francisco	2	2	100.0	0	0
San Joaquin	3	0	0	0	0
San Luis Obispo	1	1	100.0	0	0
San Mateo	8	6	75.0	0	0
Santa Barbara	1	1	100.0	0	0
Santa Clara	3	3	100.0	1	0
Santa Cruz	3	3	100.0	0	0
Shasta	1	1	100.0	0	0
Sierra	2	1	50.0	0	0
Sonoma	8	8	100.0	0	0
Stanislaus	1	0	0	0	0
Tehama	1	1	100.0	0	0
Ventura	3	1	33.3	0	0

County	No. tested	No. Exposed	Percent Exposed	No. Confirmed Toxicosis	No. Undetermined Toxicosis
Not specified	1	1	100.0	0	1
Total	**109**	**86**	**78.9**	**1**	**3**

Table 11. Exposure prevalence and toxicosis of anticoagulant rodenticide residues detected in the livers of 109 small game and non-game mammals submitted to the Wildlife Health Laboratory for postmortem examination in 2022 by species. Livers were submitted for toxicology testing to the California Animal Health and Food Safety Laboratory in Davis, CA. In some cases, rodenticide residues were detected in the liver, but postmortem evidence could not confirm or exclude toxicosis due to advanced decomposition. Therefore, these diagnoses are reported as "undetermined" toxicosis.

Species	No. Tested	No. Exposed	Percent Exposed	No. Confirmed Toxicosis	No. Undetermined Toxicosis
Badger	1	1	100.0	0	0
Bobcat	38	33	86.8	0	0
Brush rabbit	5	0	0	0	0
Coyote	6	6	100.0	1	0
Eastern fox squirrel	1	0	0	0	0
Gray fox	13	12	92.3	0	2
Mountain Lion	19	17	89.5	0	1
Raccoon	7	3	42.9	0	0
Red fox	2	1	50.0	0	0
Ringtail	1	0	0	0	0
River otter	5	3	60.0	0	0
San Joaquin kit fox	8	7	87.5	0	0
Striped skunk	3	3	100.0	0	0
Total	**109**	**86**	**78.9**	**1**	**3**

American river otter | Keenan Adams, USFWS

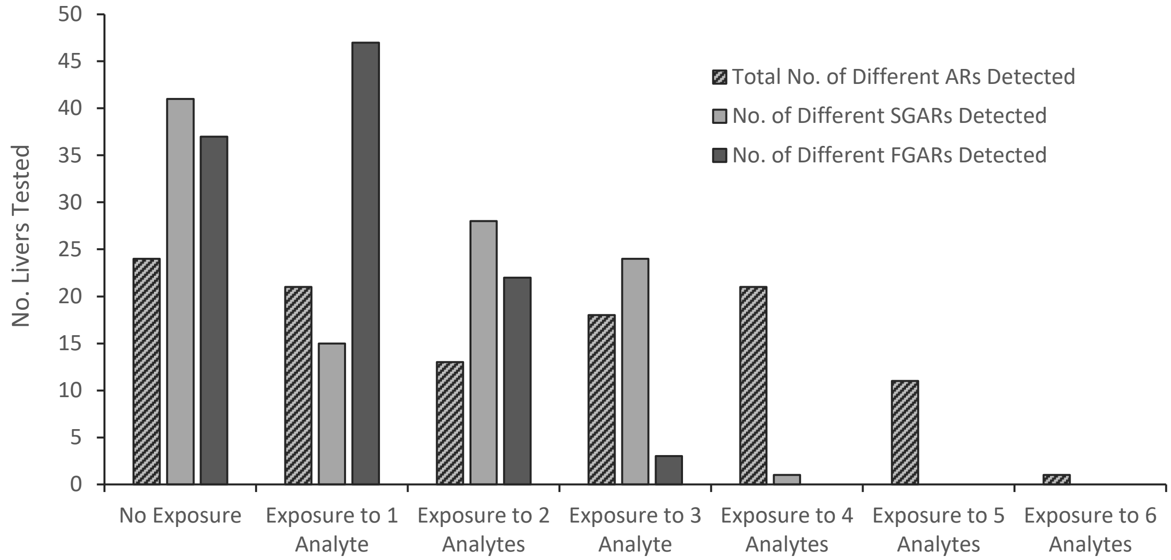


Figure 5. Number of anticoagulant rodenticide residues detected in the livers of 109 small game and non-game mammals submitted to the Wildlife Health Laboratory for postmortem examination in 2022. After postmortem examination, livers were submitted for toxicology testing to the California Animal Health and Food Safety Laboratory in Davis, CA.

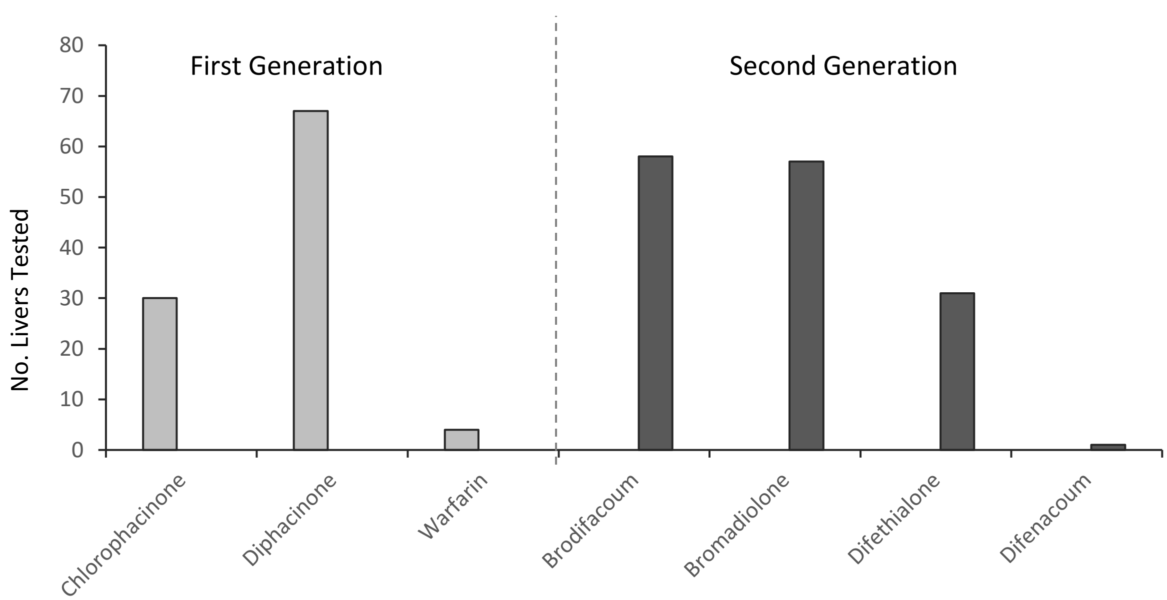


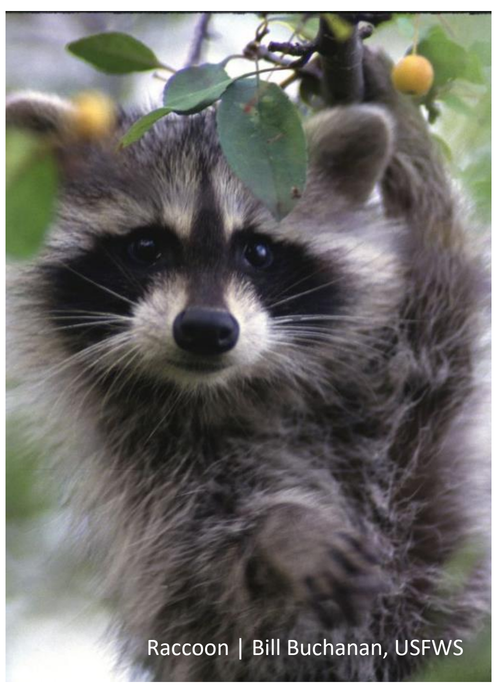
Figure 6. Anticoagulant rodenticide residues detected in the livers of wild small game and non-game mammals submitted to the Wildlife Health Laboratory for postmortem examination in 2022. After postmortem examination, livers were submitted for toxicology testing to the California Animal Health and Food Safety Laboratory in Davis, CA.

Table 10. Bromethalin exposure and toxicosis in wild small game and non-game wildlife submitted to the Wildlife Health Laboratory in 2022 by county. Adipose or brain were submitted for toxicology testing to the California Animal Health and Food Safety Laboratory in Davis, CA. In some cases, bromethalin were detected in but antemortem and postmortem evidence could not confirm or exclude toxicosis due to advanced autolysis which may preclude histologically significant lesions or the inability to observe the animal while alive. Therefore, these diagnoses are reported as "undetermined toxicosis."

County	No. tested	No. Exposed	Percent Exposed	No. Confirmed Toxicosis	No. Undetermined Toxicosis
Butte	1	0	0	0	0
Calaveras	2	0	0	0	0
Contra Costa	3	1	33.3	0	0
El Dorado	1	0	0	0	0
Fresno	1	0	0	0	0
Imperial	1	0	0	0	0
Kern	7	0	0	0	0
Los Angeles	4	1	25.0	0	0
Marin	1	1	100.0	0	0
Mendocino	3	2	66.7	0	0
Modoc	1	1	100	0	0
Mono	5	0	0	0	0
Monterey	7	2	28.6	0	0
Napa	2	0	0	0	0
Nevada	3	0	0	0	0
Orange	6	3	50.0	0	0
Placer	2	1	50.0	0	0
Plumas	1	0	0	0	0
Riverside	2	0	0	0	0
Sacramento	1	0	0	0	0
San Benito	2	0	0	0	0
San Bernardino	2	0	0	0	0
San Diego	2	0	0	0	0
San Luis Obispo	1	0	0	0	0
San Mateo	7	2	28.6	0	0
Santa Barbara	2	0	0	0	0
Santa Clara	3	0	0	0	0
Santa Cruz	3	0	0	0	0
Shasta	1	0	0	0	0
Sierra	2	0	0	0	0
Sonoma	11	6	54.5	2	3
Tehama	1	0	0	0	0
Tulare	1	0	0	0	0
Ventura	2	1	50.0	0	0
Not specified	1	1	100.0	0	0
Total	**95**	**22**	**23.2**	**2**	**3**

Table 11. Bromethalin exposure and toxicosis in wild small game and non-game wildlife submitted to the Wildlife Health Laboratory in 2022 by species. Adipose or brain were submitted for toxicology testing to the California Animal Health and Food Safety Laboratory in Davis, CA. In some cases, bromethalin were detected in but antemortem and postmortem evidence could not confirm or exclude toxicosis due to advanced autolysis which may preclude histologically significant lesions or the inability to observe the animal while alive. Therefore, these diagnoses are reported as "undetermined toxicosis."

Species	No. tested	No. Exposed	Percent Exposed	No. Confirmed Toxicosis	No. Undetermined Toxicosis
Badger	2	0	0	0	0
Beaver	1	0	0	0	0
Bobcat	36	4	11.1	0	0
Coyote	6	1	16.7	0	0
Eastern fox squirrel	1	0	0	0	0
Eastern gray Squirrel	1	0	0	0	0
Gray fox	11	4	36.4	0	2
Mountain lion	17	6	35.3	0	0
Opossum	1	0	0	0	0
Raccoon	8	5	62.5	1	1
Red fox	1	1	100.0	0	0
Ringtail	1	0	0	0	0
San Joaquin kit fox	7	0	0	0	0
Striped skunk	2	1	50.0	1	0
Total	**95**	**22**	**23.2**	**2**	**3**


Raccoon | Bill Buchanan, USFWS

ADDITIONAL SURVEILLANCE

Poisoning of domestic dog

The CDFW was asked to investigate the mortality of a turkey vulture and two dogs on private property. The property owner reported finding her pet dog deceased outdoors near what appeared to be meat left out on a black tray that contained a blue substance and a white plastic container full of yellow liquid. The suspicious meat and liquid were placed along the fence line of the reporting party's property and a neighbor. The property owner buried her pet but found a deceased stray dog and turkey vulture on her property the following day. The property owner reported that the stray dog had foam coming from its mouth, a bloody nose, and vomit next to the dog. By the time CDFW LE officers were contacted, the suspicious meat and yellow liquid had been removed. Brain and stomach contents from the deceased stray dog were collected and submitted to the California Animal Health and Food Safety Lab in Davis. Methomyl, a carbamate insecticide, was detected in the stomach contents. Signs of carbamate toxicosis include hypersalivation, gastrointestinal hypermotility, abdominal cramping, vomiting, diarrhea, dyspnea, cyanosis, miosis, muscle fasciculations (in extreme cases, tetany followed by weakness and paralysis), and convulsions. Death usually results from respiratory failure and hypoxia due to bronchoconstriction leading to tracheobronchial secretion and pulmonary edema[2,3]. Pathological findings of toxicosis include dried saliva around the oral cavity and on other parts of the body that an animal may have touched with their mouth (e.g., forelegs), epistaxis, diffuse uveal congestion and hyphema, subcutaneous and muscular hemorrhage, food with carbamate in the stomach, microhemorrhages in the lower gastrointestinal tract, hemorrhagic pericardial content, diffuse cardiac hemorrhage, diffuse upper respiratory congestion and bilateral pulmonary congestion and edema of the lungs[3]. According to the U.S. Environmental Protection Agency, "There are no residential uses of methomyl. All methomyl products, except the bait formulations, are classified as Restricted Use Pesticides (RUPs). RUPs can only be used by or under the direct supervision of specially trained and certified applicators[4]." In California, a permit is required for the use and application of restricted materials, which includes carbamates such as methomyl[5].

Carbamate insecticides act similarly to organophosphate insecticides and inhibit cholinesterase activity, however cholinesterase activity levels in the brain were elevated. Elevate levels are of unknown clinical significance, however postmortem examination of the dog's remains were consistent with carbamate toxicosis (e.g., hypersalivation, vomiting, pulmonary edema, and hemorrhaging).

No toxic compounds were detected in the turkey vulture by gas chromatography - mass spectrometry (GC/MS) and liquid chromatography - mass spectrometry (LC/MS) organic chemical screens.

Evaluation of Assembly Bill 1788

A temporary moratorium was placed on the public sales and use of second generation anticoagulant rodenticides (SGARs) on January 1, 2021 under AB1788. Given the long half-lives of many SGARs and their ability to bioaccumulate in the livers of living animals, evaluating any immediate changes resulting from this temporary moratorium may be difficult. The CDFW proposed guidelines for monitoring the short-term, immediate effects of AB1788s as well as the continued long-term monitoring and surveillance of anticoagulant rodenticide exposure in non-target wildlife, especially given the special exceptions to this moratorium that still allow for SGAR use.

Short-term evaluation of the efficacy of AB1788 include looking at animals born or hatched after January 1, 2021 and cases of exposure and/or acute toxicosis. Our reasoning is that most wildlife born or hatched after implementation of AB1788 should not have exposure to SGARs (although there is a chance that mammals could have been exposed in utero[6-12]). A study by CDFW looking at anticoagulant rodenticide exposure in mountain lions found that cubs are less likely to have SGAR exposure when compared to adults[12] despite evidence of fetal exposure[6]. Further, we posit that wildlife that have died from acute toxicosis were likely recently exposed at concentrations large enough to cause coagulopathy and death rather than chronic exposure accumulating over time. It is important to note, however, that most wildlife have more than one analyte detected in their livers belonging to both first generation and second generation anticoagulant rodenticides. Additionally, there is no minimum threshold concentration indicative of anticoagulant rodenticide toxicosis and determining whether toxicosis was due to a first generation or second generation is difficult in the presence of multiple analytes and lack of information on the cumulative effects.

Twenty-one wild birds (n = 17) and mammals (n = 4) were determined to have a died, or suspected to have died, from acute coagulopathy due to anticoagulant rodenticide toxicosis (Table 14).

Thirty-one wild birds (n = 9: included < 1 yr old and 1.5 yr old) and mammals (n = 22: included <1 yr old) in calendar year 2022 had exposure to one or more anticoagulant rodenticide(s) (Table 15). Age and age classes were determined based on plumage and/or the presence of a bursa (for avians), dentition (mammals), and date of death since most species have reproductive seasons in which they predictively mate and produce offspring.


Great horned owl | Tom Koerner, USFWS


Bobcat | Grayson Smith, USFWS


Red-tailed hawk | Mark Bohn, USFWS

Table 14. Summary of cases of anticoagulant rodenticide (AR) toxicosis in non-target wildlife since the implementation of AB1788 on January 1, 2021. Livers from necropsied wildlife were submitted for toxicology testing to the California Animal Health and Food Safety Laboratory in Davis, CA. In some cases, rodenticide residues were detected in the liver, but postmortem evidence could not confirm or exclude toxicosis due to advanced decomposition. Therefore, these diagnoses are reported as "undetermined" toxicosis.

SGAR = second generation anticoagulant rodenticide, FGAR = first generation anticoagulant rodenticide

Date of Death	Species	County	Sex	Age Class	AR Toxicosis	No. SGARs Detected	No. FGARS Detected
AVIAN SUBMISSIONS							
1/18/2022	Red-tailed hawk	Santa Clara	F	Juvenile	Yes	1	0
1/20/2022	Great horned owl	Marin	F	Adult	Yes	3	1
2/3/2022	Barn owl	Ventura	M	Adult	Suspect	3	0
2/14/2022	Red-shouldered hawk	Ventura	M	Adult	Yes	2	0
4/4/2022	Great horned owl	Marin	M	Adult	Yes	3	1
2/10/2022	Great horned owl	Santa Cruz	F	Adult	Yes	3	1
3/31/2022	Great horned owl	Los Angeles	M	Juvenile	Yes	0	1
7/25/2022	Great horned owl	Los Angeles	F	Adult	Yes	3	2
7/26/2022	Great horned owl	Los Angeles	M	Adult	Yes	2	1
7/20/2022	Red-shouldered hawk	Sonoma	F	Adult	Yes	2	0
10/2/2022	Great horned owl	Los Angeles	M	Juvenile	Yes	3	2
10/5/2022	Great horned owl	Contra Costa	M	Juvenile	Yes	3	1
10/21/2022	Great horned owl	San Diego	M	Juvenile	Yes	2	1
4/25/2022	Great horned owl	San Bernardino	F	Adult	Suspect	1	0
11/14/2022	Great horned owl	Santa Clara	F	Adult	Yes	3	1
12/13/2022	Barn owl	San Mateo	F	Juvenile	Yes	2	1
11/15/2022	Great horned owl	Kern	M	Juvenile	Yes	3	0
MAMMAL SUBMISSIONS							
1/6/2022	Coyote	Santa Clara	F	Adult	Yes	2	3
2/10/2022	Gray Fox	Sacramento	M	Adult	Suspect	1	1
10/30/2022	Mountain Lion	Not specified	M	Cub	Suspect	3	1
12/16/2022	Gray Fox	Monterey	M	Adult	Suspect	0	1

Table 15. Summary of cases of anticoagulant rodenticide (AR) exposure in non-target wildlife born or hatched after the implementation of AB1788 on January 1, 2021. Age classes were determined based on plumage, dentition, and reproductive phenology of the species. Livers from necropsied wildlife were submitted for toxicology testing to the California Animal Health and Food Safety Laboratory in Davis, CA. In some cases, rodenticide residues were detected in the liver, but postmortem evidence could not confirm or exclude toxicosis due to advanced decomposition. Therefore, these diagnoses are reported as "undetermined" toxicosis.

SGAR = second generation anticoagulant rodenticide, FGAR = first generation anticoagulant rodenticide

Date of Death	Species	County	Sex	Age Class	AR Toxicosis	No. SGARs Detected	No. FGARS Detected
AVIAN SUBMISSIONS							
1/14/2022	Golden eagle	San Luis Obispo	M	Juvenile	No	0	1
1/18/2022	Red-tailed hawk	Santa Clara	F	Juvenile	Yes	1	0
3/31/2022	Great horned owl	Los Angeles	M	Juvenile	Yes	0	1
4/26/2022	Great horned owl	Ventura	F	Juvenile	No	0	0
5/9/2022	Great horned owl	Sonoma	M	Juvenile	No	0	0
10/2/2022	Great horned owl	Los Angeles	M	Juvenile	Yes	3	2
10/5/2022	Great horned owl	Contra Costa	M	Juvenile	Yes	3	1
10/21/2022	Great horned owl	San Diego	M	Juvenile	Yes	2	1
11/16/2022	Great horned owl	Santa Clara	M	Juvenile	No	1	0
12/13/2022	Barn owl	San Mateo	F	Juvenile	Yes	2	1
11/15/2022	Great horned owl	Kern	M	Juvenile	Yes	3	0
MAMMAL SUBMISSIONS							
8/30/2022	Black bear	San Bernardino	Male	1st Year	No	0	1
8/30/2022	Black bear	San Bernardino	Male	1st Year	No	1	1
10/4/2022	Black bear	El Dorado	Female	1st Year	No	1	1
11/10/2022	Black bear	Ventura	Male	1st Year	No	1	0
11/21/2022	Black bear	El Dorado	Male	1st Year	No	1	0
1/20/2022	Coyote	Orange	M	Juvenile	No	3	1
Found 2022	Mountain lion	El Dorado	M	Juvenile	No	0	1
1/19/2022	Coyote	Mono	F	Yearling	No	3	1
2/19/2022	Bobcat	Monterey	F	Juvenile	No	0	1
3/4/2022	Striped skunk	San Francisco	F	Juvenile	No	2	0
3/22/2022	Bobcat	San Mateo	F	Yearling	No	2	1
5/25/2022	Red fox	Contra Costa	M	Pup	No	0	1
7/5/2022	Mountain lion	Nevada	F	Yearling	No	2	1
8/4/2022	Gray fox	Contra Costa	F	Juvenile	No	1	3
9/4/2022	Bobcat	Placer	M	Yearling	No	3	2
10/3/2022	Striped skunk	Plumas	M	Juvenile	No	0	1
10/12/2022	Mountain lion	Orange	F	Cub	No	2	2
10/30/2022	Mountain lion	Not specified	M	Cub	Suspect	3	1
10/18/2022	Mountain lion	Sonoma	M	Cub	No	2	1
11/30/2022	Raccoon	Sonoma	F	Juvenile	No	0	0
12/19/2022	Gray fox	Shasta	F	Juvenile	No	0	1
12/26/2022	San Joaquin kit fox	Kern	F	Juvenile	No	1	1

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Pesticide Exposures & Mortalities in Non-target Wildlife

CALIFORNIA DEPARTMENT OF FISH & WILDLIFE

2023 Annual Report
Wildlife Health Laboratory

2023 Summary of Pesticide Exposures & Mortalities in Non-target Wildlife

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With contributions from The Wildlife Health Lab staff

CDFW's Canebrake Ecological Reserve. Photo: Ryan Bourbour, CDFW

PREPARED BY THE WILDLIFE HEALTH LABORAOTRY OF THE CALIFORNIA DEPARTMENT OF FISH & WILDLIFE

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INTRODUCTION

The mission of the California Department of Fish and Wildlife (CDFW) is to manage California's diverse fish, wildlife, and plant resources, and the habitats upon which they depend, for their ecological values and for their use and enjoyment by the public. As such, a memorandum of understanding (MOU) was developed between the California Department of Pesticide Regulation (CDPR), the County Agriculture Commissioners (CAC), and the CDFW. The purpose of the memorandum is to ensure that pesticides registered in the state of California are used in a manner that protects non-target fish and wildlife resources, while recognizing the need for responsible pest control.

In partial fulfillment of the MOU, this 2023 annual report summarizes documented pesticide exposure and toxicosis in California's fish and wildlife for the respective authorities of CDPR, CAC, and CDFW. These data represent a minimum number of reports for tested animals that died within the reported calendar year and are subject to change as new information becomes available.

DATA COLLECTION & ANALYSIS

The Wildlife Health Laboratory (WHL, formerly the Wildlife Investigations Laboratory) was established in 1941 and is mandated by Fish and Game Code Section 1008 to investigate all diseases and problems relating to wildlife. The WHL has accomplished this goal through collaboration with the public and various organizations to record, collect, and submit wildlife mortalities of interest to the WHL for examination and further diagnostics as needed. The WHL continues communication with interested parties as new information is discovered to aid further cooperation in the goal of maintaining healthy wildlife populations throughout California.

Programmatically the WHL is divided into three units which address health issues: 1) avian, 2) big game, 3) small game and non-game species. The avian unit oversees nearly 600 avian species including non-game (e.g., songbirds, raptors, shorebirds, waders, and seabirds) and game species (e.g., doves, pigeons, quail, turkey, and waterfowl). The big game unit primarily oversees black bear, bighorn sheep, deer, elk, pronghorn, and wild pig with shared responsibility of small game such as tree squirrels, rabbits, and hares. In addition to sharing health surveillance responsibilities with the big game unit, the non-game unit also oversees native non-game mammals, fur bearers, reptiles, and amphibians. This includes a consortium of species such as California tiger salamander, western pond turtles, pika, riparian brush rabbits, skunks, raccoons, foxes, bobcats, mountain lions, and gray wolves.

Wildlife Submissions

Wildlife remains are submitted to the WHL in various ways, primarily by the public – either direct submissions of deceased wildlife to the WHL, submission of living or deceased wildlife to wildlife rehabilitation centers ("rehab"), notification of mortalities to CDFW staff and law enforcement, or other government agency reports (e.g., animal control, sheriff, state and federal Department of Agriculture, U.S. Fish and Wildlife Service, the Park Service, etc.). The WHL also collaborates with universities, non-governmental organizations (NGO), and other agencies on statewide population monitoring projects and provides diagnostic support by conducting postmortem examinations. The WHL contracts with the California Animal Health and Food Safety (CAHFS) Laboratory for further disease and toxicology testing.

Postmortem Examination

Postmortem examinations (necropsies) are performed on wildlife remains at the WHL or the CAHFS Laboratory. If remains cannot be examined within 48 hours of collection, they are stored in a -20°C freezer until an examination can be performed. Prior to necropsy, frozen carcasses are thawed at 4°C or room temperature until they are ready for necropsy. Sex, age class, body condition and, when possible, the cause of death is determined. In addition to necropsy, mortality investigations often include microscopic evaluation of tissues (histology) and ancillary disease and toxicology testing. Tissue samples are collected and placed in 10% formalin for histological evaluation and a complimentary set of tissues are archived in -20C° freezers until submitted to the CAHFS Laboratory for analysis.

Carcasses in advanced stages of decomposition and autolysis are necropsied but formalin tissues may not be collected or submitted since autolysis can obscure or destroy microscopic lesions. In these cases, necropsies are performed, and tissue samples are collected for toxicology testing to assess pesticide exposure but not necessarily toxicosis.

Anticoagulant Rodenticides: Anticoagulant rodenticides (ARs) are grouped into two categories: "first generation anticoagulant rodenticides" (FGARs) which include warfarin (war), coumachlor (cou), diphacinone (diph), and chlorophacinone (chl) and the more toxic "second generation anticoagulant rodenticides" (SGARs) which include brodifacoum (brd), bromadiolone (brm), difenacoum (dfn), and difethialone (dif).

Non-Anticoagulant Rodenticides & Other Pesticides**:** There are several acutely toxic compounds also used to manage rodent and insect pests, such as bromethalin, strychnine, zinc phosphide, cholecalciferol, organophosphates, and carbamates. Like anticoagulant rodenticides, these compounds, or their metabolites, have been documented in non-target wildlife as a form of mortality or exposure.

Appropriate tissue samples (e.g., gastrointestinal contents, adipose, brain, spinal cord, kidney, liver, gills) for requested tests are also submitted to the CAHFS Laboratory for testing.

Exposure & Toxicosis

Pesticides, including ARs, are not always acutely fatal and there is a high degree of variability among species and individuals in their vulnerability. In the absence of a universal threshold residue value that could indicate AR "toxicosis," we must also rely on antemortem and/or postmortem evidence of coagulopathy unrelated to another identifiable cause of hemorrhage (e.g., trauma, disease, infection).

Individuals are considered to have AR "exposure" if their livers had detectable levels of one or more AR residues (regardless of concentration, reported in parts per billion or ppb) and lack antemortem and/or postmortem evidence of coagulopathy.

For non-ARs, diagnosing toxicosis requires the detection of the compound in the appropriate tissue sample or gastrointestinal contents, and antemortem and/or postmortem evidence in the absence of another identifiable cause (e.g., disease, infection, trauma).

In some cases, rodenticide residues are detected in the tissue sample, but postmortem evidence could not confirm or exclude toxicosis due to advanced decomposition which precludes a definitive diagnosis. Therefore, these diagnoses are reported as "suspected" or "undetermined" toxicosis.

It is important to note that exposure in the absence of toxicosis should not be ignored[1]. The uncertainties about the magnitude and drivers of chronic exposure and/or sub-lethal levels of rodenticide exposure demonstrate the need for continued monitoring. Exposure to ARs may predispose wildlife to excessive hemorrhage following an otherwise non-lethal traumatic injury or increase sensitivity to additional exposure(s)[1].

Additionally, it is important to note that the concentration of ARs quantified in tissue samples does not necessarily equate to risk of toxicosis, as even trace levels (quantities detected below the reporting limit) can be associated with signs of coagulopathy and a toxicosis diagnosis.

AVIAN SUMMARY

According to CDFW records at the time of this report, 936 birds were submitted to the WHL for necropsy, and/or disease or toxicology testing in calendar year 2023. The Eurasian strain of highly pathogenic avian influenza H5N1 continued to impact a diversity of wild birds in California, elsewhere in the United States, and globally. Similar to 2022, the demand for avian influenza surveillance testing increased the number of avian submissions to WHL.

Birds were submitted for various reasons by wildlife rehabilitators, members of the public, non-profit organizations, universities, CDFW staff and law enforcement, and other agencies (Table 1). Wildlife rehabilitators made up the majority of submissions, followed by agencies and specifically, CDFW. However, it should be noted that the majority of these reports originated with a member of the public.

Flight and tail feathers of an adult Red-tailed Hawk. Photo: Ryan Bourbour, CDFW

Table 1. Total number of wild bird remains submitted to the Wildlife Health Laboratory for necropsy in 2023 based on the primary submitter's affiliation. Many submissions that are non-public originated as a public report.

Submitter Affiliation	No. Birds Submitted
CDFW	143
NGO/Non-Profit	34
Other Government / Military	72
Private Consultant / Energy	26
Public	30
Rehab / Zoo / Sanctuary	627
University	4
Total	**936**

Anticoagulant Rodenticide Exposure & Toxicosis

Of necropsied birds, 42 were tested for anticoagulant rodenticide exposure. Tested birds represent 33% (19/58) of California counties (Table 2). All age classes and sexes were represented in submitted carcasses.

Waterfowl and waterbirds (n = 391) accounted for the largest percentage of birds submitted followed by raptors (n = 340). Raptors were disproportionally screened for exposure to anticoagulant rodenticides given they are more likely to be exposed to one or more analyte(s) through their diet (Table 3). Of the 73.8% (31/42) of birds with exposure, 35.5% (11/31) were cases of raptors diagnosed with anticoagulant rodenticide toxicosis. One common raven screened for anticoagulant rodenticides had exposure (Table 3).

Seventeen of the 31 exposed birds had two or more anticoagulant rodenticides detected in the liver (Figure 1). Prevalence of exposure to second generation anticoagulant rodenticides was 61.9% (26/42) while exposure to first generation anticoagulant rodenticides was 35.7% (15/42). Brodifacoum, bromadiolone, and difethialone were the most common second-generation anticoagulant rodenticides detected in liver samples (Figure 2). Diphacinone and chlorophacinone were the most common first-generation anticoagulant rodenticides detected in liver samples (Figure 2). Diagnoses of anticoagulant toxicosis were associated with varying liver concentration levels including trace (Figure 3; Table 4). Detectable FGAR concentration levels ranged from 96 to 460 ppb with detections of trace levels in 13 liver samples (Table 5). Detectable SGAR concentration levels ranged from 53 to 560 ppb with detections of trace levels in 28 liver samples (Table 5). None of the birds sampled had detectable levels of exposure to warfarin, difenacoum, or coumachlor. Out of the 31 birds exposed to ARs, 45.2% (14/31) were Hatch-Year (<1 year old; Table 6). Out of the Hatch-Year birds that were exposed, 35.7% (5/14) died from AR toxicosis (Table 6)

Other Pesticides

Other pesticide-related investigations included one incident involving common ravens in Mendocino County. Avitrol was detected in a single common raven submitted from Mendocino

County in September 2023 where multiple ravens had been reported dead over several days. The resident who reported the raven that was ultimately submitted for testing observed the raven having seizures before death.

Table 2. Exposure prevalence and number of confirmed toxicosis cases of anticoagulant rodenticides in 42 tested wild birds submitted to the Wildlife Health Laboratory in 2023 by county. After postmortem examination, livers were submitted for toxicology testing to the California Animal Health and Food Safety

County	Birds Tested	Birds with Exposure	Exposure Prevalence (%)	Confirmed/ Suspected Toxicosis
Alameda	5	5	100.0	0
Contra Costa	3	2	66.7	1
Del Norte	1	1	100.0	0
Humboldt	3	3	100.0	0
Kern	2	2	100.0	1
Los Angeles	1	1	100.0	1
Modoc	1	0	0.0	0
Monterey	2	1	50.0	0
San Diego	5	5	100.0	3
San Joaquin	1	1	100.0	1
San Luis Obispo	5	3	60.0	1
San Mateo	1	1	100.0	1
Santa Clara	2	2	100.0	1
Shasta	1	0	0.0	0
Siskiyou	1	0	0.0	0
Solano	2	0	0.0	0
Sonoma	1	1	100.0	0
Ventura	4	2	50.0	1
Yolo	1	1	100.0	0
Total	**42**	**31**	**73.8**	**11**

Barn Owl nestlings in an urban nest box in Yolo County. Photo: Ryan Bourbour, CDFW

Table 3. Exposure prevalence and number of confirmed toxicosis cases of anticoagulant rodenticides in 42 wild birds submitted to the Wildlife Health Laboratory in 2023 by species (common name).

Species	No. Tested	No. Birds with Exposure	Exposure Prevalence (%)	No. Confirmed/ Suspected Toxicosis
Bald Eagle	1	0	0.0	0
Barn Owl	8	4	50.0	3
Common Raven	1	1	100.0	0
Cooper's Hawk	1	0	0.0	0
Golden Eagle	5	4	80.0	0
Great Horned Owl	11	10	90.9	4
Red-shouldered Hawk	1	1	100.0	0
Red-tailed Hawk	11	8	72.7	4
Turkey Vulture	3	3	100.0	0
Total	**42**	**31**	**73.8**	**11**

An adult Great Horned Owl perched on the edge of an orchard in Yolo County. Photo: Ryan Bourbour, CDFW

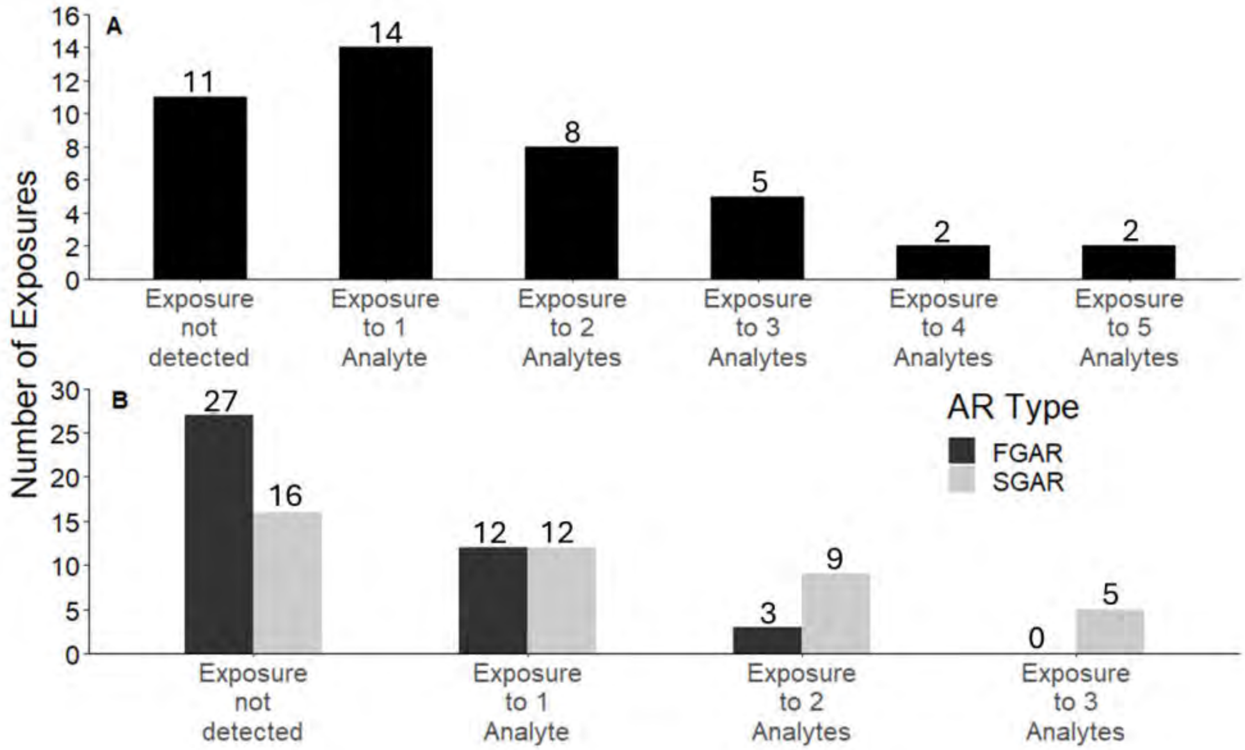


Figure 1. **(A)** Number of anticoagulant rodenticide residues detected in the livers of 31 wild birds in 2023. **(B)** Number of anticoagulant residues detected in the livers of 31 wild birds separated by SGAR and FGAR.

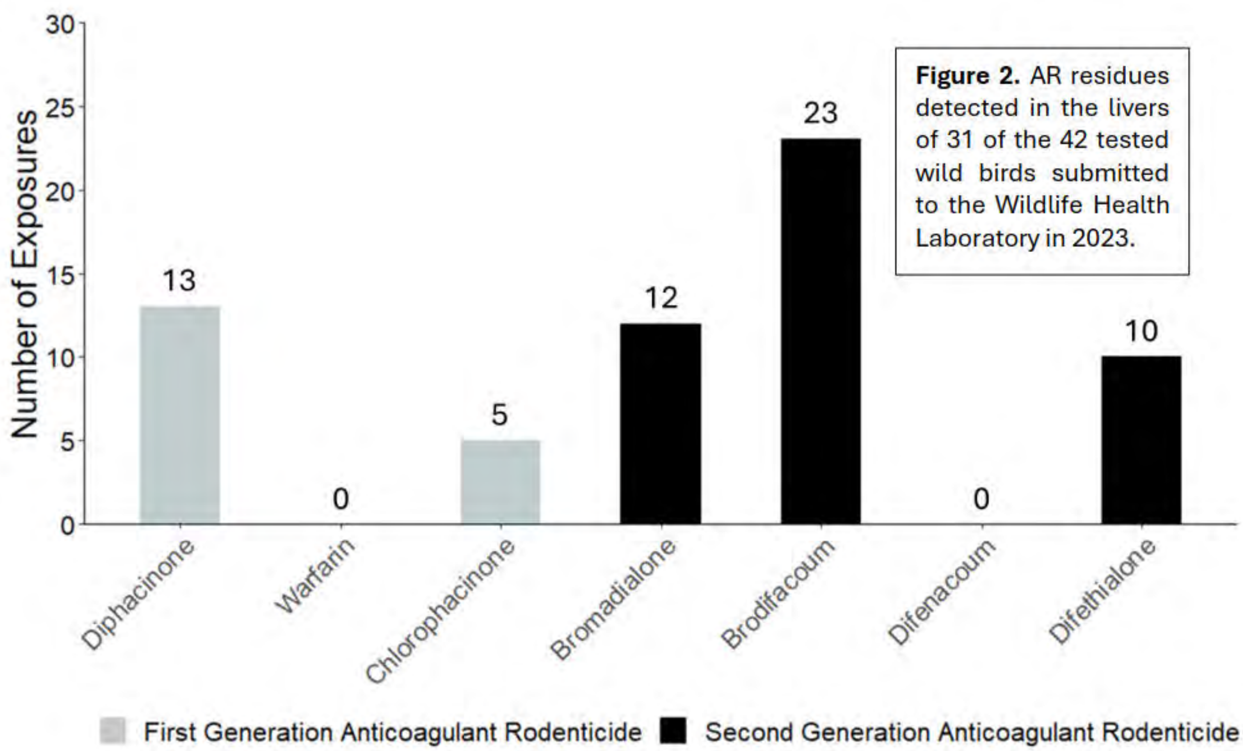


Figure 2. AR residues detected in the livers of 31 of the 42 tested wild birds submitted to the Wildlife Health Laboratory in 2023.

Table 4. AR exposure in the 11 out of 31 individual birds that had evidence supporting a diagnosis for AR toxicosis in 2023. Note that toxicosis can occur at varying levels of AR concentrations for all analytes detected, including trace levels.

Species	Brm (ppb)	Brd (ppb)	Dif (ppb)	Chl (ppb)	Diph (ppb)	Final Diagnosis
Barn Owl	180	**Trace**	—	**Trace**	—	AR toxicosis
Barn Owl	63	240	**Trace**	—	**Trace**	AR toxicosis
Barn Owl	57	100	68	**Trace**	**Trace**	AR toxicosis
Great Horned Owl	**Trace**	140	**Trace**	—	—	AR toxicosis
Great Horned Owl	180	54	**Trace**	**Trace**	**Trace**	AR toxicosis
Great Horned Owl	—	—	—	—	96	AR toxicosis
Great Horned Owl	—	—	130	—	460	AR toxicosis
Red-tailed Hawk	**Trace**	**Trace**	**Trace**	**Trace**	—	AR toxicosis
Red-tailed Hawk	—	53	**Trace**	—	—	AR toxicosis suspect
Red-tailed Hawk	—	—	—	—	120	AR toxicosis
Red-tailed Hawk	—	560	—	—	—	AR toxicosis

A juvenile Red-tailed Hawk at Ash Creek Wildlife Area. Photo: Ryan Bourbour, CDFW

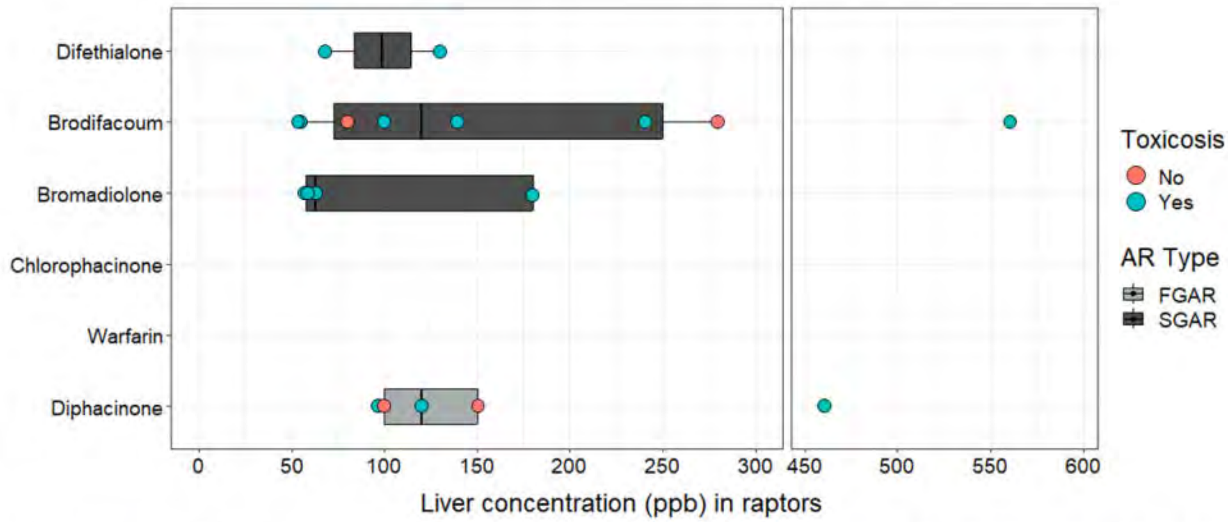


Figure 3. Boxplot to visualize AR concentrations (ppb) quantitated in the livers of 20 of the 31 wild birds that tested positive for AR exposure in 2023. Colored marks indicate concentrations whether or not toxicosis was confirmed. Note that toxicosis can occur at varying levels of AR concentrations for all analytes detected, including trace levels (Table 5). Box plot summary can be found in Appendix 1.1.

Table 5. Summary of AR liver concentration (ppb) levels detected in the 31 of 42 wild birds that tested positive for AR exposure in 2023. Summary includes concentration mean and standard error (SE) of the mean, range, and number of trace detections.

AR Type	Analyte	Mean ± SE (ppb)	Range (ppb)	No. of Trace Detections
FGAR	**Diphacinone**	185.2 ± 69.4	96 – 460	8
	Chlorophacinone	—	—	5
SGAR	**Bromadiolone**	107.6 ± 29.6	57 – 180	7
	Brodifacoum	188.3 ± 60.9	53 – 560	13
	Difethialone	99 ± 31.0	68 – 130	8

An immature Red-tailed Hawk hunting on a Yolo County farm field. Photo: Ryan Bourbour, CDFW

Table 6. FGAR and SGAR exposures in 31 wild birds submitted to the Wildlife Health Laboratory in 2023 by species, county, sex, and age, and cause of death. Birds aged as Hatch-Year (HY) and Second-Year (SY) with SGAR detections are confirmed exposures after the implementation of AB1788's restrictions on SGAR-use in California. Note: HY birds are <1 year old, SY birds are 1-2 years old.

Species	County	Sex	Age Category	No. of FGARs	No. of SGARs	Cause of Death
Barn Owl	San Mateo	F	**HY**	**1**	**2**	**AR toxicosis**
Barn Owl	San Diego	F	Adult	0	2	Trauma
Barn Owl	San Diego	M	Adult	**1**	**3**	**AR toxicosis**
Barn Owl	San Diego	F	Adult	**2**	**3**	**AR toxicosis**
Common Raven	Humboldt	M	Adult	0	1	Trauma
Great Horned Owl	Kern	M	**HY**	0	3	**AR toxicosis**
Great Horned Owl	Humboldt	M	Adult	0	2	Nutritional
Great Horned Owl	Kern	M	Adult	0	2	Nutritional
Great Horned Owl	Los Angeles	M	Adult	**2**	**3**	**AR Toxicosis**
Great Horned Owl	Humboldt	F	Adult	**1**	**2**	Trauma
Great Horned Owl	Alameda	F	**HY**	0	1	Trauma
Great Horned Owl	San Joaquin	M	**HY**	1	0	**AR Toxicosis**
Great Horned Owl	Monterey	F	**HY**	**1**	**2**	Trauma
Great Horned Owl	Ventura	M	Adult	0	1	Trauma
Great Horned Owl	San Diego	F	**HY**	**1**	**1**	**AR Toxicosis**
Golden Eagle	Alameda	F	Adult	0	2	Disease
Golden Eagle	San Diego	M	**HY**	1	0	Trauma
Golden Eagle	Alameda	F	**SY**	1	0	Trauma
Golden Eagle	San Luis Obispo	M	**HY**	**2**	**1**	Trauma
Red-shouldered Hawk	San Luis Obispo	M	Adult	0	1	Trauma
Red-tailed Hawk	Alameda	M	Adult	0	2	Trauma
Red-tailed Hawk	Del Norte	M	Adult	0	1	Trauma
Red-tailed Hawk	Contra Costa	F	Adult	**1**	**3**	**AR toxicosis**
Red-tailed Hawk	Ventura	F	Adult	0	2	**Suspect AR Toxicosis**
Red-tailed Hawk	Santa Clara	F	**HY**	1	0	**AR toxicosis**
Red-tailed Hawk	Contra Costa	M	**HY**	0	1	Nutritional
Red-tailed Hawk	San Luis Obispo	M	Adult	0	1	**AR toxicosis**
Red-tailed Hawk	Yolo	F	**HY**	0	1	Undetermined
Turkey Vulture	Alameda	M	**HY**	1	0	Trauma
Turkey Vulture	Santa Clara	F	**HY**	**1**	**1**	Trauma
Turkey Vulture	Sonoma	F	**HY**	0	1	Trauma

American Black Bear in Humboldt County. Photo: CDFW Science Institute & Lands Program

BIG GAME SUMMARY

The remains and/or tissues of 142 big game mammals were submitted to the WHL for necropsy and/or toxicology testing in the year 2023.

Approximately 92% (130/142) of the big game carcasses were submitted by the CDFW and other agencies (Table 7). However, it should be noted that public reports represent the original source for most CDFW submissions.

Table 7. Total number of wild big game mammal tissues or remains submitted to the Wildlife Health Laboratory in 2023 based on the primary submitter's affiliation. Many submissions that are non-public originated as a public report.

Submitter Affiliation	No. Big Game Mammals Submitted
CDFW	130
Other Government Agency	1
Public	6
Rehab	5
Total	**142**

Anticoagulant Rodenticide Exposure

Of necropsied big game mammals, 16 were tested for AR exposure. Big game mammals were submitted from 11 of the 58 counties in California (Table 8). All age classes and sexes were represented in submitted carcasses.

Of the 16 big game animals tested, black bears accounted for 15 (93.8%) of the animals tested. Six of the 15 black bears (40%) tested positive for AR exposure (Table 9). Four of the 15 (26.7%) black bears tested positive for one AR and 2 of the 15 (13.3%) tested positive for two ARs regardless of first- or second generation (Figure 4).

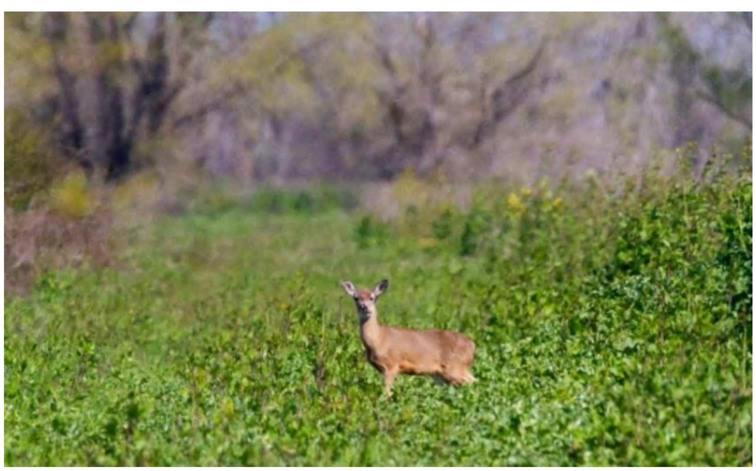
Of the 6 black bears that tested positive for ARs, 5 were positive for SGARs: brodifacoum (n=5) and difethialone (n=1). Two black bears tested positive for the FGAR diphacinone, one bear at trace levels and another bear with 1200 ppb in liver tissue (Table 9). Detectable SGAR concentration levels ranged from 99 to 630 ppb with detections of trace levels in 3 bears (Table 10).

Brodifacoum was the most common analyte detected in tested liver samples (Figure 5). Warfarin, chlorophacinone, coumachlor, bromadiolone and difenacoum were not detected in any of the submitted liver samples.

None of the 16 exposures resulted in cases of anticoagulant rodenticide toxicosis.

Bromethalin Exposure & Other Pesticides

Adipose, brain, or liver tissue from 13 black bears from 11 California counties were tested for exposure to the neurotoxic rodenticide, bromethalin (Table 10). Of the four cases where bromethalin was detected, concurrent exposure to ARs was also detected in two bears (Table 12). One bromethalin positive bear tested positive for diphacinone (trace levels), and the second bromethalin positive bear tested positive for diphacinone (1200 ppb) and brodifacoum (trace levels). Acetylcholinesterase activity was measured as within normal limits for one bear from Sierra County.



Black-tailed Deer at Upper Butte Wildlife Area. Photo: Ryan Bourbour, CDFW

Table 8. Exposure prevalence and number of confirmed toxicosis cases of anticoagulant rodenticides in 16 tested wild big game mammals submitted to the Wildlife Health Laboratory in 2023 by county.

County	No. Tested	No. Exposed	%Exposed	No. Confirmed Toxicosis
Butte	2	0	0	0
Del Norte	1	0	0	0
El Dorado	3	1	33.3	0
Humboldt	1	0	0	0
Los Angeles	1	1	100	0
Placer	2	2	100	0
San Bernardino	1	1	100	0
Sierra	1	1	100	0
Siskiyou	2	0	0	0
Sonoma	1	0	0	0
Tuolumne	1	0	0	0
Total	**16**	**6**	**37.5**	**0**

Table 9. Exposure prevalence and number of confirmed toxicosis cases of anticoagulant rodenticides in 16 wild big game mammals submitted to the Wildlife Health Laboratory in 2023 by species.

Big Game Species	No. Tested	No. Exposed	%Exposed	No. Confirmed Toxicosis
Black Bear	15	6	40	0
Black Tailed Deer/ Mule Deer	1	0	0	0
Total	**16**	**6**	**37.5**	**0**

American Black Bear with cubs at Hallelujah Junction Wildlife Area. Photo: CDFW Science Institute & Lands Program

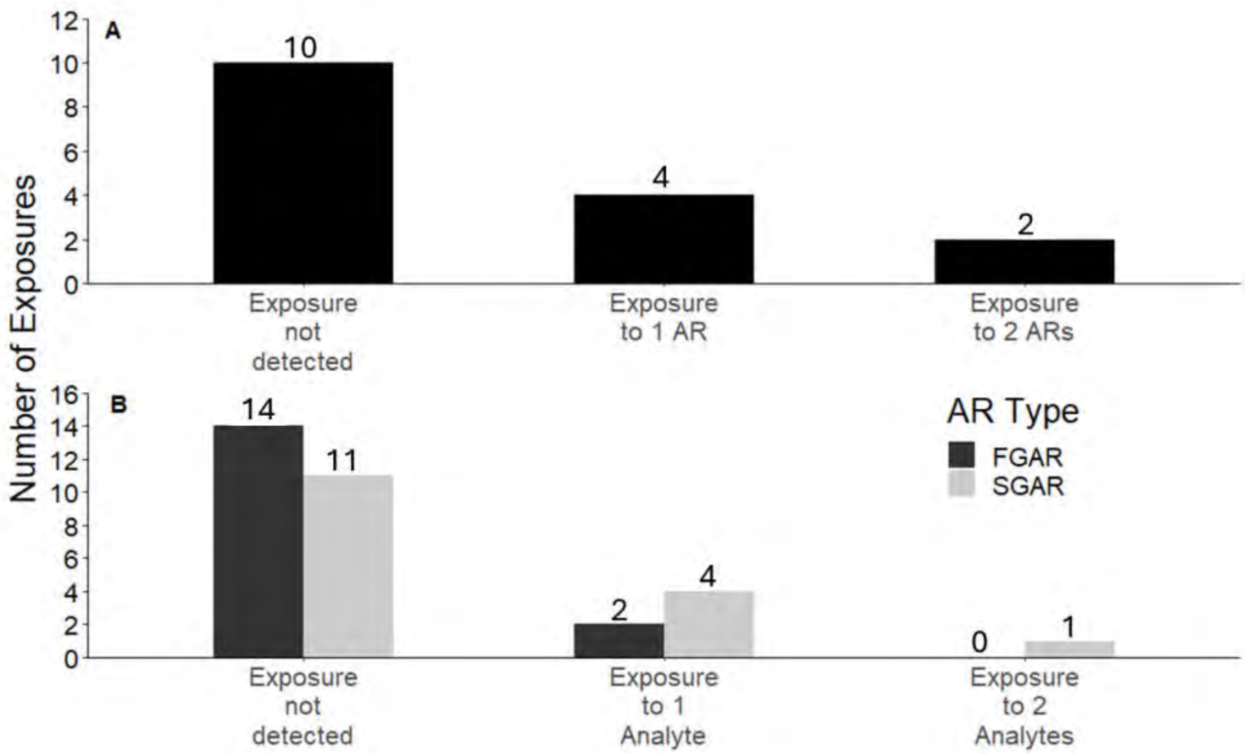


Figure 4. **(A)** Number of AR residues detected in the livers of 16 wild big game mammals in 2023. **(B)** Number of AR residues detected in the livers of 16 wild big game mammals separated by FGAR and SGAR in 2023. After postmortem examination, livers were submitted for toxicology testing to the California Animal Health and Food Safety Laboratory in Davis, CA.

Table 10. Summary of AR liver concentration (ppb) levels detected in the 6 black bears that tested positive for AR exposure in 2023.

AR Type	Analyte	Liver concentration (ppb)	No. of Trace Detections
FGAR	Diphacinone	1200	1
SGAR	Brodifacoum	150, 99	3
	Difethialone	630	0

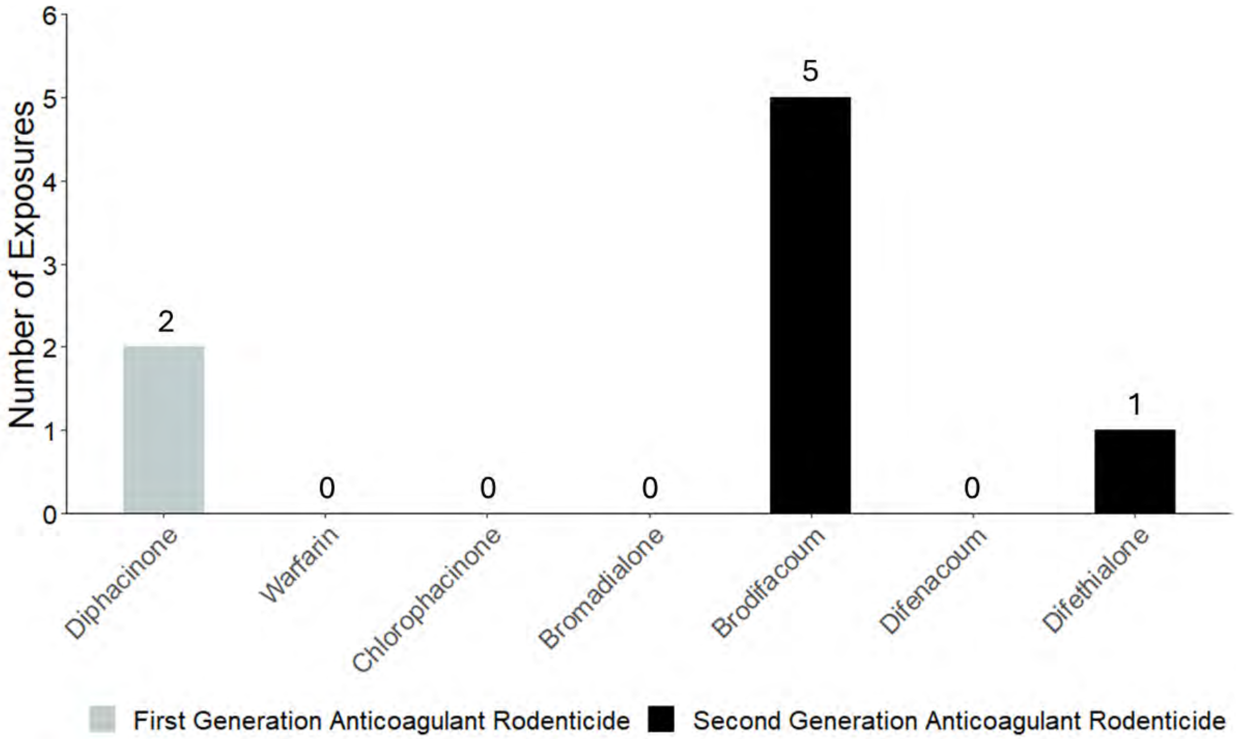


Figure 5: Anticoagulant rodenticide residues detected in the livers of 6 of the 16 tested wild big game mammals submitted to the Wildlife Health Laboratory in 2023.

Pronghorn at Great Basin Springs. Photo: Ryan Bourbour, CDFW

Table 11. Bromethalin exposure in 13 wild black bears submitted to the Wildlife Health Laboratory in 2023 by county. Adipose, brain, or liver were submitted for toxicology testing to the California Animal Health and Food Safety Laboratory in Davis, CA. *Suspicion for bromethalin toxicosis was raised for one bear in Placer County; however, lesions in the brain tissue could not confidently be distinguished from freeze-thaw artifacts.

County	No. Tested	No. Exposed	%Exposed	No. Suspected Toxicosis
Butte	2	0	0	0
El Dorado	3	1	33.3	0
Humboldt	1	0	0	0
Los Angeles	1	0	0	0
Placer	2	1	50	0*
San Bernardino	1	1	100	0
Sierra	1	0	0	0
Siskiyou	1	1	100	0
Sonoma	1	0	0	0
Total	**13**	**4**	**30.8**	**0**

Table 12. AR and bromethalin exposure in 8 wild black bears submitted to the Wildlife Health Laboratory in 2023. Adipose, brain, or liver were submitted for toxicology testing to the California Animal Health and Food Safety Laboratory in Davis, CA. *Suspicion for bromethalin toxicosis was raised for one bear in Placer County; however, lesions in the brain tissue could not confidently be distinguished from freeze-thaw artifacts.

County	Sex	Age Category	FGAR Exposure	SGAR Exposure	Bromethalin Exposure
El Dorado	Male	2nd Year	—	—	**Yes**
El Dorado	Female	Adult	—	Yes	—
Los Angeles	Male	Sub-adult	—	Yes	—
Placer	Male	2nd Year	**Yes**	—	**Yes***
Placer	Male	Adult	—	Yes	—
San Bernardino	Female	2nd Year	**Yes**	**Yes**	**Yes**
Sierra	Female	Adult	—	Yes	—
Siskiyou	Male	2nd Year	—	—	Yes

Coyotes at Hallelujah Junction Wildlife Area. Photo: CDFW Science Institute & Lands Program

SMALL GAME & NON-GAME SUMMARY

The remains of 172 small- and non-game wildlife were submitted to the WHL for necropsy in 2023. Small game and non-game animals were submitted for various reasons by wildlife rehabilitators, members of the public, non-profit organizations, universities, CDFW staff and law enforcement, and other agencies. Wildlife rehabilitators made up 21% (36/172) of submissions, followed by 48% (82/172) submissions from CDFW (Table 13). Toxicology testing was not performed on the herptiles in 2023. Therefore, the remainder of this section will address completed test results for mammals.

Table 13. Total number of wild small- and non-game animal tissues or remains submitted to the Wildlife Health Laboratory in 2023 based on the primary submitter's affiliation. Many submissions that are non-public originated as a public report.

Submitter Affiliation	No. Small and Non-game Animals Submitted
Animal Control	5
CDFW	82
NGO/Non-Profit	4
Other	2
Other Government Agency	21
Private Biological Consultant	2
Public	12
Rehab/Zoo/Sanctuary	36
University Affiliate	8
Total	**172**

Anticoagulant Rodenticide Exposure

Of necropsied small- and non-game wildlife, 70 were tested for pesticide exposure. Sampled remains with final reports represented 53.4% (31/58) of California counties (Table 14). All age classes and sexes were represented.

Mountain lions accounted for the largest percentage of mammal samples submitted to the WHL (Table 15). In total, 78.6% (55/70) of mammals tested had exposure to one or more anticoagulant rodenticide and 54% (38/70) of the tested animals had exposure to two or more anticoagulant rodenticides regardless of first- or second generation (Figure 9). Three mountain lions from Placer, Santa Cruz, and Ventura counties tested positive for five different anticoagulant rodenticides. Five anticoagulant rodenticides were also detected in one bobcat from El Dorado County, one gray fox from Santa Clara County, and one San Joaquin kit fox from Kern County. None of the 56 exposures in 2023 were confirmed anticoagulant rodenticide toxicosis (Table 15).

Brodifacoum, bromadiolone, and diphacinone were the most common analytes detected in liver samples (Figure 10). Analytes detected in liver tissues were quantitated at a wide range of concentrations, including trace levels (Figure 11; Table 16). None of the tested samples in 2023 had detectable levels of exposure to coumachlor or difenacoum.

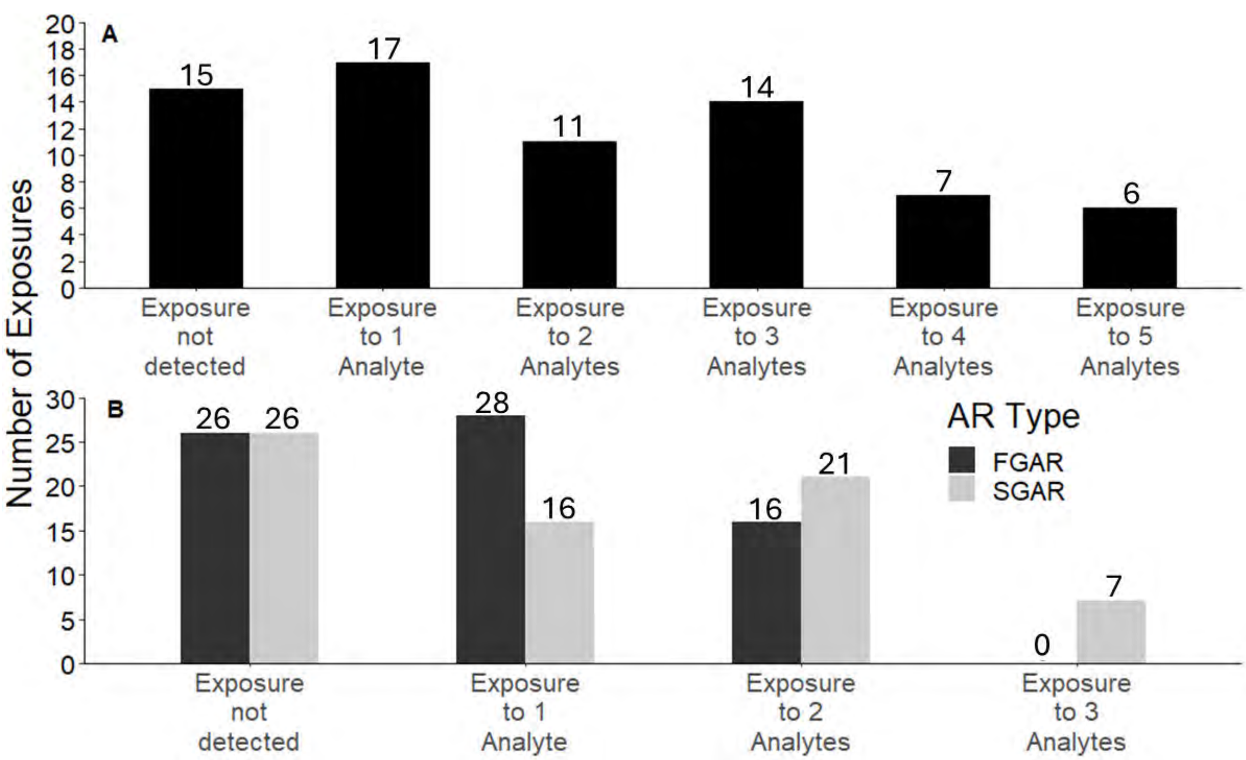


Figure 9. **(A)** Number of anticoagulant rodenticide residues detected in the livers of 70 wild non-game mammals in 2023. **(B)** Number of anticoagulant residues detected in the livers of 70 wild non-game mammals separated by first (FGAR) and second (SGAR) generation anticoagulant rodenticides in 2023.

Mountain Lion at Burton Mesa Ecological Reserve. Photo: CDFW Science Institute & Lands Program

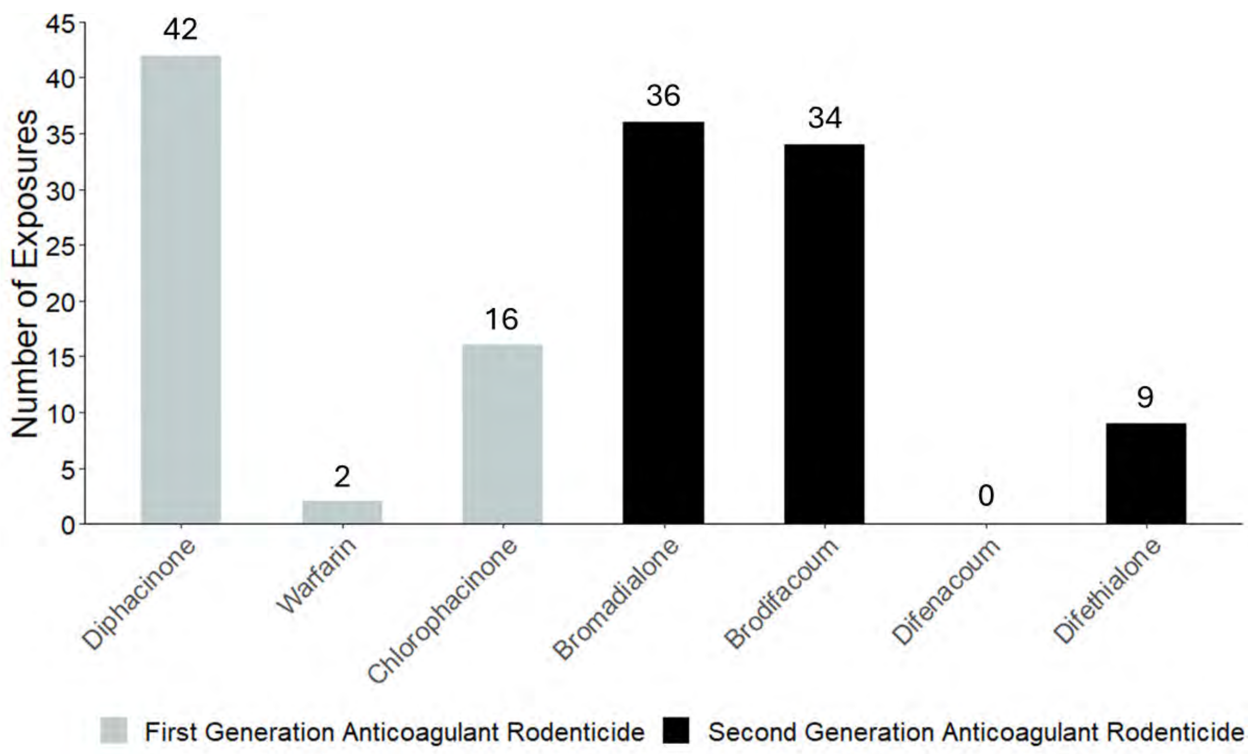


Figure 10. AR residues detected in the livers of 55 of the 70 tested wild non-game mammals submitted to the Wildlife Health Laboratory in 2023. Each bar displays number of exposures at the top.

Table 14. Exposure prevalence and number of confirmed toxicosis cases of anticoagulant rodenticides in 70 tested wild non-game animals submitted to the Wildlife Health Laboratory in 2023 by California county.

County	No. Non-game Tested	No. Non-game Exposed	Exposure Prevalence (%)	No. Confirmed or Suspected Toxicosis
Alameda	1	1	100.0	0
Butte	5	3	60.0	0
Calaveras	1	1	100.0	0
Contra Costa	1	0	0.0	0
El Dorado	3	3	100.0	0
Humboldt	1	1	100.0	0
Inyo	3	2	66.7	0
Kern	6	6	100.0	0
Lake	1	1	100.0	0
Lassen	2	1	50.0	0
Mariposa	2	1	50.0	0
Mendocino	2	1	50.0	0
Modoc	5	3	60.0	0
Mono	3	3	100.0	0
Napa	1	1	100.0	0
Placer	1	1	100.0	0
Plumas	2	1	50.0	0
Riverside	1	1	100.0	0
Sacramento	1	1	100.0	0
San Bernardino	3	2	66.7	0
San Diego	5	4	80.0	0
San Joaquin	1	1	100.0	0
San Mateo	1	1	100.0	0
Santa Clara	2	1	50.0	0
Santa Cruz	3	3	100.0	0
Shasta	1	1	100.0	0
Siskiyou	3	2	66.7	0
Sonoma	5	5	100.0	0
Tehama	1	1	100.0	0
Ventura	1	1	100.0	0
Yuba	2	1	50.0	0
Total	**70**	**55**	**78.6**	**0**

Table 15. Exposure prevalence and number of confirmed toxicosis cases of anticoagulant rodenticides in 70 wild non-game mammals submitted to the Wildlife Health Laboratory in 2023 by species (common name).

Species	No. Non-game Tested	No. Non-game Exposed	Exposure Prevalence (%)	No. Confirmed or Suspected Toxicosis
Beaver	1	0	0.0	0
Bobcat	13	11	84.6	0
Coyote	2	2	100.0	0
Desert Cottontail	1	0	0.0	0
Eastern Gray Squirrel	1	0	0.0	0
Fisher	3	1	33.3	0
Gray Fox	10	9	90.0	0
Gray Wolf	2	0	0.0	0
Mountain Lion	28	26	92.8	0
Porcupine	1	0	0.0	0
Raccoon	2	2	100.0	0
San Joaquin Kit Fox	3	3	100.0	0
Striped Skunk	3	1	33.3	0
Total	**70**	**55**	**78.6**	**0**

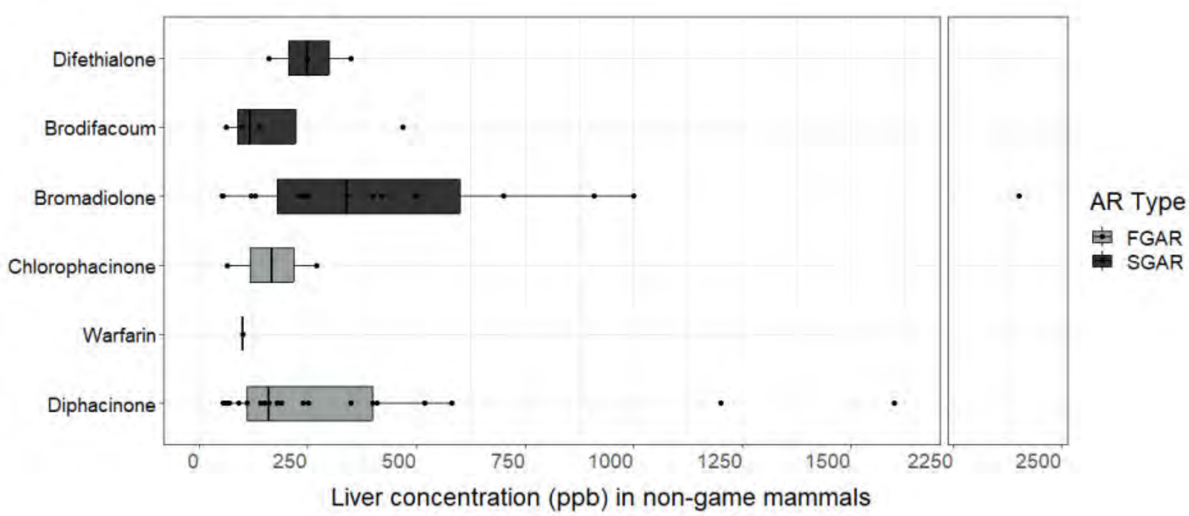


Figure 11. Boxplot to visualize AR concentrations (ppb) in the livers of 50 of the 70 tested wild non-game mammals submitted to the Wildlife Health Laboratory in 2023 where detectable levels were quantitated. This figure does not include instances of trace level detections (see Table 14). Box plot summary can be found in Appendix 1.2.

Table 16. Anticoagulant rodenticide concentrations (ppb) and number of trace detections in the livers of wild non-game mammals submitted to the Wildlife Health Laboratory in 2023. Summary includes concentration mean and standard error (SE) of the mean, range, and number of trace detections.

AR Type	Analyte	Mean ± SE (ppb)	Range (ppb)	Trace Level Detections
FGAR	Diphacinone	308.5 ± 73.0	56 – 1600	18
	Warfarin	100	100	1
	Chlorophacinone	167.5 ± 102.5	65 – 270	14
SGAR	Bromadiolone	516.5 ± 154.1	52 – 2400	21
	Brodifacoum	192.5 ± 93.8	63 – 670	30
	Difethialone	253.3 ± 54.9	160 – 350	6

Bromethalin Exposure

Adipose or brain from 62 animals across 28 counties was tested for exposure to the neurotoxic rodenticide, bromethalin (Table 17). Nine of the tested animals (14.5%) had exposure to bromethalin. These exposures resulted in one case each of confirmed toxicosis and suspected toxicosis (Table 17; Table 18). The case of confirmed bromethalin toxicosis was a gray fox in Mendicino County observed with neurological symptoms before death and tested positive for the bromethalin metabolite in adipose tissue, stomach contents, and feces. In the suspected bromethalin toxicosis case, a raccoon in good nutritional condition from Sonoma County showed neurological symptoms and tested positive for bromethalin in brain tissue, but also had trace exposure to chlorophacinone with some signs of hemorrhaging. With the raccoon testing negative for diseases that could cause neurological signs, this case was classified as suspected toxicosis.

Of the nine non-game wildlife that tested positive for bromethalin, six were concurrently tested for anticoagulant rodenticide exposure. Five out of six (83.3%) non-target wildlife were concurrently exposed to bromethalin and to one or more anticoagulant rodenticides. Anticoagulant rodenticides were not detected in one gray fox from Mendicino County; however, this mortality was confirmed bromethalin toxicosis. Concurrent exposures for all ages are summarized in Tables 19 and 20.

Gray Foxes at Sycuan Peak Ecological Reserve. Photo: CDFW Science Institute & Lands Program.

Table 17. Bromethalin exposure in 62 wild non-game mammals submitted to the Wildlife Health Laboratory in 2023 by county. Adipose, brain, or liver were submitted for toxicology testing to the California Animal Health and Food Safety Laboratory in Davis, CA.

County	No. Non-game Tested	No. Non-game Exposed	Exposure Prevalence (%)	No. Confirmed or Suspected Toxicosis
Butte	6	1	16.7	0
Calaveras	1	0	0.0	0
Contra Costa	1	0	0.0	0
El Dorado	3	0	0.0	0
Inyo	3	0	0.0	0
Kern	5	0	0.0	0
Lake	1	0	0.0	0
Lassen	2	0	0.0	0
Mariposa	1	0	0.0	0
Mendocino	2	1	50.0	1
Modoc	4	0	0.0	0
Mono	2	0	0.0	0
Napa	1	0	0.0	0
Nevada	2	1	50.0	0
Placer	2	0	0.0	0
Plumas	2	0	0.0	0
Sacramento	1	0	0.0	0
San Bernardino	2	0	0.0	0
San Diego	4	0	0.0	0
San Joaquin	1	0	0.0	0
San Mateo	1	0	0.0	0
Santa Clara	1	1	100.0	0
Santa Cruz	2	0	0.0	0
Siskiyou	3	1	33.3	0
Sonoma	6	4	66.7	1
Tuolumne	1	0	0.0	0
Ventura	1	0	0.0	0
Yuba	1	0	0.0	0
Grand Total	**62**	**9**	**14.5**	**2**

Table 18. Bromethalin exposure in 62 wild non-game mammals submitted to the Wildlife Health Laboratory in 2023 by county. Adipose, brain, or liver were submitted for toxicology testing to the California Animal Health and Food Safety Laboratory in Davis, CA.

Species	No. Non-game Tested	No. Non-game Exposed	Exposure Prevalence (%)	No. Confirmed or Suspected Toxicosis
Bobcat	5	0	0.0	0
Coyote	2	0	0.0	0
Desert Cottontail	1	0	0.0	0
Fisher	2	0	0.0	0
Gray Fox	13	5	38.5	1
Gray Wolf	2	0	0.0	0
Mountain Lion	23	1	4.3	0
Opossum	1	0	0.0	0
Porcupine	1	0	0.0	0
Raccoon	2	1	50.0	1
San Joaquin Kit Fox	4	0	0.0	0
Striped Skunk	6	2	33.3	0
Total	**62**	**9**	**14.5**	**2**

Bobcat at Camp Cady Wildlife Area. Photo: CDFW Science Institute & Lands Program

Table 19. Concurrent anticoagulant rodenticide and bromethalin exposure in 20 young non-game mammals submitted to the Wildlife Health Laboratory in 2023. Juveniles, pups, and cubs are confirmed exposures that occurred after the implementation of AB1788. *Represents confirmed/suspected bromethalin toxicosis case.

Species	County	Sex	Age Class	No. FGARs	No. SGARs	Bromethalin Exposure
Bobcat	Santa Cruz	F	Sub-adult (1-2 years)	1	0	not tested
Bobcat	Riverside	M	Juvenile (<1 year)	**1**	**1**	not tested
Coyote	San Bernardino	M	Juvenile (<1 year)	1	0	—
Gray Fox	San Diego	M	Pup (<1 month)	**1**	**1**	not tested
Gray Fox	San Joaquin	F	Juvenile (<1 year)	**1**	**1**	—
Gray Fox	Butte	M	Juvenile (<1 year)	1	0	—
Mountain Lion	Lake	M	Sub-adult (<2 years)	**2**	**1**	—
Mountain Lion	Santa Cruz	M	Sub-adult (<2 years)	**2**	**3**	—
Mountain Lion	Plumas	M	Sub-adult (<2 years)	1	0	—
Mountain Lion	Lassen	M	Cub (<1 year)	1	0	—
Mountain Lion	Mono	F	Cub (<1 year)	**1**	**2**	—
Mountain Lion	Mono	F	Sub-adult (<2 years)	**2**	**2**	not tested
Mountain Lion	Shasta	F	Cub (<1 year)	1	0	not tested
Mountain Lion	Mariposa	F	Sub-adult (<2 years)	**1**	**1**	—
Mountain Lion	Tehama	M	Yearling (1 year)	**1**	**2**	not tested
Mountain Lion	Siskiyou	F	Cub (<1 year)	0	1	—
Mountain Lion	Siskiyou	M	Sub-adult (<2 years)	**1**	**0**	**Yes**
Mountain Lion	San Diego	F	Sub-adult (<2 years)	**1**	**1**	—
Raccoon	Sonoma	M	Juvenile (<1 year)	**1**	**0**	**Yes***
Raccoon	El Dorado	M	Juvenile (<1 years)	1	0	—

Coyote at Napa-Sonoma Marshes Wildlife Area. Photo: CDFW Science Institute & Lands Program

Table 20. Concurrent anticoagulant rodenticide and bromethalin exposure in 36 adult non-game mammals submitted to the Wildlife Health Laboratory in 2023. AR exposures may or may not have occurred after the implementation of AB1788. *Represents confirmed bromethalin toxicosis case.

Species	County	Sex	Age Class	No. FGARs	No. SGARs	Bromethalin Exposure
Bobcat	Humboldt	F	Adult	0	1	not tested
Bobcat	El Dorado	M	Adult	**2**	**3**	—
Bobcat	Kern	F	Adult	**1**	**1**	—
Bobcat	Sacramento	M	Adult	0	2	not tested
Bobcat	Kern	F	Adult	**1**	**3**	not tested
Bobcat	Alameda	Unknown	Adult	0	2	not tested
Bobcat	San Bernardino	F	Adult	**2**	**2**	—
Bobcat	San Diego	M	Adult	**2**	**1**	—
Bobcat	Kern	F	Adult	0	1	not tested
Coyote	Butte	M	Adult	**2**	**1**	—
Fisher	Mendocino	M	Adult	**1**	**2**	—
Gray Fox	Sonoma	M	Adult	**1**	**2**	**Yes**
Gray Fox	Sonoma	Unknown	Adult	**1**	**2**	**Yes**
Gray Fox	Napa	F	Adult	0	1	—
Gray Fox	Santa Cruz	M	Adult	0	1	—
Gray Fox	Santa Clara	F	Adult	**2**	**3**	**Yes**
Gray Fox	Calaveras	F	Unknown	1	0	—
Gray Fox	Mendocino	M	Adult	0	0	Yes*
Mountain Lion	Ventura	F	Adult	**2**	**3**	—
Mountain Lion	San Mateo	M	Adult	**1**	**2**	—
Mountain Lion	Butte	M	Adult	**1**	**2**	—
Mountain Lion	Modoc	F	Adult	0	2	—
Mountain Lion	Modoc	M	Adult	**1**	**2**	not tested
Mountain Lion	Placer	F	Adult	**2**	**3**	—
Mountain Lion	El Dorado	F	Adult	**2**	**2**	—
Mountain Lion	Inyo	M	Adult	**2**	**2**	—
Mountain Lion	Mono	M	Adult	**1**	**2**	—
Mountain Lion	Inyo	M	Adult	**1**	**2**	—
Mountain Lion	Sonoma	M	Adult	**1**	**2**	—
Mountain Lion	San Diego	F	Adult	**2**	**2**	—
Mountain Lion	Modoc	M	Adult	0	1	—
Mountain Lion	Yuba	F	Adult	**2**	**2**	not tested
San Joaquin Kit Fox	Kern	M	Adult	**2**	**3**	—
San Joaquin Kit Fox	Kern	F	Adult	0	2	—
San Joaquin Kit Fox	Kern	M	Adult	2	0	—
Striped Skunk	Sonoma	M	Adult	0	1	—

Other Pesticide Surveillance

When warranted, wild small- and non-game mammals and fish were tested for additional pesticides, including organophosphates and carbamates, neonicotinoids, pyrethroids, and other compounds.

A general toxicology panel (GMCS/LCMS) was performed on one mountain lion from Mono County, one gray fox from Santa Cruz County, one Mexican free-tailed bat from Santa Clara County, and for three fish mortality cases from Trinity, San Diego, and Lake counties. Results of these tests are summarized in Table 21.

In March 2023, a colony of Mexican free-tailed bats experienced a mortality event at a property in Yuba County. The property was reported to use "mothballs" to deter bats, and the attic of the property had a strong chemical smell. Crystals and a bat carcass were recovered at the scene and tested for the compound dichlorobenzene. The crystals tested positive for 1,4-Dichlorobenzene. Liver tissue from the bat carcass tested negative, possibly due to low sample size, tissue volume, and relatively high reporting limit for tested tissue sample.

Cholinesterase levels were tested in a gray wolf from Lassen County and levels were above thresholds that indicate exposure to cholinesterase-inhibiting compounds.

Table 21. Results from GCMS/LCMS screenings conducted on non-game wildlife and fish submitted to the Wildlife Health Laboratory in 2023. No significant findings (NSF) are noted for results where the no analytes were detected, or detections were expected within normal ranges. *Fish cases were not included in small game and non-game AR surveillance summaries.

Species	County	GCMS/LCMS Detections	Concurrent AR Exposure
Mountain Lion	Mono	caffeine	Brd, brm, chl (Trace); diph (520 ppb)
Gray Fox	Santa Cruz	chlorpyrifos	brm (2400 ppb)
Mexican Free-tailed Bat	Santa Clara	NSF	—
Pooled fish fry	Trinity	NSF	—
Spotted Bay Bass*	San Diego	p,p'-DDE	Not detected
Moray Eel*	San Diego	p,p'-DDE	brd (Trace)
Bullhead Catfish	Lake	Fluridone; Endothall; cocaine; nicotine	—
Cleark Lake Hitch	Lake	NSF	—

RECENT WILDLIFE-RODENTICIDE LEGISLATION AND CURRENT RODENTICIDE-USE TRENDS

Evaluation of Assembly Bill (AB) 1788

On January 1, 2021, a temporary moratorium was placed on the public sales and use of SGARs in California (AB1788). CDFW proposed guidelines to monitor the effects of implementing AB1788, while also continuing long-term monitoring and surveillance efforts in non-target wildlife, given the long half-lives of many SGARs and their ability to bioaccumulate in the livers of animals[2].

The CDFW 2022 annual report summarized the CDFW-led short-term evaluation of the efficacy of AB1788, which entailed assessing cases of exposure in animals born or hatched after January 1, 2021 and any cases of acute toxicosis[2]. Detections of AR compounds in wildlife born or hatched after implementation of AB1788 could indicate exposure rates under the new restrictions; however, it is possible that mammals could have been exposed in utero prior to implementation of the law[5-11]. Additionally, wildlife of any age that succumbed to acute toxicosis in 2022 were likely to have been exposed to compounds recently and in concentrations high enough to cause coagulopathy and death, rather than chronic exposure accumulating over time. It is important to note, however, that most wildlife had more than one analyte detected in their livers belonging to both FGARs and SGARs. Furthermore, it is important to acknowledge that there is no minimum threshold concentration indicative of anticoagulant rodenticide toxicosis. Determining whether toxicosis was due to either an FGAR or SGAR is challenging in the presence of multiple analytes and lack of empirical data on cumulative effects. The CDFW 2022 annual report indicated that, despite the implementation of AB1788 that restricted SGAR-use, non-target wildlife was still at risk of exposure and toxicosis.

In 2023, we detected anticoagulant rodenticide exposure in 71.9% (92/128) of non-target wildlife tested. Despite the long-half lives of SGARs, which may persist in liver tissues for upwards of six to 12 months and potentially beyond (i.e., brodifacoum can have a half-life of approximately 350 days in liver tissues[12]), exposures detected in 2023 were most likely related to use after AB1788 was implemented (January 1, 2021). In birds that were tested, 26 individuals were exposed to one or more SGARs, resulting in 45 SGAR detections; 15 individual birds were exposed to one or two FGARs, resulting in 18 FGAR detections. In non-game mammals, 44 individuals were exposed to one or more SGARs, resulting in 79 SGAR detections; 44 individual non-game mammals were exposed to one or more FGARs, resulting in 60 FGAR detections. In big game mammals (black bear) tested, five individuals were exposed to SGARs, resulting in six SGAR detections; two individual black bears were exposed to FGARs, resulting in two FGAR detections. For all non-target wildlife with quantitated anticoagulant rodenticide liver concentrations, we found an average (mean ± standard error of the mean) liver concentration of 310.0 ± 65.2 ppb and 302.2 ± 61.7 ppb for SGARs and FGARs in wildlife tested in 2023, respectively (Figure 12; Figure 13; Table 22).

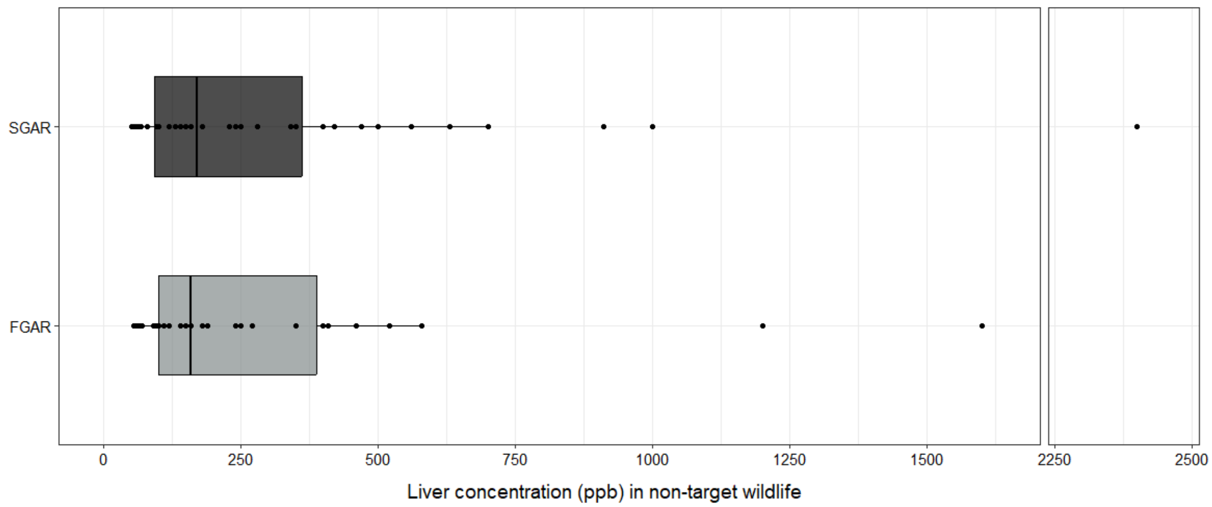


Figure 12. Box plot to visualize FGAR and SGAR concentrations (ppb) in the livers of 74 of the 128 tested wild non-game mammals submitted to the Wildlife Health Laboratory in 2023 where detectable levels were able to be quantitated. This figure does not include instances of trace level detections (see Table 22). Box plot summary can be found in Appendix 1.3.

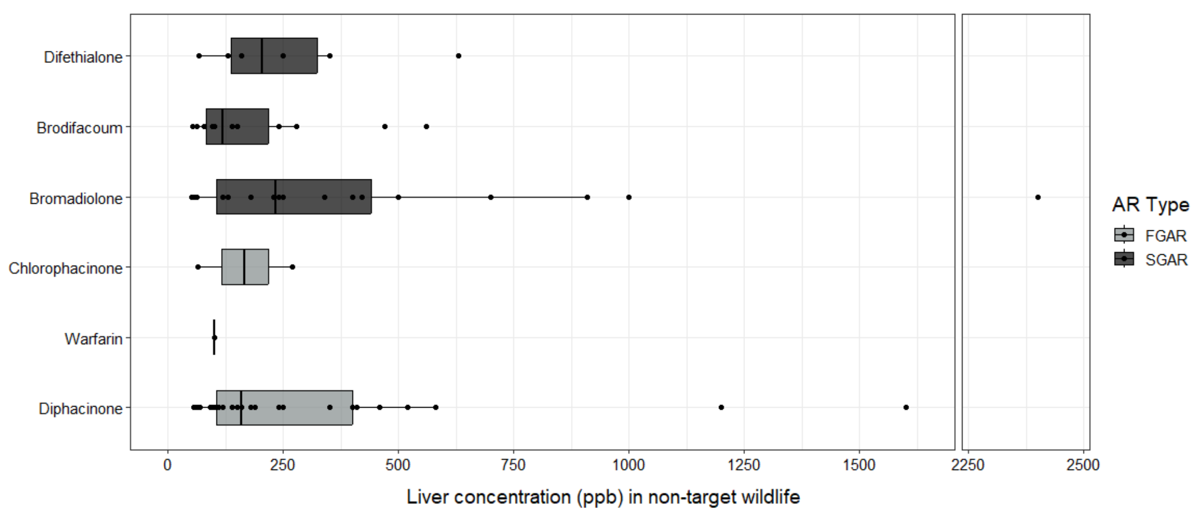


Figure 13. Box plot to visualize AR analyte concentrations (ppb) in the livers of 74 of the 128 tested all non-target avian, game, and non-game wildlife submitted to the Wildlife Health Laboratory in 2023 where detectable levels were able to be quantitated. This figure does not include instances of trace level detections (see Table 22). Box plot summary can be found in Appendix 1.4.

Table 22. AR concentrations (ppb) and number of trace detections in the livers of all non-target avian, game, and non-game wildlife submitted to the Wildlife Health Laboratory in 2023. Summary includes concentration mean and standard error (SE) of the mean, range, and number of trace detections.

AR Type	Analyte	Mean ± SE (ppb)	Range (ppb)	No. of Trace Detections
FGAR	**Diphacinone**	317.4 ± 66.9	56 –1600	27
	Warfarin	100	100	1
	Chlorophacinone	167.5 ± 102.5	65 – 270	19
SGAR	**Bromadiolone**	414.3 ± 121.8	52 – 2400	28
	Brodifacoum	180.4 ± 42.1	53 – 560	46
	Difethialone	264.7 ± 83.4	68 – 630	14

A juvenile Cooper's Hawk with rat prey in Yolo County. Photo: Ryan Bourbour, CDFW

Rodenticide surveillance and the changing rodenticide landscape

Continued rodenticide exposure in wildlife and changing patterns of state-wide use highlight the need for ongoing and adaptive surveillance efforts. Exposure to rodenticide compounds continues to be a risk to non-target wildlife in California (Table 23; Table 24). According to DPR's Pesticide Use Reporting (PUR) data, the number of rodenticide applications used for the control of commensal rodents (collectively: ARs, bromethalin, and cholecalciferol) have remained relatively constant from 2013 to 2022 (Figure 14). Notably, legislation that aims to protect non-target wildlife from anticoagulant rodenticide exposure, such as AB1788, may have implications on the types of compounds applied and rates different compounds are applied throughout the state (Figure15).

Following the implementation of AB1788 on January 1st, 2021, the PUR data shows a decline in the reported use of restricted SGARs and the increase in use of FGARs, bromethalin, and cholecalciferol (Figure 15).

Understanding the rodenticide exposure rates in non-target wildlife populations across California is challenging because in addition to long-term surveillance of tested animals, a systematic biomonitoring approach is needed. Moving forward, rodenticide surveillance efforts that reflect the evolving rodenticide landscape will be important, as different rodenticide types require different sampling and testing methods, validation methods, and data interpretation. Increases in the reported use of other rodenticides that are replacing restricted ARs create the need for adaptive surveillance strategies to inform pest management and conservation decisions. However, these adaptive efforts may be challenging to implement. For example, screening for both ARs and neurotoxic bromethalin multiplies the financial cost of pesticide screening for a single animal. Given the emerging evidence of both primary and secondary exposure risks to non-target wildlife that are tested for bromethalin[13,14] (Tables 11,12, 18–20, 24), continued surveillance and additional resources from regulating agencies are warranted to facilitate systematic monitoring of both AR and non-AR exposure for the biomonitoring of California's wildlife.

Table 23. Summary of anticoagulant rodenticide exposure and toxicosis rates from CDFW WHL Annual Reports 2020–2023[2,3,4].

Year	Total Submitted to WHL	Total Tested for ARs	Total Exposed to ARs	% Exposed to ARs	Total Confirmed Toxicosis	% Toxicosis Confirmed
2020	1,040	159	108	67.9	24	22.2
2021	1,020	250	175	70.0	19	10.9
2022	1,543	158	128	81.0	18	14.1
2023	1,250	128	92	71.9	11	12.0

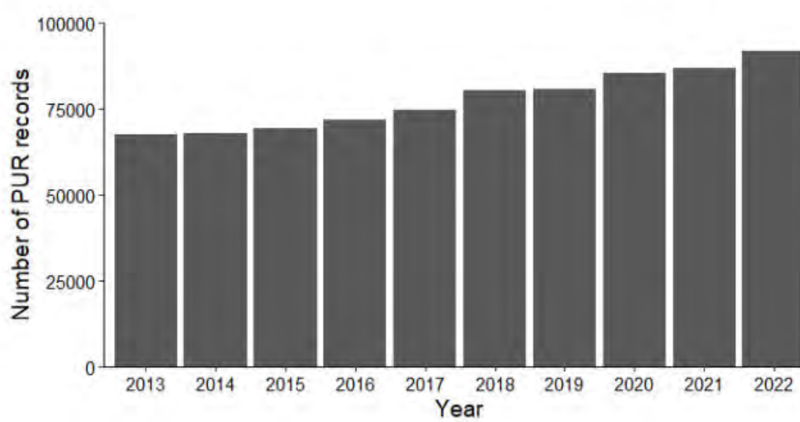


Figure 14. The total number of Pesticide Use Reporting (PUR) records for ARs, bromethalin, and cholecalciferol in California between 2013–2022. PUR data shown in graph was obtained from DPR's California Pesticide Informational Portal; 2023 PUR data was not available when this report was written. The PUR records in the figures do not indicate pounds of product or active ingredients applied.

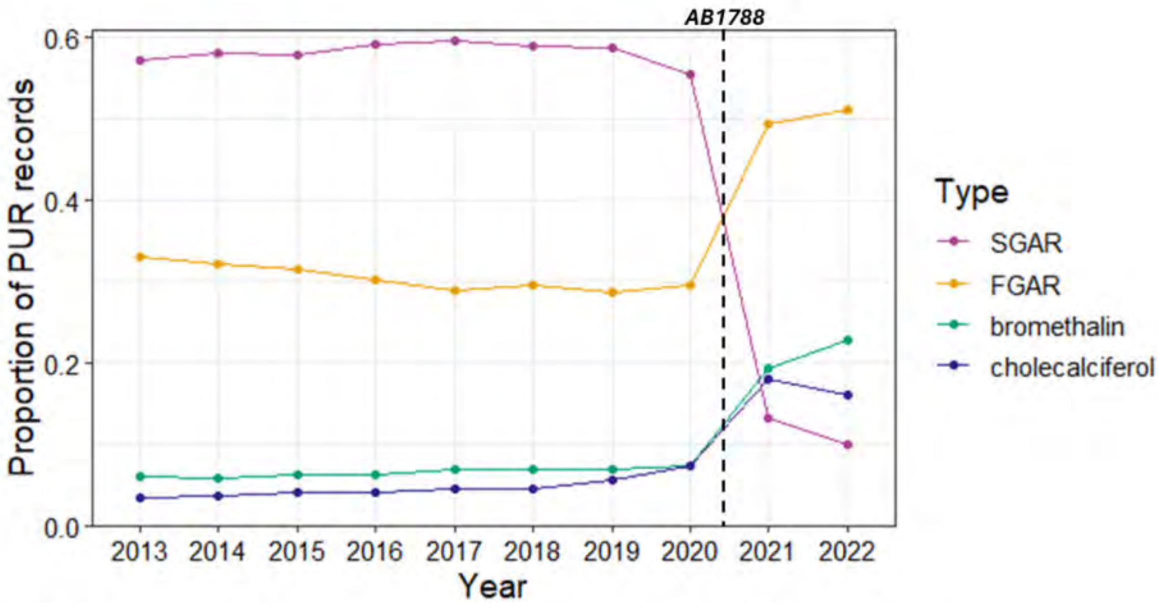


Figure 15. Proportions of the number of rodenticide applications for ARs, bromethalin, and cholecalciferol according to Pesticide Use Reporting (PUR) records in California 2013–2022. PUR data was obtained from DPR's California Pesticide Informational Portal. The black dotted line represents implementation of AB1788 on January 1st, 2021. The 2023 PUR data was not available when this report was written.

Bobcat at Semitropic Ecological Reserve. Photo: CDFW Science Institute & Lands Program

Table 24. Summary of bromethalin exposure rates for a subset of commonly tested non-target wildlife reported in CDFW WHL Annual Reports 2021–2023[2,3]. Between 2021 and 2023, CDFW detected bromethalin in 22.0% (74/338) of non-target mammals tested.

Bromethalin Detections in Non-target Wildlife (2021-2023)	
Black Bear	30.3% (10/33)
Mountain Lion	15.3% (11/72)
Bobcat	15.6% (15/96)
Coyote	20% (3/15)
Gray Fox	25% (10/40)
Raccoon	64.7% (11/17)
Striped Skunk	50% (6/12)

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An adult Great Horned Owl hunting from an artificial raptor perch in a Yolo County orchard. Photo: Ryan Bourbour, CDFW

APPENDIX 1

1.1. Summary statistics from box plot in Figure 3; calculated with *geom_boxplot* command in the R package *ggplot2*. Concentration numbers reported are in parts per billion (ppb).

Avian - Figure 3

Compound	Lower Q1	Median	Upper Q3	Min	Max	Outliers
Diphacinone	100	120	150	96	150	460
Bromadiolone	58	63	180	57	180	—
Brodifacoum	72.75	120	250	53	280	560
Difethialone	83.5	99	114.5	68	130	—

1.2. Summary statistics from box plot in Figure 11; calculated with *geom_boxplot* command in the R package *ggplot2*. Concentration numbers reported are in parts per billion (ppb).

Nongame - Figure 11

Compound	Lower Q1	Median	Upper Q3	Min	Max	Outliers
Diphacinone	110	160	400	56	580	1600, 1200
Warfarin	100	100	100	100	100	
Chlorophacinone	116.25	167.5	218.75	65	270	
Bromadiolone	180	340	600	52	1000	2400
Brodifacoum	88.5	118.5	222.5	63	222.5	470
Difethialone	205	250	300	160	350	

1.3. Summary statistics from box plot in Figure 12; calculated with *geom_boxplot* command in the R package *ggplot2*. Concentration numbers reported are in parts per billion (ppb).

All non-target - Figure 12

Compound	Lower Q1	Median	Upper Q3	Min	Max	Outliers
SGAR	100	160	387.5	56	580	1200, 1200, 1600
FGAR	92.5	170	362.5	52	700	910, 1000, 2400

1.4. Summary statistics from box plot in Figure 13; calculated with *geom_boxplot* command in the R package *ggplot2*. Concentration numbers reported are in parts per billion (ppb).

All non-target - Figure 13

Compound	Lower Q1	Median	Upper Q3	Min	Max	Outliers
Diphacinone	105	160	400	56	580	1200, 1200, 1600
Warfarin	100	100	100	100	100	
Chlorophacinone	116.25	167.5	218.75	116.25	270	
Bromadiolone	105.75	235	440	105.75	910	1000, 2400
Brodifacoum	83.5	120	217.5	83.5	280	470, 560
Difethialone	137.5	205	325	137.5	350	630

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News Releases, 2022-Present

Poison Detection in Wild Pigs Brings Attention to Pesticide Exposure in Hunter-Harvested Wildlife

July 30, 2025

Wild pigs in the Monterey County area were exposed to pesticide bait containing the anticoagulant rodenticide diphacinone, according to findings by the California Department of Fish and Wildlife's (CDFW) Wildlife Health Lab (WHL) and the California Animal Health and Food Safety Laboratory in Davis.

In March, a wildlife trapper reported multiple observations of blue muscle or fat found in wild pigs. The blue tissue can be a sign of rodenticide bait ingestion. CDFW's WHL investigated, finding the anticoagulant rodenticide diphacinone in the stomach and liver contents of one of the wild pigs that was recovered with blue tissues.

Wildlife can be inadvertently exposed to rodenticides either by eating rodenticide bait or by eating other animals that have ingested rodenticides. Rodenticide baits often contain dye to identify them as a poison. Blue-colored muscle or fat may be a sign that game meat has been contaminated by rodenticides, although this blue discoloration may not always be present. CDFW urges hunters to always use caution when harvesting game animals and be aware of potential risks.

“Hunters should be aware that the meat of game animals, such as wild pig, deer, bear and geese, might be contaminated if that game animal has been exposed to rodenticides,” said CDFW Pesticide Investigations Coordinator Dr. Ryan Bourbour. “Rodenticide exposure can be a concern for non-target wildlife in areas where applications occur in close proximity to wildlife habitat.”

A 2018 study of anticoagulant rodenticide exposure in game animals across California found anticoagulant rodenticide residue in 10 out of 120 (8.3%) of the wild pig and 10 out of 12 (83%) of the bear tissue samples collected largely from animals that were frequenting agricultural or residential areas where rodenticides are commonly/more likely to be utilized.

CDFW encourages hunters to report unusual findings in harvested wildlife, including blue tissue, and not to consume any part of an animal with blue fat or muscle or other abnormalities. Incidents may be reported to the CDFW’s Wildlife Health Lab at WHLab@wildlife.ca.gov or (916) 358-2790.

Pesticide applicators are urged to take measures when applying rodenticides so as not to expose wildlife. Prior to application, it is important to ensure non-target wildlife are not using the area where the pesticide is to be applied. It is also important to use appropriate bait stations and application methods that exclude access to non-target species. Using an integrated pest management approach for rodent control may help reduce the opportunities for rodenticide exposure for non-target wildlife.

For questions about pesticide use and regulations, or to report misuse, contact your local county agricultural commissioner’s office. For Monterey County, call (831) 759-7325.

Visit CDFW’s human-wildlife conflicts web page for more information and resources for managing squirrels and other rodents.

###

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Categories: Environment, Hunting, Wildlife, Wildlife Health

Tagged: Wild Pig | Pesticide Esposure | Rodenticides | Wildlife Health Lab

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Department of Pesticide Regulation
Pesticide Registration Branch
November 16, 2018

An Investigation of Anticoagulant Rodenticide Data Submitted to the Department of Pesticide Regulation

Introduction

In 1999, the California Department of Pesticide Regulation (DPR) placed pesticide products containing brodifacoum into reevaluation in response to a request from the California Department of Fish and Game (now the California Department of Fish and Wildlife [DFW]). In 2013, DPR assessed available data on second-generation anticoagulant rodenticides (SGARs) currently registered in California (brodifacoum, bromadiolone, difenacoum, and difethialone) and determined that the use of SGARs presented unmitigated risks related to persistent residues in target animals, resulting in impacts to non-target wildlife.

To mitigate the risks identified by the assessment, effective July 1, 2014, DPR designated the SGAR active ingredients brodifacoum, bromadiolone, difenacoum, and difethialone as California restricted materials. As a result, rodenticides containing the four active ingredients can only be sold by licensed dealers and purchased by certified applicators (DPR, 2014). DPR also added additional use restrictions and revised the definition of a private applicator. Products containing first-generation anticoagulant rodenticides (FGARs), which include warfarin, chlorophacinone, and diphacinone, were not included in these regulatory changes.

Since implementation of the regulatory change in 2014, DPR continued to receive and analyze data regarding exposure to non-target wildlife from anticoagulant rodenticides (ARs). Thorough analysis is required to fully assess the impact of these regulatory changes over time and aid in determining if further regulatory action is warranted. This report incorporates information and data from a variety of sources, including peer-reviewed scientific publications, statewide sales and use reporting data, and unpublished wildlife incident and mortality data. Publications and data utilized in the decision-making process are reviewed and discussed below.

On December 22, 2017, DPR received a letter, accompanied by data and exhibits, from the law offices of Michael W. Graf, on behalf of Raptors Are the Solution and Project Coyote, requesting that the following seven pesticide active ingredients be placed into reevaluation based on significant impacts on wildlife health and the environment: 1) brodifacoum, 2) bromadiolone, 3) difethialone, 4) difenacoum, 5) diphacinone, 6) chlorophacinone, and 7) warfarin. DPR currently registers rodenticides containing these active ingredients for sale and use in California.

This report analyzes the data and exhibits submitted to DPR by Mr. Graf, as well as all information and data that has been submitted to DPR by DFW (2014-2018). It also incorporates information and data from a variety of sources, including statewide sales and use reporting data, and unpublished wildlife incident and mortality data.

Background

Anticoagulant rodenticides are typically classified as either first-generation or second-generation. First-generation anticoagulants, such as warfarin, though initially efficacious, began to lose their effectiveness. The appearance of rats and mice resistant to warfarin necessitated the development of alternatives. This eventually led to the development of SGARs, brodifacoum, bromadiolone, difethialone, and difenacoum. FGARs and SGARs share a similar mechanism of action, but SGARS have increased toxicity, prolonged half-lives, and increased lipophilicity.

The increased toxicity of the SGARs corresponds to lower effective doses. For instance, in rats, warfarin has an oral LD_{50} of 58.0 mg/kg, whereas brodifacoum has an oral LD_{50} of 0.26 mg/kg (U.S. EPA, 2004; Redfern et al., 1976; Thomson, 1988). Accordingly, it may take multiple feedings of a FGAR to reach a lethal dose, but a single feeding of a SGAR can result in lethality. Table 1 presents a comparison of the most sensitive LD_{50} values for birds and mammals (not just rats) for the ARs.

Toxicity is one component of the ARs' efficacy in animals. Due to their mechanism of action, there is a delay between consumption of a lethal dose and death of the exposed organism. As a result, the target organism may continue to consume the bait. In the case of an SGAR, this allows for super-lethal concentrations of the rodenticide to accumulate in its body. Secondary non-target wildlife exposure may occur, when non-target wildlife feed on the exposed target pest.

The SGARs are more persistent than FGARs in the livers of animals that have been exposed. For example, warfarin has a hepatic (liver) half-life of 26.2 days, whereas brodifacoum has a hepatic half-life of up to 350 days (Table 2; U.S. EPA, 2004). The significantly extended hepatic half-lives for SGARs means that an animal that ingested the anticoagulant can potentially carry that compound for years, as compared to days or months for an FGAR.

Finally, the increased lipophilicity of the SGARs can increase the amount of AR that is absorbed to the tissues. For example, brodifacoum has an octanol-water partition coefficient (K_{ow}) that is approximately five orders of magnitude higher than warfarin (Table 3). This suggests that if two animals are dosed with equal amounts of brodifacoum and warfarin, the animal dosed with brodifacoum will have a higher initial concentration in its liver because brodifacoum is more lipophilic. A higher initial concentration in the liver tissue means that there will be detectable residues in the liver for a longer time, even if the rate of decline is the same for both compounds. This, in effect, further amplifies the persistence of the SGARs.

Table 1 – Comparison of toxicity values for birds and mammals for ten rodenticides.

Type of Rodenticide	Active Ingredient	Most Sensitive LD_{50} for Birds (mg ai/kg bw) [a, b]	Most Sensitive LD_{50} for Mammals (mg ai/kg bw) [a, b]
SGARs	**Brodifacoum**	**0.26**	**0.13**
	Bromadiolone	138	0.56
	Difenacoum	66	0.45
	Difethialone	**0.26**	**0.29**
FGARs	Chlorophacinone	>100	0.49
	Diphacinone	96.8	0.2
	Warfarin	620	2.5

Bold font represents those active ingredients that have similar LD_{50} values for mammals and birds. The other active ingredients have a substantial difference between the LD_{50} values for mammals and birds.
[a] Data summarized from DPR, 2013
[b] LD_{50} values presented in units of milligrams of active ingredient per kilogram of body weight

Table 2 – Hepatic half-lives of seven ARs in the livers of target species.

Type of Rodenticide	Active Ingredient	Hepatic half-lives (Days) [a]
SGARs	Brodifacoum	113.5-350
	Bromadiolone	170-318
	Difenacoum	118
	Difethialone	126
FGARs	Chlorophacinone	< 2
	Diphacinone	3
	Warfarin	26.2

[a] Data summarized from DPR, 2013

Table 3 – Octanol-water partition coefficient (K_{ow}) values for seven ARs.

Type of Rodenticide	Active Ingredient	Log K_{ow}
SGARs	Brodifacoum	8.5 [a]
	Bromadiolone	4.3 [b]
	Difenacoum	7.6 [c]
	Difethialone	9.82 [d]
FGARs	Chlorophacinone	1.98 [e]
	Diphacinone	4.3 [f]
	Warfarin	2.70 [g]

References: [a] U.S. EPA, 2016-a; [b] U.S. EPA, 2016-b; [c] U.S. EPA, 2007; [d] U.S. EPA, 2016-c; [e] U.S. EPA, 2015-a; [f] U.S. EPA, 2012; [g] U.S. EPA, 2015-b

<u>Descriptions of Data and Exhibits Submitted to DPR by Michael Graf</u>

- **California Department of Fish and Wildlife (DFW) AR Exposure Cases**

The Department of Fish and Wildlife receives animals from various sources including wildlife rehabilitation centers and County Agricultural Commissioners. These animals are generally necropsied by DFW and then liver samples are sent to the California Animal Health and Food Safety Laboratory at UC Davis for AR testing. DFW then submits loss reports (i.e., necropsy reports) to DPR for non-target wildlife that test positive for exposure to rodenticides. DPR examines the submitted loss reports, compiles them in a database, and analyzes the data (Table 4, Figures 1-5).

There are several limitations in the loss reports provided to DPR that preclude the analysis of trends or overall exposure. First, DFW only provides reports for non-target wildlife that test positive for exposure to rodenticides. DFW does not inform DPR of the total number of animals tested. Second, the animals are not collected randomly. For a sample to be representative of a population, the data must be collected randomly (Ott and Longnecker, 2010). For example, when distressed animals are brought to wildlife rehabilitation centers, they are not collected randomly, are not healthy animals and are, therefore, not representative of the general population of healthy animals. Third, when wildlife rehabilitators suspect that an animal may have been exposed to rodenticides, they send the body to DFW for necropsy. This further biases the data collected toward positive tests for rodenticide exposure. Finally, DFW prioritizes which animals to necropsy and/or test for rodenticide exposure, and the criteria that DFW uses to prioritize animals for necropsy is unknown. This means the data may potentially have multiple levels of bias which result in a high percent of animals testing positive for AR exposure. This does not mean that the data is invalid, or that the data does not have value from a regulatory perspective. However, it must be noted that the data is not representative of the general population of all wild animals, conclusions drawn from these data have to explain the caveats and uncertainties including its limitations in representing the percentage of all wild animals that may be exposed to anticoagulant rodenticides. DPR has requested more information on DFW’s methodology and selection procedures.

Table 4 – DPR analysis of AR exposure rates based on DFW loss reports

Parameter	2014	2015	2016	2017	2018
Total Reported Animals Tested	18	42	56	24	12
No. of Reported Mammals Tested	16	28	45	14	6
No. of Reported Birds Tested	2	14	10	10	6
No. of Reported Non-Bird/Mammals Tested	0	0	1	0	0
No. of Reported Animals with Detectable Levels of ARs	16 / 18	41 / 42	52 / 56	20 / 24	12 / 12
Maximum No. of ARs Detected	5	4	5	5	4
Minimum No. of ARs Detected	0	0	0	0	1
Mean No. of ARs Detected	2.5	2.1	2.2	2.5	2.4
No. of Reported Animals with Detectable Levels of FGARs	9 / 18	21 / 42	16 / 56	9 / 24	3 / 12
No. of Reported Animals with Detectable Levels of Chlorophacinone	1 / 18	3 / 42	3 / 56	6 / 24	0 / 12
No. of Reported Animals with Detectable Levels of Diphacinone	9 / 18	18 / 42	15 / 56	6 / 24	3 / 12
No. of Reported Animals with Detectable Levels of Warfarin	1 / 18	1 / 42	1 / 56	1 / 24	0 / 12
No. of Reported Animals with Detectable Levels of SGARs	16 / 18	35 / 42	51 / 56	19 / 24	12 / 12
No. of Reported Animals with Detectable Levels of Brodifacoum	14 / 18	32 / 42	48 / 56	19 / 24	11 / 12
No. of Reported Animals with Detectable Levels of Bromodiolone	14 / 18	18 / 42	32 / 56	13 / 24	7 / 12
No. of Reported Animals with Detectable Levels of Difenacoum	1 / 18	2 / 42	0 / 56	3 / 24	1 / 12
No. of Reported Animals with Detectable Levels of Difethialone	5 / 18	15 / 42	23 / 56	12 / 24	7 / 12

Notes:
This table includes all data provided to DPR by DFW from 2014 to 2018.
ARs: Anticoagulant Rodenticides
FGARs: First Generation Anticoagulant Rodenticides
SGARs: Second Generation Anticoagulant Rodenticides

Figure 1 – DPR's preliminary analysis of SGAR non-target wildlife exposure rates based on loss reports submitted by DFW.

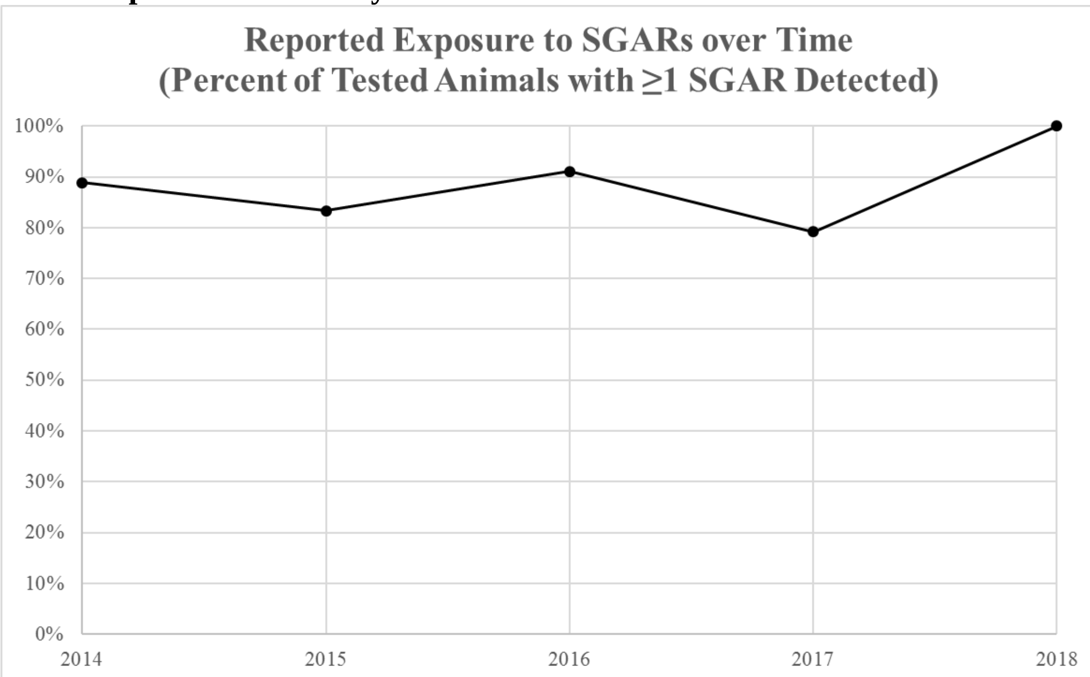


Figure 2 – Exposure rates of individual SGAR active ingredients from 2014-2018 (chart created by DPR scientists from non-target wildlife loss reports submitted by DFW).

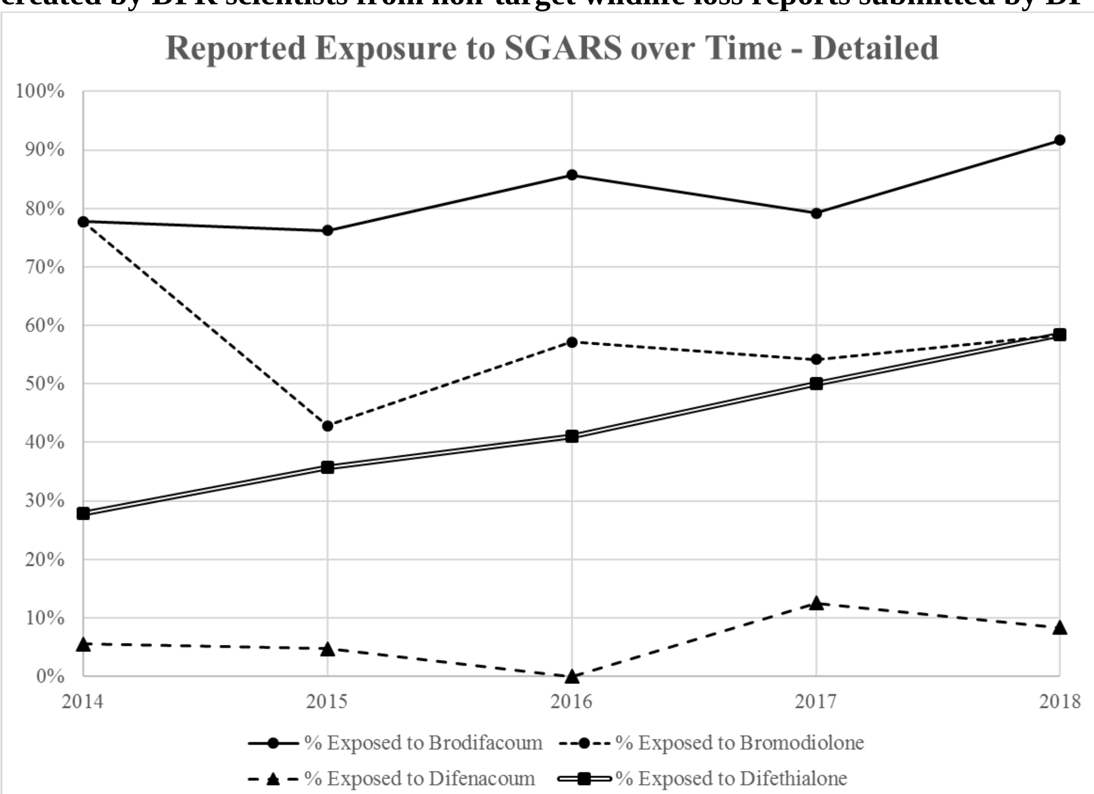


Figure 3 – DPR's preliminary analysis of FGAR non-target wildlife exposure rates based on loss reports submitted by DFW.

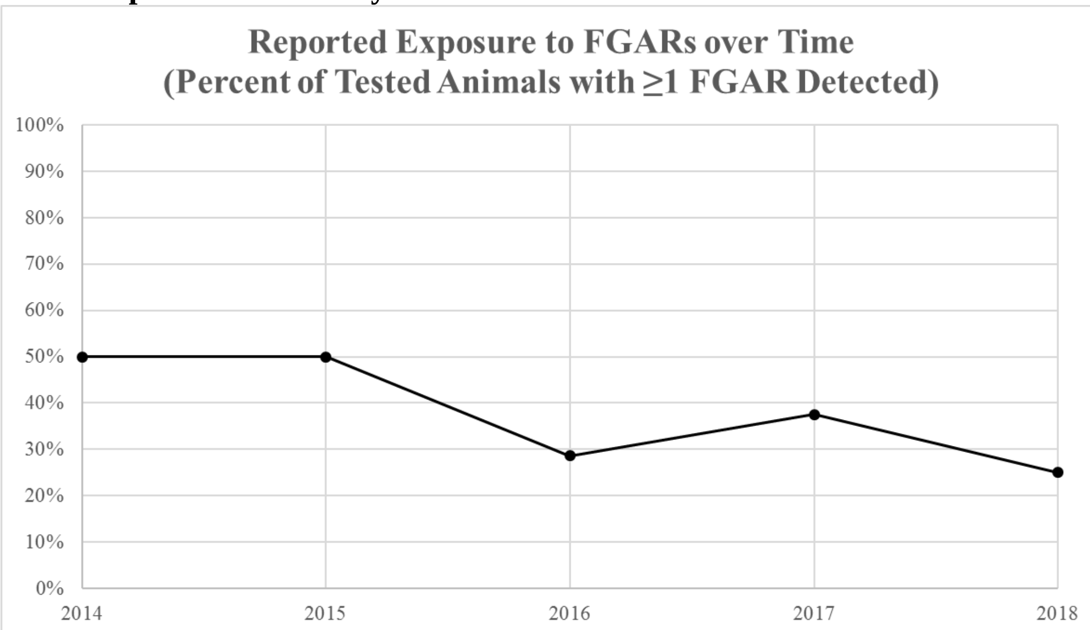


Figure 4 – Exposure rates of individual FGAR active ingredients from 2014-2018 (chart created by DPR scientists from non-target wildlife loss reports submitted by DFW).

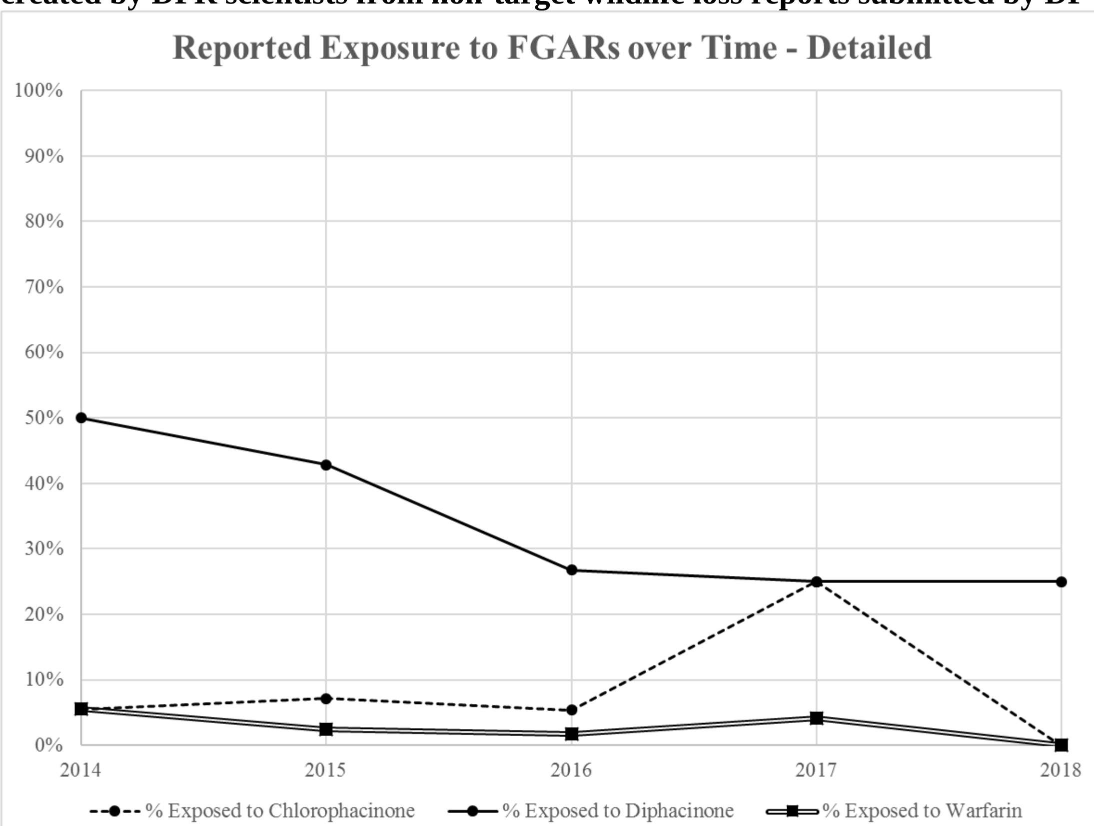
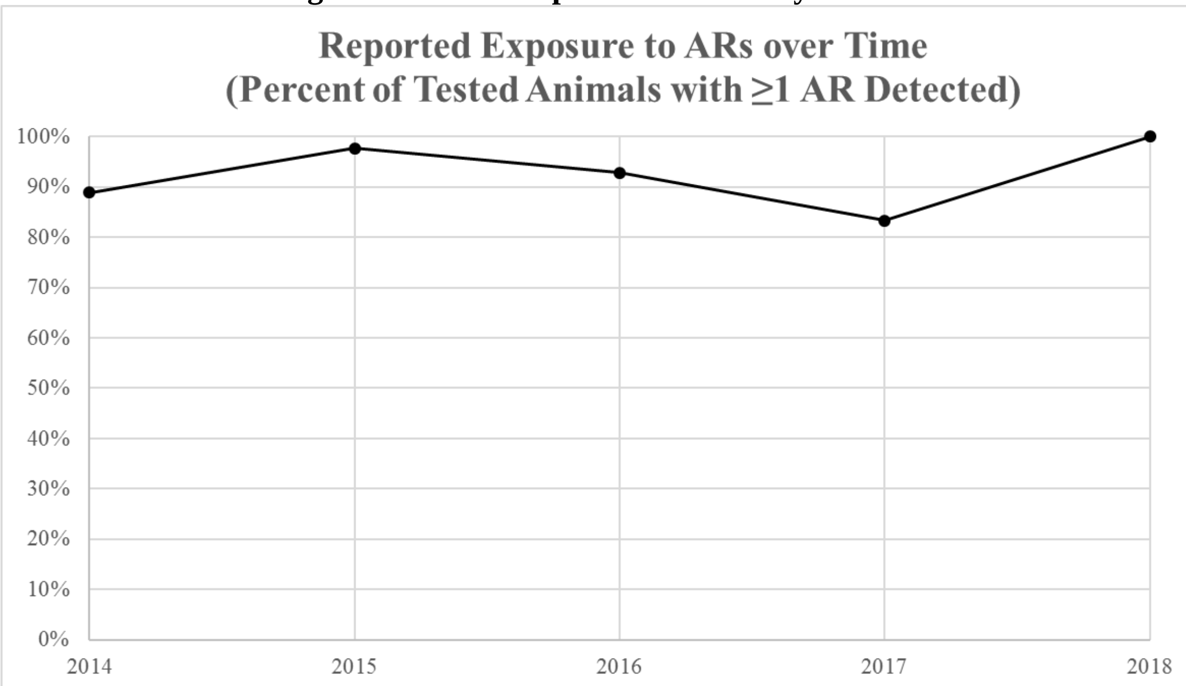


Figure 5 – DPR's preliminary analysis of AR (all ARs, 1st and 2nd generation) exposure rates based on non-target wildlife loss reports submitted by DFW.



- **<u>DFW Mountain Lion Database</u>**

DFW and Michael Graf both independently provided DPR with the same database of mountain lion AR exposure data. DFW did not provide DPR with a written account of how this data was collected, but in a recent (October 4, 2018) meeting between DFW and DPR scientists, DFW scientists stated that the rodenticide screening for mountain lions was part of a two-year grant in which DFW tested every mountain lion available. DFW stated that many of these mountain lions were killed through depredation permits, but some were also killed in vehicular collisions, as well as other causes of death. Therefore, although the sample collection was not completely random, there is minimal selection bias. DPR scientists conducted an independent analysis of this data. At this time, DPR has excluded four mountain lions without a date of death from its analysis. If additional information is provided by DFW, DPR will include all mountain lions in its analysis.

The exposure rates found in these mountain lions are high. However, given the long hepatic half-lives of the SGARs, it is possible that the mountain lions were exposed before the regulations went into effect (July 1, 2014). Difenacoum has the shortest hepatic half-life (118 days) of the SGARs. A half-life is the time required for a concentration to decrease by half in a given media (e.g., the liver). This should not be confused with the amount of time it takes for a chemical to degrade, or to be eliminated from an animal's body completely. As a rule, the length of time needed for a chemical to degrade (or metabolize) to less than one-percent of the initial concentration (i.e., 99% removal) is seven half-lives. Although this data cannot be used to evaluate the efficacy of the 2014 regulations, it can be used to compare exposure rates among different rodenticide compounds. Among mountain lions that were tested, the AR with the highest exposure rate is brodifacoum, followed by bromadiolone (Table 5, Figures 6 and 7).

Table 5 – DPR's independent analysis of the DFW Mountain Lion Database (excluding four animals without a date of death).

Parameter	2015-2016
Total Number of Animals Reported	64
Percent of Reported Animals with Detectable Levels of ARs	92%
Maximum Number of ARs Detected	6
Minimum Number of ARs Detected	0
Mean Number of ARs Detected	2.7
Percent of Reported Animals Exposed to Detected FGARs	67%
Percent of Reported Animals Exposed to Chlorophacinone	11%
Percent of Reported Animals Exposed to Diphacinone	59%
Percent of Reported Animals Exposed to Warfarin	8%
Percent of Reported Animals Exposed to Coumatetralyl	0%
Percent of Reported Animals Exposed to Detected SGARs	92%
Percent of Reported Animals Exposed to Brodifacoum	91%
Percent of Reported Animals Exposed to Bromodiolone	72%
Percent of Reported Animals Exposed to Difenacoum	0%
Percent of Reported Animals Exposed to Difethialone	25%
Notes:	
This table includes all data provided to DPR by DFW from 2014 to 2018.	
AR: Anticoagulant Rodenticide	
FGAR: First Generation Anticoagulant Rodenticide	
SGAR: Second Generation Anticoagulant Rodenticide	

Figure 6 – Second-generation anticoagulant rodenticide (SGAR) exposure rates among tested mountain lions (bar graph created by DPR scientists using DFW data).

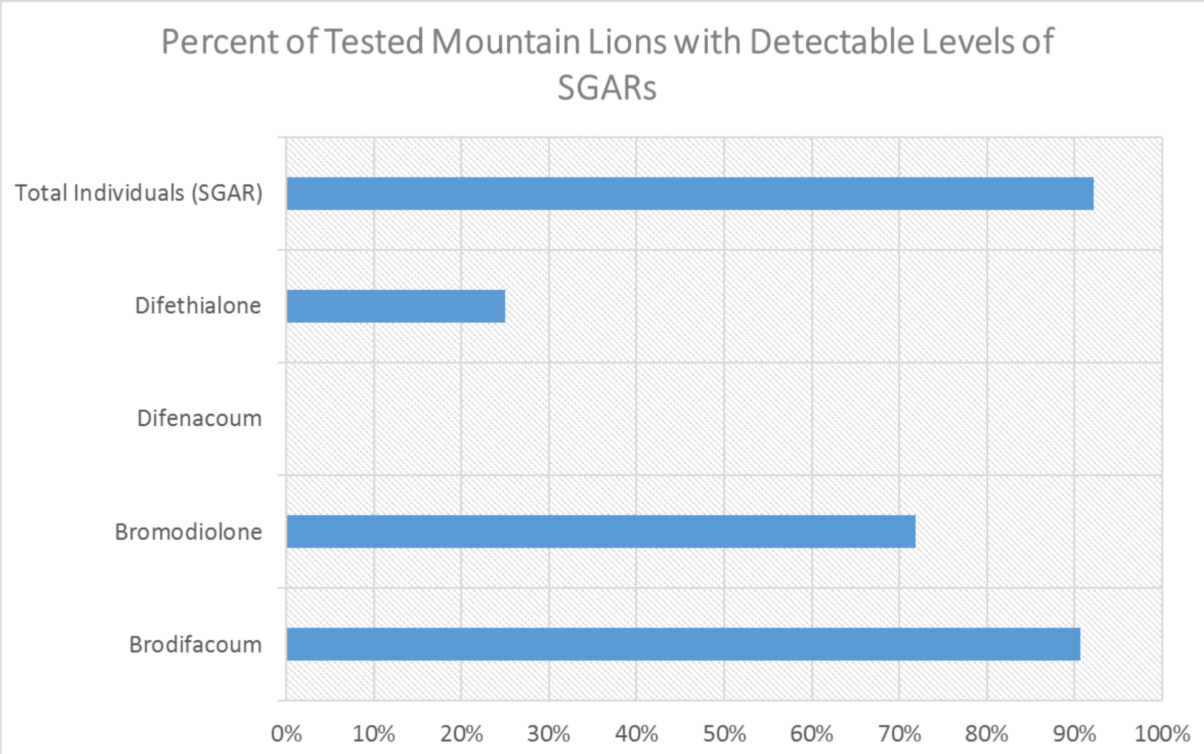
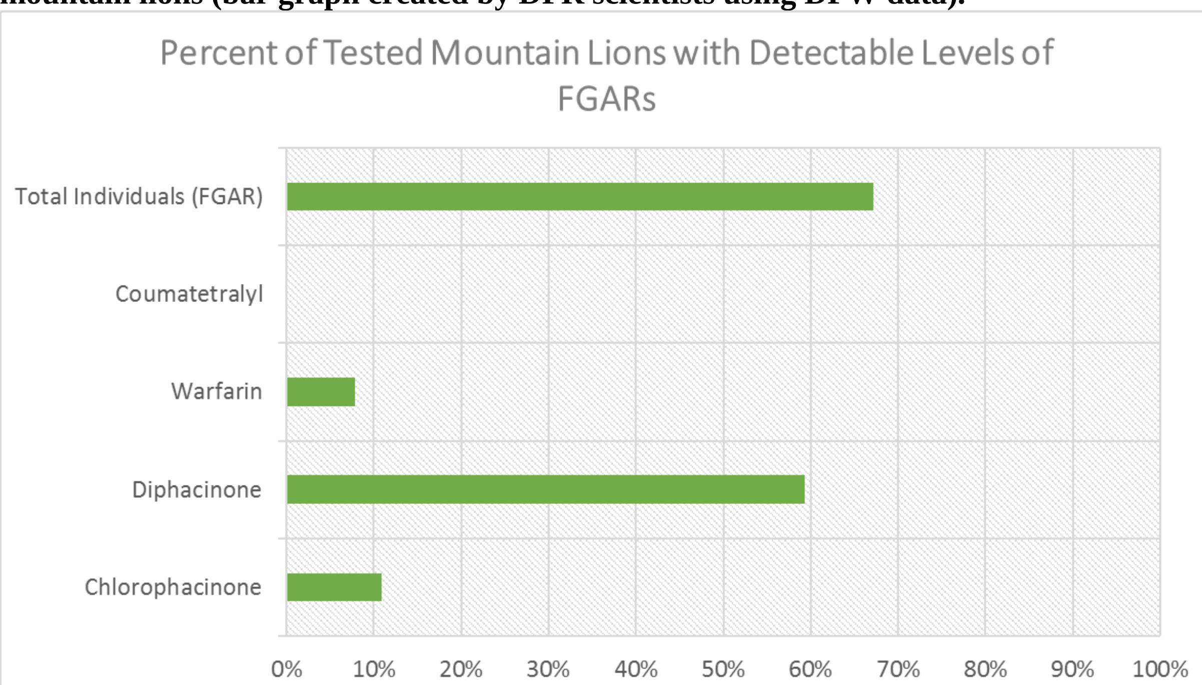


Figure 7 – First-generation anticoagulant rodenticide (FGAR) exposure rates among tested mountain lions (bar graph created by DPR scientists using DFW data).



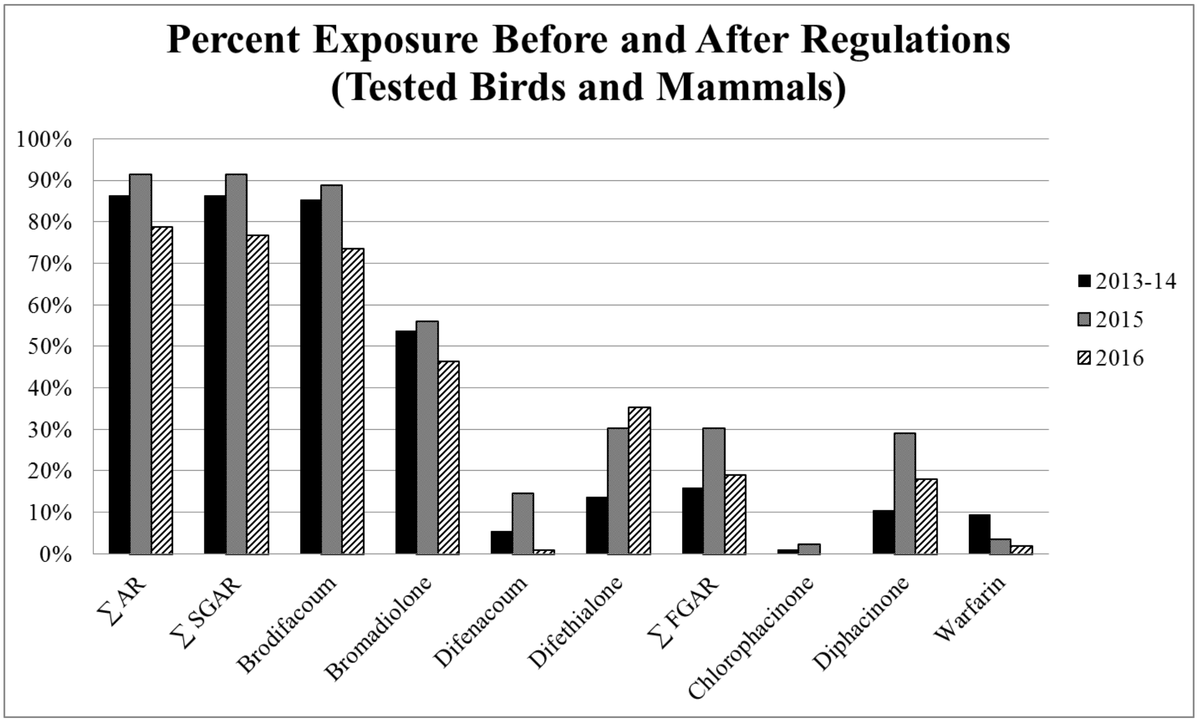
- **WildCare Wildlife Rehabilitation Center Data**

WildCare is a non-profit organization that operates a wildlife rehabilitation hospital in the San Francisco Bay Area. In 2013, DPR entered into a contract with WildCare to provide AR exposure data on non-target wildlife. In 2014, DPR renewed the contract for two more years. As of December, 2016, which is when the contract ended, WildCare provided DPR with exposure data for 115 domestic pets and 276 wild animals. Of the 115 domestic pets tested, two tested positive for exposure to FGARs. Two dogs were exposed to trace amounts of diphacinone. These were the only two exposure cases among tested domestic pets.

It is important to note that the wild animals tested were not selected randomly. This dataset is biased towards distressed animals that were brought to the WildCare wildlife hospital for rehabilitation and subsequently died or were euthanized. This does not mean that this data is not valid, or that it does not have value from a regulatory perspective, but it must be noted that the data from this study is not representative of the general population of all wild animals, so it cannot be extrapolated to draw conclusions about the percent of all wild animals that are exposed to ARs.

Of the 276 wild animals tested, exposure rates were high, both before and after the new regulations took effect (Figure 8). Nearly all SGAR exposed animals were exposed to brodifacoum and many animals were exposed to more than one anticoagulant rodenticide. However, the contract ended in 2016, which was only two years after the regulations went into effect, and it is likely too soon to expect the changes in use patterns enacted with the new regulations to influence SGAR exposure rates because of their prolonged half-lives. For example, the highest recorded concentration of brodifacoum in the liver of any non-target wildlife was 2.1 ppm in a skunk. Using a half-life of 350 days, the concentration in this particular skunk's liver after one year would be approximately 1 ppm, after two years 0.5 ppm, after three years 0.25 ppm, after four years 0.125 ppm, after five years 0.0625 ppm. The minimum reporting limit for this analysis was 0.05 ppm. This means that, had this skunk not died of a bacterial infection, it could have been brought into the WildCare Wildlife Hospital five years later, and still would have had detectable (i.e., >0.05 ppm) residues of brodifacoum in its liver. However, most animals tested (n = 276) had liver concentrations much lower than 2.1 ppm.

Figure 8 – Summary of WildCare data on file with DPR. This graph was created by DPR scientists in March 2017, using raw data received from WildCare. ∑ AR, ∑ SGAR, and ∑ FGAR represent the sum of all animals that were exposed to any AR (FGAR and/or SGAR), SGAR, and FGAR, respectively.



The following eight publicly available peer-reviewed publications were submitted by Mr. Graf. DPR scientists were already aware of many of the studies. The quality of these publications varies, but all were analyzed by DPR.

- **Vyas, N.B., Kuncir, F., and C.C. Clinton, 2017, Influence of Poisoned Prey on Foraging Behavior of Ferruginous Hawks, The American Midland Naturalist, 177(1), pp. 75-83.**

The study authors conducted an observational study at two black-tailed prairie dog (*Cynomys ludovicianus*) sub-colonies that were treated with Rozol Prairie Dog Bait (0.005% chlorophacinone, a FGAR applied at a rate of 6.9 kg of formulated end-product per hectare) and one untreated black-tailed prairie dog sub-colony. The purpose of the study was to observe the foraging behavior of ferruginous hawks (*Buteo regalis*) to see if they showed a preference for foraging in the treated or the untreated sub-colonies. The two treated sub-colonies comprised a combined 16.3 hectares with 1,986 active prairie dog burrows whereas the untreated sub-colony comprised 16.8 hectares with 2,032 active prairie dog burrows. The two treated sub-colonies were separated by a dirt county road whereas the single untreated sub-colony was approximately 100 meters (m) south on the other side of a ridge with dense vegetation. The three colonies were monitored by three people (one for each colony) concurrently on Days 8, 9, 10, 11, 16, and 17 post-application. Observers were rotated daily to avoid individual bias. The parameters examined were hawk presence, duration of activity, predation, and the overall number of prairie dogs above ground.

Over the six days of observations, hawks spent a total of 708 and 203 minutes in the treated sub-colonies and untreated sub-colonies, respectively. Hawks were observed in the treated sub-colonies on each of the six days when observations were conducted, but only on four days in the untreated sub-colony. Four predations were observed in the treated sub-colonies and zero predations were observed in the untreated sub-colony. There was a significant decline in the overall number of above ground prairie dogs in the treated sub-colony, but not in the untreated sub-colony. The study authors concluded that the hawks showed a preference for foraging in the treated sub-colonies because the poisoned prairie dogs were easier to capture due to lethargy and decreased awareness. However, they also stated that "prey accessibility is affected by vegetation cover and perch availability" and that the two sub-colonies that had been treated with Rozol had more structures that hawks could use as perches (ten utility poles and 2,519 m of barbed wire fencing in the treated sub-colonies vs. no utility poles and 597 m of fencing in the untreated sub-colonies). Although this may seem like a major confounding factor, the study authors stated that the difference in the availability of structures available for hawks to use as perches did not impact the overall results because the hawks that captured prey in the treated sub-colonies were observed doing so from soaring flights, not from perches. Overall, hawks were only observed preying on prairie dogs in the treated sub-colonies, despite the fact that in the three sub-colonies the untreated sub-colony has four times more above ground prairie dogs than the treated sub-colonies. Although the sample size was small and the duration was short (a total of 19 visits by hawks and six days of observations), DPR scientists have concluded that this study is scientifically sound and provides a qualitative line of evidence that ferruginous hawks show a preference for foraging on prairie dogs that have been treated with chlorophacinone.

- **Gabriel, M.W., Woods, L.W., Wengert, G.M., Stephenson, N., Higley, J.M., Thompson, C., Matthews, S.M., Sweitzer, R.A., Purcell, K., Barrett, R.H., Keller, S.M., Gaffney, P., Jones, M., Poppenga, R., Foley, J.E., Brown, R.N., Clifford, R.L, and B.N. Sacks, 2015, Patterns of Natural and Human-Caused Mortality Factors of a Rare Forest Carnivore, the Fisher (*Pekania pennanti)* in California. PLoS ONE 10(11): e0140640.**

In this study, the study authors used histology, toxicology, and gross necropsy to determine the cause of death for 167 individual fishers (*Pekania pennant*) collected between 2007 and 2014 from two sub-populations in California. Both of these sub-populations are considered to be evolutionarily significant units by DFW (2015). The first sub-population was located in the Northern Coast and Southern Cascade mountain ranges and the second sub-population was located in the Southern Sierra Nevada. The second sub-population is listed as threatened under the California Endangered Species Act and is believed to be comprised of roughly 300-350 fishers with fewer than 120 breeding females. Fifty-two of the fishers included in this study were from the first sub-population and 115 from the second. Of the 167 fishers included in this study, 44% were males, 56% were female. In terms of age groups: 63% were adults, 19% were sub-adults, 16% were juveniles, and 2% were kits.

Overall, the cause of death was determined for 129 fishers: 70% were determined to have died from predation, 16% from natural diseases, 10% from poisoning, 2% from getting hit by cars, and 2% from other human causes. Of the 101 fishers that had their livers tested for anticoagulant exposure, 86 individuals were determined to have been exposed to one or more ARs. Animals can be exposed to ARs without being killed by them. The criteria for diagnosing AR toxicosis as the cause of death generally requires coagulopathy without any other signs of trauma in addition to the detection of ARs in the liver. The study authors determined that AR exposure was the cause of death for 11 fishers. They stated that these 11 fishers exhibited coagulopathy and significant hemorrhage in addition to detection of ARs in the liver. It is unclear if the 11 fishers determined to have died from AR exposure had any other signs of trauma. All of the fishers that were determined to have died from anticoagulant intoxication had illegal cannabis cultivation sites in their home ranges. The mean (± SD) number of AR compounds found in the livers of dead fishers was 1.73 ± 0.91 and some fishers were found to have been exposed to as many as five different ARs. The study authors stated that cholecalciferol "was assumed to be the contributing cause of death in one male fisher from Northern California", but that fisher was also exposed to five different ARs. Another fisher was noted as displaying neurological signs and was found near an illegal cannabis cultivation site where bromethalin was also found, but bromethalin was not detected in the stomach contents, liver, urine, or kidney. However, DPR scientists recognize that bromethalin is normally detected in adipose or brain tissue, which the study authors did not test, so it is unclear if that fisher had been exposed to bromethalin. Overall, the study authors concluded that on an annual basis from 2007 to 2014, an average of 1.86 fisher toxicosis cases were noted in California. The study authors also concluded that when the first phase of the study (with 46 of 58 fishers tested from 2007-2011 exposed) was compared to the second phase of the study (with 86 of 101 fishers tested from 2012-2014 exposed) exposure to ARs increased by 6%. It is important to note that the study authors attributed the exposure of fishers to various rodenticide compounds to be associated with illegal cannabis cultivation sites, so it is likely that most of this exposure resulted from the illegal use of rodenticides (i.e., uses not in compliance with the label). Currently, most of these sites are not remediated after being discovered and dismantled. The study authors recommend that toxicants left at illegal cannabis grow sites be removed when they are shut down. This study shows that 85% of fishers that were tested for ARs are exposed, even though they are in remote forested areas, far from urban development. Considering that DPR's regulations making SGARs restricted materials went into effect in July of 2014, this study does not provide any information on the efficacy of those regulations in reducing non-target wildlife exposure rates. The restricted material designation means that these rodenticides can only be sold in California to licensed applicators, which makes it more difficult for persons engaged in illegal cannabis cultivation operations to purchasing SGARs in California, which in turn, should reduce exposure rates among these rare forest carnivores.

- **Poessel, S.A., S.W. Breck, K.A. Fox, and E.M. Gese, 2015, Anticoagulant Rodenticide Exposure and Toxicosis in Coyotes in the Denver Metropolitan Area, Journal of Wildlife Diseases, Vol. 51, No. 1, pp. 265-268.**

In this study the livers of five coyotes (*Canis latrans*) were tested for ARs. Initially, 32 coyotes were captured and fitted with radio collars to track their movements. Thirteen of the 32 collared coyotes died during the study and the study authors decided to test the livers of five coyotes (of those coyotes that died during the study) because those coyotes were noted with sarcoptic mange. This selection procedure introduced bias into the study because they only tested the livers of coyotes that they suspected had been exposed to ARs. The coyotes' liver tissue was tested for brodifacoum, bromadiolone, difenacoum, difethialone, chlorophacinone, diphacinone, and warfarin. Additionally, one of the five coyotes tested was not collared. That coyote was euthanized because it sustained self-inflicted injuries related to being trapped. When this coyote was tested for ARs, it was noted as having 95 ppb of brodifacoum in its liver. Overall, only 36% (5 of 14) of the coyotes that died during the study were tested. All five of the coyotes whose livers were tested were determined to have been exposed to brodifacoum and one of those was noted as having been exposed to brodifacoum and bromadiolone.

There are many issues which impact this study and make some of the authors' conclusions questionable. The study authors concluded that ARs were contributing factors in at least two of the five coyotes that had their livers tested for exposure. The descriptions of these two coyotes contained some confusing statements:

> "The first case was a juvenile male (24M) found dead in open space, with no obvious external injuries or other signs of trauma. Upon necropsy, we found free blood in the abdominal cavity. A puncture wound was present on the left side of the body overlying the spleen but not penetrating the abdominal wall. The spleen was fractured and surrounded by clotted blood. We found no radiographic evidence of gunshot and no evidence of bite wounds. The interpretation for cause of death was acute severe hemorrhage, disproportionate to the amount of trauma observed. This coyote's liver was positive for brodifacoum (176 ppb)."

In the first sentence of this description the study authors state that this coyote had "no obvious external injuries or other signs of trauma" but then, two sentences later they state that a "puncture wound was present on the left side of the body." It is unclear if the study authors consider a puncture wound to be an external injury. Additionally, it does not appear that this coyote, or any of the coyotes in this study, were tested for bacterial or viral infections. The description of the second coyote is as follows:

> "The second case was a juvenile male coyote (21 mo) found dead on a two-lane road, with minor evidence of skin tearing over the ventral neck and chest. Necropsy findings indicated additional moderate tearing of the muscle in the region overlying the thoracic inlet, although injuries did not penetrate the chest cavity. The chest was filled with blood. The interpretation for cause of death was severe acute hemorrhage, disproportionate to the mild to moderate trauma received from being hit by a vehicle. We suspected rodenticide toxicosis, and the liver was positive for brodifacoum and bromadiolone."

While it is possible that exposure to ARs was a contributing factor in the death of this coyote, it is unclear if this coyote would have recovered if it had not been hit by a vehicle. Typically, institutions such as the California Animal Health and Food Safety (CAHFS) lab at the University of California, Davis, require "antemortem or postmortem evidence of coagulopathy unrelated to another identifiable cause of hemorrhage (e.g., trauma)" combined with the detection of one or more AR compounds in the liver or blood of an animal in order to make a diagnosis of AR intoxication (CAHFS, 2015). The study authors did not follow this protocol because the hemorrhage noted in both coyotes was associated with "another identifiable cause of hemorrhage" (e.g., a puncture wound or getting hit by a vehicle). In both these cases, the study authors did not explicitly state that exposure to ARs was the cause of death, only that they were a contributing factor. However, they did not define "contributing factor" and there is no way to know if the puncture wound or the vehicular strike would have been sufficient to kill these coyotes if they had not been exposed to rodenticides.

Of the nine coyotes that were not tested for AR exposure, five were determined to have died due to vehicular collisions, one was determined to have died from a gunshot wound, one was killed due to “conflict resolution” at the Denver International Airport, and the causes of death for the last two coyotes were not determined. The study authors state that “The exposure of all five tested coyotes to rodenticides, especially brodifacoum, indicates the ubiquity of these toxicants in the urban landscape and their ability to reach higher levels in the food chain…” but this statement is not supported by the data because the selection procedure used to decide which animals to test was biased towards choosing those coyotes that were suspected of being exposed. Rather, the data shows that a total of 36% (5 of 14) of the coyotes that died during the study were determined to have been exposed to ARs. Alternatively, only 15% (5 of 33) of the collared coyotes included in the study tested positive for AR exposure. A sixth coyote that had been found in a rural area in Colorado was also tested because that coyote showed signs of hemorrhage. The study authors stated that they “found no evidence of any rodenticides in the liver, indicating that rodenticide toxicosis may not always occur in coyotes.” The study authors go on to compare liver concentrations to acute oral LD_{50} values: “The acute oral LD_{50} value of bromadiolone in dogs ranges from 11,000 ppb to 15,000 ppb (Stone et al. 1999); the value in our study animal was 885 ppb.” The validity of the comparison is questionable because an LD_{50} value is a dose (e.g., mg of active ingredient/kg of body weight of the animal receiving the dose), not a concentration (ppb or µg of active ingredient/kg of media [soil, food, liver, etc.]), and because the dose an animal ingests may not be comparable to the concentration detected in the liver when the time between exposure and testing (of the liver tissue) is unknown. This study contains some useful information because it provides an additional line of evidence that brodifacoum is detected more often than other rodenticides in the livers of non-target wildlife. However, the small sample size, the biased selection procedure, and criteria for diagnosis that is not in line with reputable necropsy labs reduces the validity of the study.

- **Serieys, L.E.K., Armenta, T.C., Moriarty, J.G., Boydston, E.E., Lyren, L.M., Poppenga, R.H., Crooks, K.R., Wayne, R.K., and Riley, S.P.D., 2015, Anticoagulant rodenticides in urban bobcats: exposure, risk factors and potential effects based on a 16-year study, Ecotoxicology, 24:844–862, DOI 10.1007/s10646-015-1429-5.**

This study compared AR exposure rates among bobcat (*Lynx rufus*) populations residing in two geographic areas near Los Angeles: 1) the Santa Monica Mountains National Recreation Area (SMM), and 2) public nature reserves and the Santa Ana Mountains in Orange County. AR exposure was evaluated from 1997-2012 in SMM and from 2006-2010 in Orange County. Liver samples were collected from bobcats that died in wildlife rehabilitation centers or from opportunistically found bobcat carcasses. Blood samples were collected from trapped bobcats, the majority of which were caught during the wet season, from mid-October to mid-February. Visual inspections were conducted on all bobcats for clinical signs of notoedric mange and skin scraping samples were collected to identify species of mites. Age class (greater than or less than two years), sex, weight, and various morphological measurements (e.g., body length, head circumference, etc.) were recorded for bobcats that were trapped and had blood samples collected. Necropsies were conducted on these bobcats to determine cause of death (when possible). These bobcats’ specific ages were determined using the cementum annuli aging technique on an upper canine tooth in addition to the same parameters that were recorded for trapped bobcats. Specific locations where bobcats were trapped or found dead were noted for all bobcats used in the study.

The AR screen analyzed blood, serum, and liver samples for warfarin, coumachlor, bromadiolone, brodifacoum, diphacinone, chlorophacinone, and difethialone. It is unclear why the FGAR coumachlor was included in the screen because it has never been registered in the United States. Additionally, the screen omitted difenacoum, which is a SGAR that is registered for use in California. Limits of Quantitation (LOQs) for liver samples were 10 µg/kg for brodifacoum, 50 µg/kg for bromadiolone, warfarin, and coumachlor, and 250 µg/kg for chlorophacinone, diphacinone, and difethialone. The study authors refer to these values as Limits of Detection (LODs) in the caption for their Figure 3, so it is unclear if these values represent LODs or LOQs. Blood samples had lower LOQs than liver samples, with an LOQ of 1 µg/kg for all analytes and LODs ranging from 0.28-0.45 µg/kg; the study authors did not specify which LOD went with which AR compound. Overall, 206 blood samples and 172 liver samples collected from wild bobcats were analyzed for exposure to ARs. Additionally, blood and liver samples were obtained simultaneously from 20 individual bobcats (only blood or liver samples were collected for all others).

Anticoagulant rodenticides were detected in 88% of liver samples and 39% of blood samples in both locations combined (SMM and Orange County). Anticoagulant rodenticide elimination half-lives are generally much shorter in blood and plasma samples than in liver samples (U.S. EPA, 2004). The faster elimination half-lives mean that there is less of a window, post-exposure, when these compounds can be detected in blood. Despite the high exposure rates, only one bobcat was determined to have died directly as a result of AR exposure. Brodifacoum, bromadiolone, difethialone, and diphacinone were the most frequently detected compounds overall. Brodifacoum and bromadiolone were detected in approximately 80% of the liver samples tested, whereas diphacinone and difethialone were detected in approximately 40% and 30% of the liver samples tested. In contrast, diphacinone was detected in approximately 30% of blood samples, with brodifacoum and bromadiolone detected in approximately 10% of blood samples. Coumachlor was not detected in liver samples, but it was detected in at least one blood sample, which is strange because no products containing that active ingredient have ever been registered in California or the United States. The study authors performed various statistical analyses based on data they had collected over the course of the study. Such data included age, sex, season (wet vs. dry), spatial correlates (i.e., land use in each bobcats home range), diagnoses of notoedric mange, and mortality. These parameters were compared to exposure data to see if any of them could serve as potential predictors of exposure (e.g., to see if female bobcats are more likely to be exposed than males). The study authors stated that there was no significant association between exposure and age of the 66 bobcats that were aged using the cementum annuli aging technique. There was also no significant association between exposure and sex (n = 151 for liver samples; n = 193 for blood samples), nor between exposure rates of liver samples (n = 162) comparing wet vs. dry season. However, in blood samples the study authors detected a significant difference between seasons, with anticoagulant rodenticides detected in 55% of samples in the dry season compared to 32% during the wet season (n = 195).

Generalized linear models were used to examine associations between exposure and various land uses in home ranges (approximately 5 km^2 for males and 2-3 km^2 for females) surrounding the

locations where bobcats were found (or captured). Spatial correlates were broken into five broad classifications of land use in places where bobcats were captured or found dead. These were: 1) agriculture (e.g., orchards, horse ranches, vineyards),
2) commercial and industrial (e.g., schools, offices, water facilities), 3) residential (e.g., multifamily/commercial, high and low density single family), 4) altered open space (e.g., golf courses, cemeteries, other recreational), and 5) natural (i.e., undeveloped). The last category, undeveloped natural areas, comprised the majority of land in both the SMM study area (67%) and the Orange County study area (59%). Total residential (the sum of multifamily/commercial high-density + high-density single-family + low-density single-family) comprised 22% of the land in the SMM study area and 24% of the land in the Orange Country study area. Agriculture, commercial and industrial, and altered open space composed the remaining ~11% and ~17% of land in the SMM and Orange County study areas, respectively.

Average home ranges in both study areas combined were approximately 5.4 km^2 for male bobcats and 2.8 km^2 for female bobcats. The study authors referred to these home range areas as buffer zones and used circular areas surrounding where the bobcats were found or captured to analyze land use and exposure data to make associations between land use patterns in each bobcats surrounding buffer zone and the compounds those bobcats were exposed to. Based on concentrations in liver samples, there were positive associations between: altered open space (areas such as golf courses) and bromadiolone and brodifacoum; commercial and industrial areas and bromadiolone and diphacinone; office and retail areas and brodifacoum; and total residential areas and brodifacoum and diphacinone. The study authors ran many different statistical analyses on various exposure parameters, but the validity of combining first and SGARs into a single parameter of "total residues" or "total number of compounds detected" is questionable because the SGARs are more toxic and have longer hepatic half-lives than the FGARs. The study authors acknowledge this in the discussion section, stating that diphacinone "is considered to pose less risk to nontarget wildlife than the more toxic second-generation ARs." The study authors stated that diagnoses of severe notoedric mange were found to be positively associated with difethialone exposure, brodifacoum exposure, and brodifacoum concentration. In the case of severe notoedric mange, the study authors listed "brodifacoum exposure" separately from "brodifacoum concentration." They found other associations that were also statistically significant, but the validity of those associations is questionable because they combined all ARs together into one parameter (e.g., total number of compounds detected, total residues, etc.).

Overall, this study provides a line of evidence showing that bobcats in the Los Angeles area had high exposure rates to ARs from 1997-2012. The study authors stated that a mange outbreak led to a precipitous population decline among bobcats from 2002-2006. This population decline was sufficient to cause a genetic bottleneck, a severe population level adverse effect. However, this study does not provide any useful information as to the efficacy of DPRs regulations in terms of reducing SGAR exposure rates among non-target wildlife. The study authors conclude this paper by stating that "measures that address residential use of ARs may be particularly effective in mitigating ecological risks associated with these compounds." DPR addressed this by enacting regulations in 2014 that made SGARs restricted materials, thereby taking them out of the hands of the general public and making them available only to certified pesticide applicators.

- **Gabriel, M.W., Diller, L.V., Dumbacher, J.P., Wenger, G.M., Higley, J.M., Poppenga, R.H., and Mendia, S., 2017, Exposure to rodenticides in Northern Spotted and Barred Owls on remote forest lands in northwestern California: evidence of food web contamination, Avian Conservation and Ecology 13(1):2. https://doi.org/10.5751/ACE-01134-130102**

This study examined AR exposure rates of two owl species in Del Norte, Humboldt, Western Trinity, and Northern Mendocino Counties in Northern California. This region is known for having many illegal cannabis cultivation sites. The barred owl (*Strix varia*) is considered a major threat to the viability of the threatened northern spotted owl (*Strix occidentalis caurina*) because it can outcompete them for resources and has been expanding its range into their critical habitat (as defined by the federal Endangered Species Act; https://www.fws.gov/southeast/endangered-species-act/critical-habitat/). Because of this, resource managers in California have decided to kill barred owls that reside in northern spotted owl critical habitat to improve the species chances of survival. This has provided the study authors with a rare opportunity to collect many barred owl liver tissue samples for AR testing. Northern spotted owls are federally listed endangered species, so only opportunistic sampling was conducted (i.e., carcasses found dead in the field).

Northern spotted owl livers were tested for ARs and carcasses were submitted for necropsy when they were in acceptable post-mortem condition. Rodents in the study area were also sampled and their livers were tested for ARs. Owl and rodent livers were tested for warfarin, diphacinone, chlorophacinone, coumachlor (never registered in the United States), brodifacoum, bromadiolone, difethialone, and difenacoum. The LOQ was 20 ng/g for all analytes except brodifacoum. The LOQ for brodifacoum was 50 ng/g. The livers of ten northern spotted owls were tested and seven of them were determined to be exposed to ARs. Brodifacoum was detected in all seven livers and bromadiolone was also detected in two of the seven livers (i.e., two owls were exposed to both brodifacoum and bromadiolone). The cause of death was identified for six northern spotted owls: three were killed by automobile strikes, two were due to emaciation following some unidentified infections, and one was killed by an unidentified predator. The livers of 84 barred owls were tested and 34 (40%) of them were determined to be exposed to ARs. Of those 34 barred owls, 27 were exposed to brodifacoum alone, three were exposed to bromadiolone alone, and four were exposed to both brodifacoum and bromadiolone. All of the bromadiolone detections were below LOQ. The study authors stated that six of the barred owls that tested positive for brodifacoum were above the LOQ with a range of 17-110 ng/g, but they also stated that the LOQ for brodifacoum was 50 ng/g, so it is unclear why a concentration of 17 ng/g would be included as a quantifiable level.

The study authors speculated that the lower exposure rates in barred owls may be due to their generalist dietary tendencies: whereas northern spotted owls consume rodents and lagomorphs as 81-96% of their diet, barred owls consume rodents and lagomorphs as 60-70% of their diet, with birds, insects, amphibians, reptiles, fish, snails, and crayfish making up a higher proportion of barred owl diets compared to northern spotted owls. It is unclear how the exposure rate for northern spotted owls was affected by the small sample size (n = 10) in comparison to barred owls (n = 84). A larger sample size would be more representative of the population and it is possible that a larger sample of northern spotted owls would have resulted in higher or lower exposure rates for that species. However, the difficulties in acquiring additional samples of this protected endangered species in such a remote area are understandable.

The study authors also collected and tested livers from 18 Douglas squirrels (*Tamiasciurus douglasii*), 15 chipmunks (*Tamias* sp.), two northern flying squirrels (*Glaucomys sabrinus*), and two dusky-footed woodrats (*Neotoma fuscipes*). Anticoagulant rodenticides were not detected in any rodent livers. The study authors stated that the lack of anticoagulant rodenticide detections in rodents is not unexpected because rodents normally die within a few days of exposure.

The study authors point out that there are no legal uses for SGARs in the habitats where the owls in this study were collected and go on to state that "The use of not only the ARs *(anticoagulant rodenticides)* brodifacoum or bromadiolone, but other first and second-generation ARs, in addition to neurotoxicant rodenticides like bromethalin, have been documented in large quantities (10–90 lbs. per cultivation site) at numerous illegal marijuana cultivation sites where these owls were collected..." It should be noted that the only rodenticide active ingredients (anticoagulant or otherwise) detected in the owls tested in this study were brodifacoum and bromadiolone. Overall, this study provides another line of evidence that more non-target wildlife are exposed to brodifacoum than to any other rodenticide active ingredient. Of the 94 total owls tested in this study, 38 (40%) were exposed to brodifacoum, and nine (10%) were exposed to bromadiolone. The exposure rates reported in this study are high, especially considering that this is a remote densely forested region, with no nearby urban areas, where there are no legal uses of SGARs. Additionally, this study provides another line of evidence showing that brodifacoum has higher frequency of detections compared to other ARs.

- **Serieys, L.E.K., Lea, A.J., Epeldegui, M., Armenta, T.C., Moriarty, J., VandeWoude, S., Carver, S., Foley, J., Wayne, R.K., Riley, S.P.D., and Uittenbogaart, C.H., 2018, Urbanization and Anticoagulant Poisons Promote Immune Dysfunction in Bobcats, Proceedings of the Royal Society B, 285: 20172533. http://dx.doi.org/10.1098/rspb.2017.2533**

This study focused on various immunological parameters in blood samples collected from 124 bobcats in and around the Santa Monica Mountains National Recreation Area. Samples were collected from 2007 to 2012 and, in addition to blood samples, each bobcat was sexed, measured, and assigned an age class (juvenile or adult). The study authors measured 65 total measures of immune or organ function (henceforth "health parameters" [e.g., complete blood cell counts, serum chemistry, circulating cytokine levels, total T lymphocytes, etc.]). The study authors stated that there are no reference values for many of the parameters analyzed because, to their knowledge, no one has conducted these types of analyses on bobcats. Individual bobcats were tested for exposure to various pathogens and parasites including, but not limited to *Bartonella* spp., *Mycoplasma* spp., *Toxoplasma gondii*, feline immunodeficiency virus, and feline herpesvirus. All bobcats were inspected for signs of mange and four bobcats were excluded from the study because they were determined to have mange. The study authors did not want the immune response to mange to introduce noise into the dataset because this would complicate efforts to isolate the effects of anticoagulant exposure on immune system functions. Whole blood or serum samples were also analyzed for the presence of ARs. The AR analysis that the study authors used to determine exposure included warfarin, diphacinone, chlorophacinone, coumachlor, bromadiolone, brodifacoum, and difethialone. It is important to note that coumachlor has never been registered for sale or use in the United States, and that the AR analysis did not include difenacoum, which is a SGAR that is registered for use in California. Urbanization was quantified for each individual bobcat as described in Serieys et al. (2015; reviewed above).

The three primary objectives of the study were: 1) to identify parameters indicative of immune impairment or cellular damage in organs that correlate with urban proximity or AR exposure; 2) to look for a predictable relationship between AR exposure and health parameters in a way that would allow analysis of the potential health parameter to be indicative of AR exposure; and 3) to describe a mechanism that could influence the susceptibility of bobcats living near urban environments to mange. The study authors identified three covariates (age class, *Mycoplasma haemominutum* infection, and *Bartonella* sp. exposure) which helped to explain significant variance in the top 20 (health parameter) principle components of the dataset. These three covariates were controlled for in further analyses. Next, the study authors looked for system wide associations between AR exposure and individual health parameters. A random forest classifier (an analytical method akin to a series of decision trees) was employed, which allowed them to use one analysis to evaluate the relative importance of all 65 health parameters simultaneously. The random forest method was used to complement linear models which were also used to look for associations between health parameters and AR exposure.

It is well established that the clearance time for AR residues is shorter in blood than in the liver; however, the way the study authors chose to frame this statement is somewhat misleading. The study authors stated that:

> "Testing blood for AR residues leads to 62% false negatives because blood measures only recent exposure [19]. We therefore hypothesized that (i) some individuals with no detectable levels of ARs in blood would be classified by the random forest as AR-exposed, and (ii) these individuals represent a set of truly AR-exposed individuals for whom the blood tests produced a false negative. If true, we would expect individuals living in more urbanized areas (where AR exposure is widespread) to fall into the misclassified group (i.e. to have immune profiles that are similar to known AR-exposed individuals, even though ARs were not detected in blood)."

This is confusing because the 62% false negative rate is not reported in the publication they cited (Serieys et al., 2015; reviewed above). Furthermore, the "62% false negative" rate can only be legitimately applied to the population of bobcats that they sampled during the timeframe when they were sampled. For example, the regulations making SGARs restricted materials went into effect in 2014, which is after the bobcats in Serieys et al. (2015) were sampled. If those regulations were successful in reducing exposure rates, then the 62% false negative figure could be much lower because reduced exposure rates would result in fewer negative detections in blood samples that would be labeled as false.

In another portion of the manuscript the study authors stated that

> "We previously documented that testing blood only indicates recent AR exposure events, thus leading to frequent false negatives (approximately 62% of the time; see [Serieys et al., 2015] for more detail) respective to an individual's history of exposure. Urbanization, therefore, is arguably a more sensitive measure of AR exposure than AR levels in the

> tissues we are able to sample (i.e. peripheral tissues such as blood) [Serieys et al., 2015], but it can also reflect potential exposure to other toxicants from urban environments."

To say that urbanization "is arguably a more sensitive measure of AR exposure than AR levels in the tissues" is another statement that can potentially be misinterpreted.

The study authors concluded that:

> "Random forests revealed that the differences between AR-exposed and unexposed individuals were systemic and predictable such that the parameters themselves can be used to predict an individual's exposure status (predictive accuracy = 67.3%, error rate = 32.7% and AUC = 0.68, electronic supplementary material, figure S2a–b; proportion of individuals correctly classified as exposed and unexposed = 18/29 and 31/46)."

However, estimating the number of individual bobcats that are correctly classified as exposed or unexposed, could change due to regulations that went into effect in 2014. Those regulations made second-generation anticoagulant rodenticides restricted materials, and might have reduced exposure rates among bobcats, which in turn could change the rate of false negative detections in the blood of bobcats, which could change the random forest analysis prediction of false negatives. A predictive accuracy of 67.3% means that their predictions will be wrong 32.7% of the time, and it seems logical that the predictive accuracy could change in line with the ways in which rodenticides are used (i.e., changes in use patterns intended to reduce non-target wildlife exposure), and with changes in the quantity of ARs sold and used. This study provides a qualitative line of evidence that there are many health parameters that are affected by exposure to ARs.

- **Franklin, A.B., Carlson, P.C., Rex, A., Rockweit, J.T., Garza, D., Culhane, E., Volker, S.F., Dusek, R.J., Shearn-Bochsler, V.I., Gabriel, M.W., Horak, K.E., 2018, Grass is not always greener: rodenticide exposure of a threatened species near marijuana growing operations, BioMed Central Research Notes, 11:94, https://doi.org/10.1186/s13104-018-3206-z**

This is a research note, rather than a full study. It focused on a female northern spotted owl (*Strix occidentalis caurina*) that was found dead in 2017. The study authors estimated that this owl died less than 24 hours before they found it because "(1) the carcass was fresh with the eyes not sunken, (2) there were no fly larvae on the carcass, and (3) the male owl attempted to deliver a mouse to the carcass for ~ 5 min." The study authors stated that they had conducted 9,216 surveys since 1985 and this was the first time they had discovered a recently deceased northern spotted owl. The owl was necropsied and samples of blood and liver tissue were tested for rodenticide exposure. Specifically, the blood and liver samples were tested for the ARs coumafuryl, coumatetralyl, pindone, warfarin, coumachlor, diphacinone, chlorophacinone, bromadiolone, difenacoum, brodifacoum, difethialone, as well as for desmethyl-bromethalin, a metabolite of the neurotoxicant rodenticide bromethalin (the metabolite of the neurotoxicant bromethalin). Brodifacoum was detected in both samples (33.3-36.3 ng/g in the liver and <LOD-0.54 ng/mL in the blood; LOD for analysis in blood = 0.45 ng/mL). No other rodenticides were detected.

The owl was emaciated and had a heavy parasite load "with large numbers of *Leucocytozoon* spp. protozoa in red blood cells and *Elmeria* spp., coccidia and *Capillariid* spp. in the intestine."

There were no signs of trauma and tests for avian influenza virus, West Nile virus, and exposure to lead were all negative. Cholinesterase levels were normal, indicating no exposure to organophosphate or carbamate pesticides. The study authors concluded that the cause of death was emaciation and parasitism. The study authors stated that brodifacoum was not the primary cause of death because there was no internal hemorrhage, which would be symptomatic of AR intoxication. However, they also stated that "brodifacoum may have been an additional contributor to the owl's death."

There were seven active cannabis growing operations within 1.5 km of where this owl was found. The study authors described one illegal cannabis growing operation located 450 m from where this owl was found. Although that operation was shut down in 2015, there was 23 kg of brodifacoum laced bait around its perimeter, providing evidence that many of these illegal cannabis grow operations are using pesticides illegally (i.e., not in compliance with the labeled uses). The study authors hypothesized that dusky-footed woodrats (*Neotoma fuscipes*) are the mechanism of transmission of ARs from illegal marijuana grow operations to higher trophic levels. This is because woodrats are often abundant in forest clearings such as those created by fire and logging. Illegal cannabis growing operations clear out the forests in similar ways to allow light to reach the cannabis plants. Additionally, woodrats are known to use plants with high monoterpene content (such as marijuana and California bay) as nest material because they can act as insect larvicides. The forest clearings also create increased edge, which is where northern spotted owls often forage. Overall, these illegal cannabis grow operations are creating habitat that attracts both woodrats and owls, so when ARs are available for woodrats to consume, the potential exists for them to be transferred up the food chain. This study presents an additional line of evidence that illegal uses of pesticides in illegal cannabis grow operations are contaminating food webs and impacting threatened species in remote forested areas of California where the SGARs have no legal uses.

- **Fraser, D., Mouton, A., Serieys, L.E.K., Cole, S., Carver, S., Vandewoude, S., Lappin, M., Riley, S.P.D., Wayne, R., 2018, Genome-wide expression reveals multiple systemic effects associated with detection of anticoagulant poisons in bobcats (*Lynx rufus*), Molecular Ecology, 00:1–18, https://doi.org/10.1111/mec.14531**

This study examined various sublethal effects of rodenticide exposure using 52 blood samples collected from bobcats captured in the Simi Hills, Hollywood Hills, and the Santa Monica Mountains from 2008 to 2012. Twenty-six of the blood samples were from bobcats that had been exposed to ARs and 26 of the blood samples were from bobcats that had not been exposed to ARs. The samples were also balanced in terms of age and sex. The AR screen tested for brodifacoum, bromadiolone, difethialone, diphacinone, warfarin, chlorophacinone, and coumachlor. It should also be noted that coumachlor has never been registered for use in California. Additionally, the screen did not include difenacoum, which is a SGAR that is registered for use in California. The bobcats from which these samples were collected did not appear to have any signs of disease.

Serum samples were analyzed for various viral and bacterial pathogens. Total RNA was extracted from whole blood samples, then quantified and sequenced. The genome from the domestic cat (*Felis catus*) was used as a reference genome. The study authors conducted various statistical analyses (e.g., principle components analysis, linear regression, etc.) and found that there were 1,783 genes that were significantly associated with exposure status. Of those, 530 were downregulated and 1,253 were upregulated. Among the genes that were downregulated were genes related to wound healing, epithelial integrity, white blood cell production, and several genes involved in the allergic response. Among the genes that were upregulated were genes that may lead to activation of the adaptive immune system and processes related to xenobiotic transformation. Overall, the study authors stated that "the up- and downregulation of numerous cytokines demonstrate a pronounced dysregulation of critical mediators of immune function, implying both immunosuppressive and stimulating effects of AR [anticoagulant rodenticide] exposure." Other genes that were downregulated in AR exposed bobcats suggested that exposure could influence epithelial maintenance and formation. The study authors stated that some of these genes could potentially help provide an explanation as to the link between AR exposure and mange in bobcats. More specifically, the study authors stated that the association between AR exposure and genes related to immune regulation and epithelial integrity could predispose bobcats to opportunistic infection by mange causing parasites. Furthermore, the cumulative effects that interfere with the regulation of cellular functions related to AR exposure likely inhibit the healing of wounds, allowing for mange lesions to grow, which can ultimately lead to death. Overall, this study identifies several pathways through which exposure to ARs can lead to effects that decrease the fitness of bobcats and can lead to population level effects.

The following publication was submitted by Mr. Graf. DPR scientists evaluated and analyzed this publication. A summary is presented below.

- **Novak, K., Torfeh, D., 2017, Raptor Pilot Study for Levee Protection - Integrated Pest Management Program, Ventura County Public Works Agency, Watershed Protection District, available via: <https://vcportal.ventura.org/BOS/District2/RaptorPilotStudy.pdf>, accessed October 16, 2018.**

This study was not peer-reviewed and many of the statements and claims in this study are not supported by citations. The purpose of this study was to quantify and compare the efficacy of raptors in reducing ground squirrel populations in comparison to FGARs. Burrow damage caused by gophers was also quantified, but the FGAR bait used on the levees is not labeled for gophers, so ground squirrels were the main focus of the study.

A baseline was established before the start of the study by finding and filling all ground squirrel burrows in the study area with a cement bentonite grout. The amount of grout used was equal to the volume of two cement trucks (4,400 gallons of grout in a 2.56 mile stretch). There were two phases: Phase 1 compared two 6,000 foot reaches of the levee that runs along Revolon Slough in Oxnard, CA. During Phase 1, the first reach was called the raptor test site and the second reach was called the control site. The two reaches were separated by a 3,000 foot buffer zone. In the raptor test site, AR bait stations were removed and replaced with raptor perches. In the control site, diphacinone bait was applied using rodenticide bait stations. The study authors monitored the perches, and quantified new rodent burrows, burrow grouting, rodenticide consumption, raptor sightings, agricultural use in adjacent fields, as well as an analysis of scat and raptor pellet contents (undigested materials, such as hair and bones, regurgitated by the raptors). Monitoring was conducted by five individuals on each reach during alternating weeks (control site one week, then the raptor site the next week). Additionally, the contents of the raptor pellets were analyzed to determine what the raptors were feeding upon. The study authors noted that the crops grown in adjacent fields were impacting the efficacy of the bait stations because ground squirrels have a preference for some crops, such as berries, over diphacinone treated grains. This motivated the study authors to develop a second phase for the study. During Phase 2, the control site was renamed as the "modified control site" and the rodenticide bait stations were replaced with raptor perches at that site.

The crops grown in adjacent fields were similar during the two phases of the study, but there was more fallow land in 2017, compared to 2016. The study authors stated that fewer annual crops in 2017 could result in fewer squirrels. The study authors tallied raptor observations during 65 monitoring outings from April 2016 to August 2017. Red-tailed hawks had the most observations (101), but the study authors estimated that the same three to four hawks were observed repeatedly. White tailed kites were the next most common, with 27 observations, followed by Cooper's hawks (20 observations), ospreys (10 observations), and northern harriers (8 observations). Red-shouldered hawks, peregrine falcons, merlins, and burrowing owls were all observed three times each. Great horned owls were observed twice and there was one observation of a Swainson's hawk. Barn owls were not observed, but raptor pellet analysis indicated that barn owls and great horned owls were hunting gophers during the study. The presence of scat revealed that the perches were being used by raptors soon after installation. During Phase 1, from April to November of 2016, there was a 66% reduction in new ground squirrel burrows on a per mile, per month basis in the raptor site compared to the control site. When October and November were excluded from the 2016 analysis, there was a 57% reduction in new ground squirrel burrows on a per mile, per month basis in the raptor site compared to the control site. When the control site during Phase 1 was compared to the modified control site during Phase 2, there was a 47% reduction in new ground squirrel burrows on a per mile, per month basis (Table 3). It is unclear why the study authors decided to exclude September, October, and November from Phase 2. In the control site, those three months accounted for more new squirrel burrows than the period from April to August of 2016. There were 206 observed new squirrel burrows in the control site from April to August of 2016, and 224 observed new squirrel burrows in the control site from September to November of 2016. This presents some uncertainty as to the results, because it is unclear how the comparison between the control site during Phase 1 and the modified control site during Phase 2 would have been different if September, October, and November had been included in the analysis. The study authors did not provide an explanation as to why the months with the most new squirrel burrows were excluded from Phase 2.

The study authors only reported burrow grouting for the entire study area, and did not distinguish between the control site, the raptor site, or the 3,000 foot buffer zone separating the two sites. During Phase 1, new burrows were grouted eight times after the additional baseline grouting and a total of 1,400 gallons of grout was injected into the levees. During Phase 2, a total of 700 gallons of grout was injected into the levees during six grouting operations from March 3rd to August 27th of 2017. Although anecdotal, the grouting crews reported that there were fewer burrows in 2017 and the burrows that were grouted had less penetration into the levees. An independent contractor was used for rodenticide applications. They made weekly inspections and applied oats infused with diphacinone at 0.005% into bait stations as needed. The study authors reported that a total of 84.5 pounds of bait was consumed during Phase 1. The contractor who applied the rodenticide also reported to the study authors that consumption of rodenticide bait increased after raspberries were harvested adjacent to the control site.

A total of 107 raptor pellets were analyzed to determine which raptor species were hunting in the area and what the raptors were feeding upon. Of the pellets analyzed, 49% were from owls and 51% were from hawks or other non-owl raptors. The study authors discussed which target species were found in the raptor pellets in the text of the report, and even provided a table, but they did not mention any impacts on non-target wildlife in the text of the report. However, Appendix F on Page 52 of their report contains raw data for the raptor pellet analysis which shows that the raptors were consuming many non-target wildlife. Ground squirrels were the focus of the study and the raptor pellet analysis found a minimum of nine ground squirrels. However, a minimum of 18 American coots and 18 passerine species were also found in the raptor pellets and/or raptor scat, suggesting the raptors were killing twice as many non-target birds as ground squirrels. Additionally, the raptor pellet analysis showed that raptors were also feeding on frogs (e.g., *Pseudacris* sp., African clawed frog, *Rana* sp.), snakes (e.g., gopher snake), lizards, other reptile species, crabs (e.g., kelp crab), crayfish, other bird species (e.g., Virginia rail, red-winged blackbird, Eurasian collared dove, song sparrow), lepidopteran larvae, as well as a variety of mammals and terrestrial invertebrates. Many of the non-target wildlife species found in raptor pellets would most likely not have been exposed to or affected by ARs (e.g., coots, blackbirds, sparrows, frogs, lizards), so there is a trade-off in impacts to non-target wildlife that the study authors did not discuss in the text of the report.

This study was not replicated. However, Phase 2 allowed the study to continue into a second year with nearly identical agricultural conditions during both years in the raptor site, and the similarity of the results in the raptor site (15.7 new burrows/mile/month during Phase 1 and 15.8 new burrows/mile/month during Phase 2) increase confidence in the results (Table 3). The study authors stated that "neither method has completely eliminated burrows" and that "regular inspection and burrow grouting are critical elements" that must continue to determine whether rodenticides or raptors have greater efficacy at controlling populations of burrowing rodents. The study authors created a criteria for expanding the program. They stated that "earthen facilities that have natural areas on adjacent properties" would be appropriate candidates for expansion of the raptor program, but that urban areas would not be good candidates for raptor perches. Overall, this study showed that the installation of raptor perches and nesting boxes can be more effective than rodenticides under certain conditions.

Table 3 – New ground squirrel burrows per mile per month during the Raptor Pilot Study for Levee Protection. In the raptor test site, rodenticide bait stations were removed and replaced with raptor perches. The control site used rodenticide bait stations without raptor perches. In 2017, the control site was renamed the modified control site because the rodenticide bait stations were removed and replaced with raptor perches.

Table 3. New Ground Squirrel Burrows (new burrows per mile per month) *	
Phase 1 (April to November 2016)	
Raptor Test Site	16.0
Control Site	47.3
Percent reduction in burrows	*66.2%*
Phase 1 (April to August 2016)	
Raptor Test Site	15.7
Control Site	36.3
Percent reduction in burrows	*56.7%*
Phase 2 (April to August 2017)	
Raptor Test Site	15.8
Modified Control Site	19.4
*Percent reduction in burrows ** *	*46.6%*
* This table was reproduced and modified from Novak and Torfeh (2017). ** Percent reduction when comparing the control site during Phase 1 (from April to August of 2016) to the modified control site during Phase 2 (from April to August of 2017). The study authors did not explain why Phase 2 ended in August, rather than November.	

- **Emails from Drs. Seth Riley and Laurel Serieys to Jan Dougall (Las Virgenes Municipal Water District), Kian Schulman (Poison Free Malibu), and other National Park Service staff**

These emails, submitted by Mr. Graf, discuss research and opinions about ARs in response to an inquiry from a concerned citizen. The emails do not provide scientific data.

- **Letter from Allen M. Fish, Director, Golden Gate Raptor Observatory**

A letter from Allen M. Fish was submitted to DPR by Michael Graf. The letter does not provide any additional scientific data.

- **Table contained in Mr. Graf's letter**

This table contains numbers without any units and was provided to DPR without any explanation of what these numbers represent, how they were generated, or if the methods used to generate these numbers are scientifically sound. As a result, it cannot be evaluated or used to make regulatory decisions. Raw data is also required so that DPR scientists can conduct independent calculations and reproduce the numbers in the table.

Table 4

	Pre-Regs	Year 1	POST
brodifacoum	94.	78.	89.
bromadiolone	59.	52.	69.
difethiolone	10.	28.	34.
difenacoum	1.5	7.4	0.
diphacinone	13.	50.	47.
chlorophacinone	4.4	11.	9.6
warfarin	1.5	5.6	6.1
Total Cases	68	54	114
Bromethalin Cases	0	3	7

Summaries of AR Data and Information from Regulatory Agencies

- **A Summary of Studies Described in a U.S. EPA Risk Assessment**

The U.S. EPA (2004) compared risks to non-target birds in a review of secondary toxicity studies. In some of the studies they reviewed, prey (mostly rats or mice) were poisoned with rodenticides and their whole or ground carcasses were fed to birds (raptors and scavengers). The review noted 42% mortality (63 of 149 individual birds) in 11 studies in which birds were fed brodifacoum-poisoned prey. In contrast, five studies conducted with bromadiolone resulted in 8% mortality (9 of 118 individual birds) when birds were fed bromadiolone-poisoned prey. Although not all these studies examined sublethal effects, surviving birds that were fed bromadiolone-poisoned prey exhibited fewer sublethal effects than surviving birds that were fed prey poisoned with brodifacoum. The U.S. EPA review also described two more studies in which barn owls were fed mice that had been poisoned with brodifacoum or bromadiolone. In those studies, four of six owls fed brodifacoum-poisoned mice died, but all six of the owls fed bromadiolone-poisoned mice survived (U.S. EPA, 2004).

Another study described in the review compared secondary toxicity risks of three FGARs and three SGARs to barn owls. Six owls per test group were fed rats that had been offered nontoxic laboratory feed or baits laced with either brodifacoum (20 ppm), bromadiolone (50 ppm), or difenacoum (50 ppm). The rats were free to choose between the non-toxic laboratory feed or the rodenticide-laced bait. The barn owls were exposed to these rats for ten days. After ten days of exposure, five of six owls fed rats exposed to brodifacoum were dead, one of six owls fed bromadiolone-exposed rats was dead, and all six of the owls fed difenacoum-exposed rats survived. It is important to note that owl mortality in the brodifacoum test group was higher despite the fact that the concentration of brodifacoum bait that the rats fed upon was lower than for the other two SGARs. In the same experiment, two owls per test group were exposed to rats fed either diphacinone (50 ppm), chlorophacinone (50 ppm), or fumarin (250 ppm; an FGAR never registered for use in California). There were no mortalities and no observed sublethal effects in any of the owls fed rats exposed to FGARs (U.S. EPA, 2004).

- **DPR Pesticide Sales and Use Reporting Data**

DPR tracks the sales and use of pesticides, including ARs. It is important to note pesticide use reporting data only includes pesticides used by professional applicators that have been licensed and certified by DPR. Sales data is reflective of pounds of pesticides sold as self-reported by registrants. However, the fact that a pesticide is sold in a given year is not necessarily reflective of its use.

DPR can then use the sales and use data to qualitatively compare exposure rates from different active ingredients to their sales (Figure 9) and use (Figure 10). For example, according to DPR's use and sales data more diphacinone was used/sold, with the exception of use of bromadiolone in 2016, than any of the other rodenticides. However, exposure rates for diphacinone are relatively low in comparison to other ARs.

There are some trends in the sales and use data. Specifically, diphacinone use increased from 2009 to 2013, then decreased back to 2009 levels in 2015 (Figure 9). Diphacinone, being a FGAR, was not affected by the 2014 regulations enacted by DPR, so it is unclear what is driving this trend. In contrast, sales of diphacinone declined from 2011 to 2014, then increased from 2014 to 2017 (Figure 10).

Bromadiolone use increased approximately three-fold from 2015 to 2016, then declined in 2017, but the increased use of bromadiolone is not reflected in the sales data (Figures 9 and 10). Brodifacoum use has always been relatively low compared to other ARs, because it is not favored by professional applicators (DPR, 2013). Brodifacoum sales have decreased since the 2014 regulations went into effect, from 34.5 pounds of active ingredient in 2013, to a low of 3.5 pounds in 2015, and have increased slightly since then to 5.7 pounds in 2017 (Figure 10). Based on the limited data on file, DPR determined that decreased sales of brodifacoum do not appear to have led to decreased exposure rates among non-target wildlife.

Figure 9 – A summary of Pesticide Use Report data from 2005-2017. All certified applicators in California are required to submit pesticide use reports to county agricultural commissioners, who in turn, report to DPR. This chart displays AR use by professional certified applicators, not the general public. Certified applicators report use to County Agricultural Commissioners, who report to DPR. Therefore, DPR cannot attest to accuracy of the values used to generate this graph.

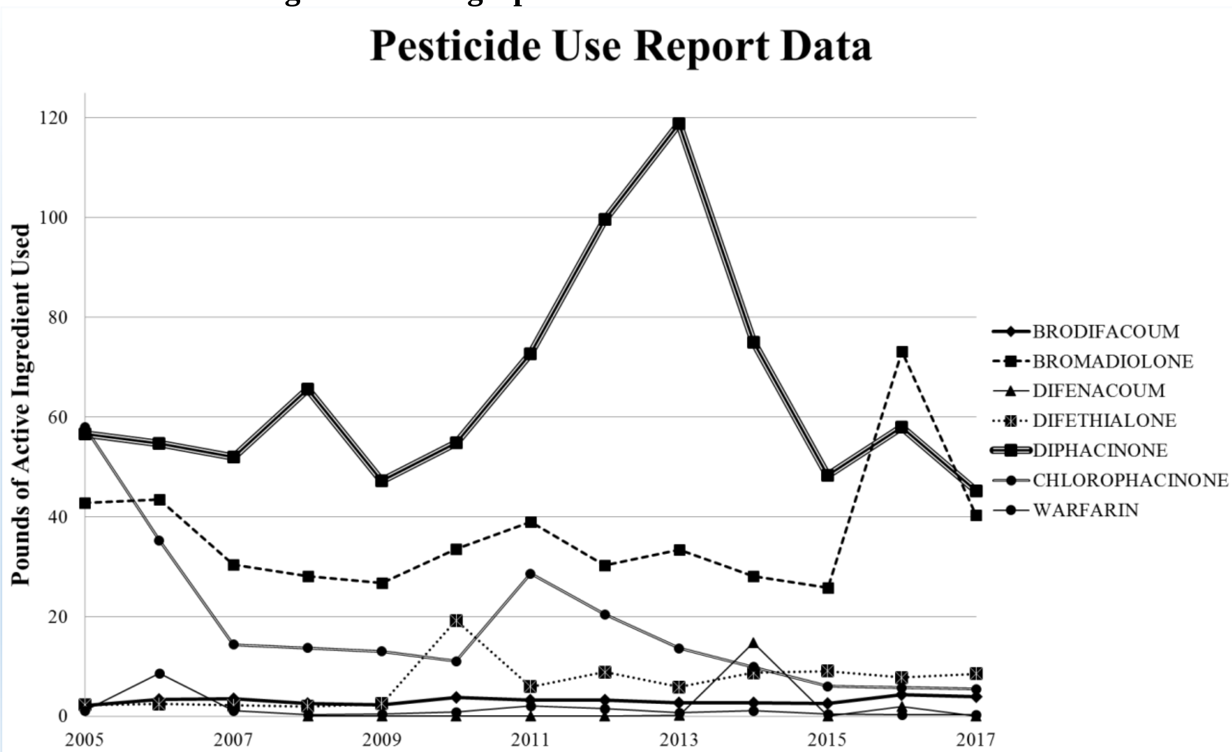
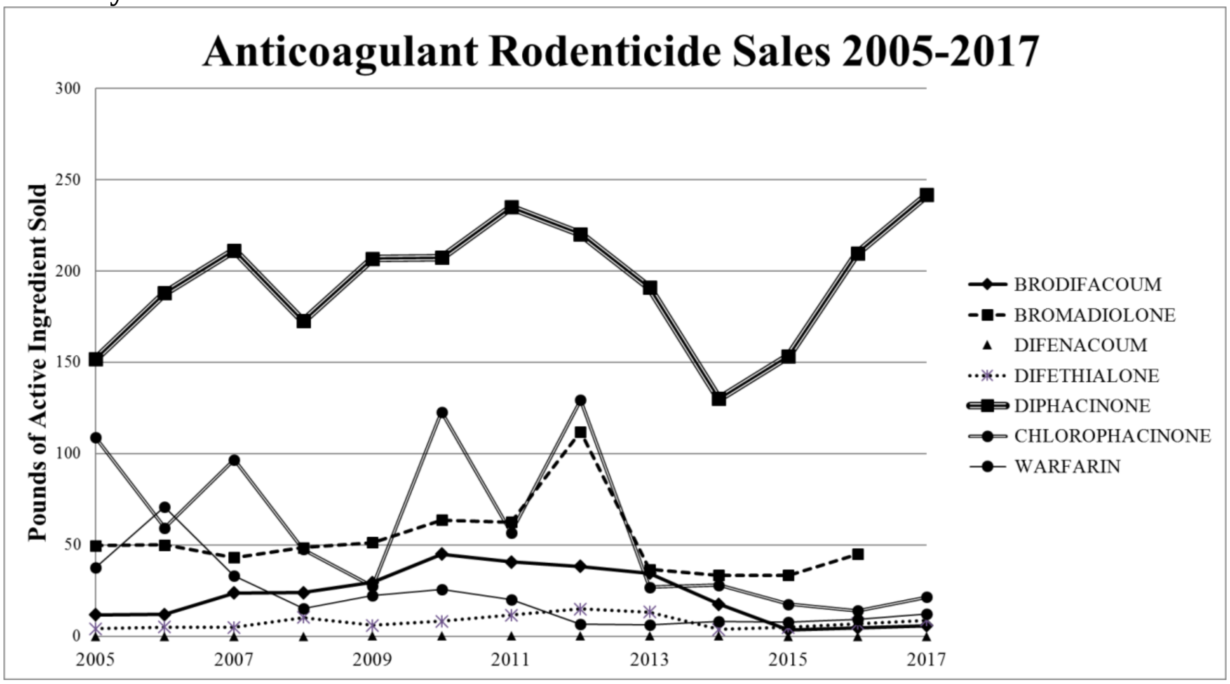


Figure 10 – A summary of AR sales data from 2005-2017. Sales data for bromadiolone in 2017 indicated that 638 pounds of active ingredient was sold. This is most likely an error, so 2017 sales data for bromadiolone is not present in this graph. DPR sales reports are based on information obtained from a system of self-reporting, so DPR cannot attest to the accuracy of the data.



Conclusion

As evidenced by its mission statement, DPR is guided by the principle that pesticide use should not cause unacceptable risks to human health or the environment. California law (Food and Agricultural Code 12824) requires DPR to "eliminate from use in the state" any pesticide that "endangers the agricultural or nonagricultural environment, is not beneficial for the purposes for which it is sold, or is misrepresented." To fulfill this mandate, DPR is required to enact "continuous evaluation" of currently registered pesticides. Multiple programs are set in place for this goal, including DPR's formal Reevaluation Program. Given evidence that the use of a pesticide may be causing significant adverse effects to people or the environment, DPR is required to investigate. If the Director finds from the investigation that a significant adverse impact has occurred or is likely to occur, DPR is required to reevaluate the pesticide and determine if it should remain registered or if additional mitigation measures are needed.

Risk is the combination of hazard and exposure. When evaluating a pesticide's risk to non-target organisms, toxicity, persistence, and bioaccumulation are the three main factors that should be considered. These three factors stem from inherent physicochemical parameters of a molecule that cannot be changed and are determined through laboratory testing. They are controlled by the interaction, on a molecular level, between the active ingredients and the biological receptors in target and non-target organisms. In addition, the way that a pesticide product is used (i.e., the use patterns) also affects its risk to non-target organisms. Use patterns can be changed by modifying the directions for use and/or by adding additional restrictions (e.g., only allowing use in or near structures such as houses). In this case, DPR is investigating the risk of non-target wildlife exposure to anticoagulant rodenticides.

The data currently on file with DPR provide no basis for placing FGARs into reevaluation. First, the physicochemical properties of the FGARs are less toxic (Table 1), less persistent (Table 2), and less bioaccumulative (Table 3) than the SGARs, demonstrating that the inherent risk of the FGARs is lower. Second, the exposure rates among non-target animals are lower for FGARs than for SGARs (Figures 1, 3, 6, 7, and 8). For example, U.S. EPA (2004) observed that owls that were fed rats exposed to FGARs showed no mortalities and no observed sublethal effects. Finally, there is a general downward trend in FGAR exposure rates (Figure 3). As a result, DPR finds that current uses of FGARs are unlikely to have a significant adverse impact to non-target wildlife.

Compared to FGARs, SGARs are all more toxic, more persistent, and more bioaccumulative. Several of the publications submitted by Graf provide lines of evidence showing that there have been population-level adverse effects among bobcats in Southern California due to exposure to SGARs. Of particular note is Serieys et al. (2015), which found statistically significant associations between SGARs and mange, but not between FGARs and mange. These sublethal effects can affect fitness and have population level effects (Serieys et al., 2015). A severe outbreak of mange from 2002 to 2006 caused a genetic bottleneck among bobcats in Southern California (Serieys et al., 2015) which may be irreversible. Though available data is extremely limited and the true extent of exposure is unknown, it is possible that other predatory/scavenger species may also suffer similar significant adverse effects.

DPR enacted regulations in 2014 that were designed to reduce the risk of non-target wildlife exposure to SGARs. The regulations changed the use patterns, and restricted the purchase, sales, and use of second-generation ARs to certified applicators only. However, the limited data that DPR has on file shows that exposure rates have not decreased among SGARs (Figures 1, 2, and 8).

In addition, there is evidence to suggest that brodifacoum may have the highest level of risk within the SGARs. Brodifacoum consistently had higher exposure rates in non-target organisms than any other rodenticide that was disproportionate to its use: in the DFW mountain lion database; in the non-target organism loss reports submitted by DFW (compiled into a database and independently analyzed by DPR scientists); in the WildCare data that DPR already had on file (Part 4); and in the following peer-reviewed publications submitted by Graf: Vyas et al. (2017); Poessel et al. (2015); Gabriel et al. (2017); and Franklin et al. (2018). These lines of evidence indicate that more non-target organisms are exposed to brodifacoum than to any of the other ARs tested.

Collectively, the physiochemical properties of the SGARs, high exposure rates, and population-level impacts demonstrate that SGARs have a significant adverse impact to non-target wildlife.

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DPR Anticoagulant Rodenticide Informal Public Workshop

September 24, 2025

Overview

- Overview of Anticoagulant Rodenticides (ARs)
- High level proposed mitigation
- Current AR restrictions based on legislative action
- Details of draft proposal
- Comment Period
- Next Steps

Anticoagulant Rodenticides

Anticoagulant rodenticides prevent blood from clotting, leading to uncontrolled hemorrhaging and toxicosis.

- Second-generation anticoagulant rodenticides (SGARs)
  - **Brodifacoum**
  - **Bromadiolone**
  - **Difenacoum**
  - **Difethialone**
- First-generation anticoagulant rodenticides (FGARs)
  - Chlorophacinone
  - **Diphacinone**
  - Warfarin

***Bolded pesticides are under formal DPR reevaluation**

The proposed mitigations would mitigate all FGARs and SGARs as a holistic approach.

Mitigation: Reduce impacts to wildlife and maintain necessary uses of ARs

Reduce repeat exposure of non-target wildlife for all ARs

- Reduce overall amount in the environment
- Reduce how long they are available in the environment

Educate users on sustainable rodent management

- Education
- Sustainable Rodent Management Plan

How are we proposing to do this?

Propose regulations that:

- Classify all ARs **restricted materials.**
- Limit **where** ARs can be used to those that protect public health, agriculture, and water.
- Limit applications to a maximum of **35 consecutive days** at most sites with a maximum of 105 days annually per site for any AR.
- Require **training** on sustainable rodent management that incudes rodent biology and choosing the right tool for managing rodents.
- Require developing and maintaining a **sustainable rodent management plan** that addresses how the businesses or operators will approach rodent management decision making.

What is a Site?

Existing product labels specify the sites where a product can be used

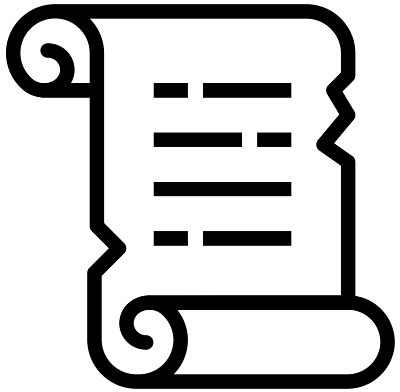
Proposed regulations would further restrict sites where ARs could be used

- Restricts use in and around man-made structures to within 50 ft of listed structures
- Specifies when use would be exempted from regulations and, in some cases, the sites where they would be exempt.

Legislation

Section 12978.7 of the California Food and Agricultural Code (FAC) contain use restrictions, considerations for reevaluation and concurrence requirements with the California Department of Fish and Wildlife (CDFW).

- 2020: **AB1788 -** Prohibits use of SGARs except at certain sites
- 2023: **AB1322 -** Prohibits use of diphacinone (FGAR) except at certain sites
- 2024: **AB 2552 -** Prohibits use of remaining FGARs (chlorophacinone and warfarin) except at certain sites



Current vs Proposed Restrictions

Current restrictions (FAC § 12978.7):

- Applications are only allowed by exempted users or at exempted use sites

Proposed restrictions:

- Specifies manmade structures where ARs can be used, via site definitions in statute
- Limits duration of use
- Requires applicator training and development of a Sustainable Rodent Management plan

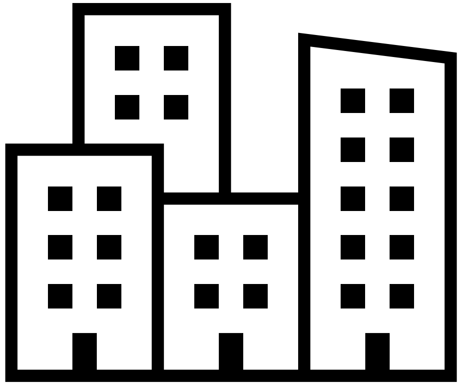
Allowed Use at Manmade Structures

Use at man-made sites is only allowed in listed sites

- Sites picked to protect public health
- Subject to the use duration restriction

Use for public health, water supply, agriculture, protecting endangered species, and research that meet statutory definitions

- Exempt from duration restriction as specified

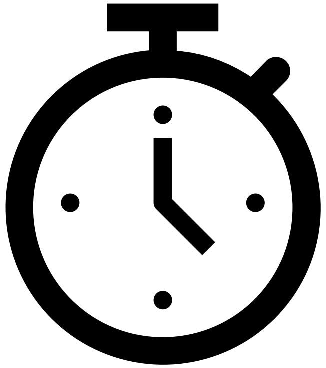


Limitation on Duration of Baiting

- **35 consecutive day** limit of any AR per application
- 2 additional 35-day applications permitted per year, for a cumulative annual total of **105 days** per site.

Basis:

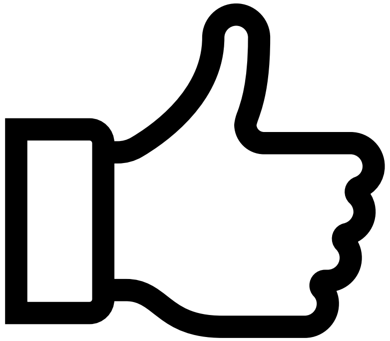
- Registrant submitted data indicate that this timeframe is efficacious
- Studies have shown a 70% reduction in rodent populations in 35 days



Proposed Exemptions

The following uses **would be exempt** from the manmade structures and duration restrictions:

- Public health
  - As declared by State Public Health Officer
  - Use by vector control
- Nonnative invasive species eradication on offshore islands
- CDFW invasive rodent population eradication to protect endangered species/habitats
- To protect water and hydroelectric infrastructure
- FGAR use in agriculture
- Research for continuous evaluation



Holistic rodent management

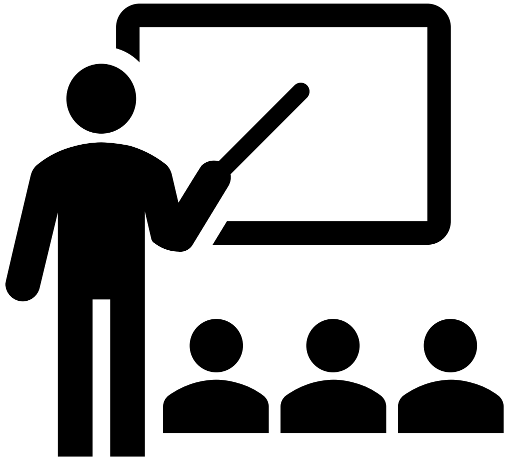
- Reduced use is critical to protecting non-target wildlife and will help ensure effective pest management critical to addressing rodent management more holistically.

- To support this, the draft mitigation includes a training requirement for AR applicators and development of a Sustainable Rodent Management plan for businesses and private applicators.

Sustainable Rodent Management Training

- **Proposed use requirement**: To use ARs individuals must take annual training to increase awareness and adoption of integrated pest management (IPM) practices, with record retention for two years.

- The course would include **Integrated Pest Management and Sustainable Pest Management principles** (as defined in the FAC sections 11401.7 and 11412).



Training Implementation Options

Outside of rulemaking, DPR is considering whether the training will:

- DPR provided or DPR approved
- Count towards DPR and SPCB licensure (CE credits)

DPR is looking for public feedback on which of these options may be the best fit for implementing this training and proposed topics to include in the required training outline detailed in the regulation.

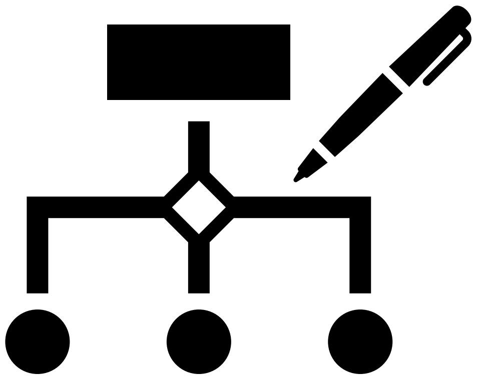
Sustainable Rodent Management Plan

Each business would be required to write, implement and retain records of a Sustainable Rodent Management plan.

- **General and is not required to be site-specific**
- Used as a **decision-making tool**, not a prescribed set of actions for every specific scenario.

Sustainable Rodent Management recordkeeping requirement:

- **Site-specific use records** kept at a central business location that tracks the dates ARs are deployed and collected by site to support compliance with the 35-day limit.



Thank you

California Department of Fish and Wildlife (CDFW)

California Department of Food and Agriculture (CDFA)

Structural Pest Control Board (SPCB)

California Department of Public Health (CDPH)

Where DPR wants feedback specifically

- Does the rulemaking text capture the intent of mitigation?
- Refinements to exempted sites
- Training topics and implementation options
- Site-specific use duration recordkeeping
- 12-month delay between effective date and training requirements

Next steps

- Draft proposed regulatory text are available on our website (www.cdpr.ca.gov).

- 45-day informal comment period
  - Please submit comments to DPR's Public Comment Portal at https://cdpr.commentinput.com?id=JsSRaG6NA by November 8, 2025.

  - Please submit clarifying questions to: Rodenticide.Comments@cdpr.ca.gov

SmartComment QR Code

Northern spotted owl | Dave Roelofs, BLM

CROSSWALK OF ANTICOAGULANT LEGISLATION AND PROPOSED REGULATIONS

CURRENTLY ALLOWED USES (FAC 12978.7 AND ENF 24-20)	DPR 2025 PROPOSED REGULATIONS
Governmental agency employee for public health (g)(1)	Maintained with proposed 3CCR (d)(3) & (5)
Employee or contractor of a governmental agency or public utility to protect the water supply and hydroelectric energy (g)(2)	Maintained with proposed 3CCR (d)(4)
Mosquito or vector control district to protect the public health (g)(3)	Maintained with proposed 3CCR (d)(3) & (5)
Eradication of nonnative invasive species on offshore islands (g)(4)	Maintained with proposed 3CCR (d)(1)
Control or eradication of invasive rodents by CDFW to protect threatened or endangered species (g)(5)	Maintained with proposed 3CCR (d)(2)
Public health need as determined by State Public Health Officer (g)(6)	Maintained with proposed 3CCR (d)(3)
Research (g)(7)(8)	Maintained with proposed 3CCR (d)(7)
Medical waste generator as defined in HSC 117705 (h)(1)(A)	Maintained with proposed 3CCR (a)(1-5) with 35 consecutive day duration restrictions
Facility registered and inspected under Federal Food, Drug, and Cosmetic Act (h)(1)(B)	Maintained with proposed 3CCR (a)(6) with 35 consecutive day duration restrictions
Agricultural Activities (h)(2)	
Warehouse storing food for human or animal consumption	Maintained with proposed 3CCR (a)(7-10) with 35 consecutive day duration restriction in and around manmade structures, FGAR use away from manmade structures maintained.
Food production sites including slaughterhouse or cannery	
Factory	
Brewery, winery	
Ag production site housing water storage and conveyance	
Ag production site housing rights-of-way and transportation infrastructure	
Prohibited Uses Under Current Law	
Residential Use	Not Allowed unless it meets an exception
Restaurant (unless attached to a brewery or winery)	Maintained with proposed 3CCR (a)(8-9) with 35 consecutive day duration restriction, FGAR use away from manmade structures maintained
Grocery stores	Maintained with proposed 3CCR (a)(7) with 35 consecutive day duration restriction, FGAR use away from manmade structures maintained
Airports, offices, constructions sites, ports and terminal buildings, shipyards, lumber yards, schools, shopping malls unless identified in allowed uses	Use not allowed unless it meets an exception.
Non-production ag sites such as cemeteries, golf courses, parks, highways, and railroads	Use not allowed in or around manmade structures unless it meets one of the exceptions. FGARs can only be used away from manmade structures with the 35 consecutive day duration limit if allowed on the product label.
Wildlife habitat area - park or wildlife refuge managed by a state agency, regional government, quasi-government agency, or a special district	

Resource for pre-regulatory workshop on mitigation updated on Sept. 9, 2025.

DPR Draft Proposed Anticoagulant Rodenticide Regulation Text

DELIBERATIVE DRAFT

Key to Draft Regulatory Text: Black text is existing reg text, Blue text is new/added, Green text is moved, Red text are proposed deletions

Restricted Materials Regulations (CCR)

Subchapter 4 - Restricted Materials (Article 1 to 5) -

Article 1 - Restricted Materials (§ 6400 to 6402), § 6400 - Restricted Materials

The Director designates the pesticides listed in this section as restricted materials.

....

(e) Certain other pesticides:

...

Carbofuran (Furadan)

Chlorophacinone

Chloropicrin

...

Difethialone

Diphacinone

Diphacinone sodium salt

Disulfoton (Di-Syston), except when labeled only for one or more of the following uses: home use, structural pest control, industrial use, institutional use, and use by public agency vector control districts pursuant to section 116180 of the Health and Safety Code.

...

Tributyltin, organotin, or a tri-organotin compound formulated as an antifouling paint, coating or compound and labeled for the control of fouling organisms in an aquatic environment.

Warfarin

Warfarin sodium salt

Zinc phosphide, except when labeled only for one or more of the following uses: home use, structural pest control, industrial use, institutional use, and use by public agency vector control districts pursuant to section 116180 of the Health and Safety Code

Article 2 - Possession and Use Limitations (§ 6404 to 6417)

§ 6414 - Permit Exemptions

.....

(h) No permit shall be required for products containing brodifacoum, bromadiolone, difenacoum, difethialone, chlorophacinone, diphacinone, diphacinone sodium salt, warfarin, or warfarin sodium salt, unless otherwise required by the commissioner.

Article 5 - Use Requirements (§ 6453 to 6489)

§ 6471 - Brodifacoum, Bromadiolone, Chlorophacinone Difenacoum, ~~and~~ Difethialone, Diphacinone, Diphacinone sodium salt, Warfarin and Warfarin sodium salt

This section supplements the label restrictions on the use of brodifacoum, bromadiolone, chlorophacinone difenacoum, ~~and~~ difethialone, diphacinone, diphacinone sodium salt, warfarin and warfarin sodium salt. For the purposes of this section, these active ingredients will collectively be referred to as anticoagulant rodenticides.

(a) ~~It is prohibited to place any above ground bait more than 50 feet from a man-made structure unless there is a feature associated with the site that is harboring or attracting the pests targeted on the label between the 50-foot limit and the placement limit specified on the label.~~

Except as provided in (d), use in and around man-made structures is only allowed at:

(1) Health facilities, as defined in California Health and Safety Code (HSC) § 1250

(2) Clinics, as defined in HSC § 1200

(3) Outpatient settings, as defined in HSC § 1248

(4) Locations storing, collecting, or distributing biologics (as defined in HSC § 1600.1) or human tissue or organs (as defined in HSC § 1635)

(5) Pharmacies, as defined in BPC 4037

(6) FDA-registered and inspected facilities involved in commercial manufacture, preparation, compounding, of drugs

(7) Grocery stores, as defined in HSC § 113948

(8) Permanent food facilities, as defined in HSC § 113849

(9) Food processing facilities, as defined in HSC § 109947

(10) Locations with the primary purpose of producing, storing, holding, or packing an agricultural commodity, livestock, poultry, or fish.

(b) Except as provided in (d), it is prohibited to place any above ground bait more than 50 feet from a listed man-made structure, unless there is a feature associated with the site that is harboring or attracting the pests targeted on the label between the 50-foot limit and the placement limit specified on the label.

(c) Except as provided in (d), applications must not exceed 35 consecutive days. All unconsumed bait must be collected at the end of the 35-day period. Double bag and dispose of bait according to the pesticide label directions. The combined application duration of anticoagulant rodenticides at a site must not exceed a total sum of 105 days within a calendar year.

(d) Use is allowed, and exempt from the restrictions in (a), (b), and (c):

(1) For the eradication of nonnative invasive species inhabiting or found to be present on offshore islands in a manner that is consistent with all otherwise applicable federal and state laws and regulations.

(2) If the Department of Fish and Wildlife determines use is required to control or eradicate an invasive rodent population for the protection of threatened or endangered species or their habitats.

(3) To control an actual or potential rodent infestation associated with a public health need, as determined by a supporting declaration from the State Public Health Officer or a local public health officer. For purposes of this section, a public health need is an urgent, nonroutine situation posing a significant risk to human health in which it is documented that other rodent control alternatives, including nonchemical alternatives, are inadequate to control the rodent infestation.

(4) When used by an employee or contractor of a governmental agency or public utility, as defined in Section 216 of the Public Utilities Code, for purposes of protecting water supply and hydroelectric energy generating infrastructure and facilities in a manner that is consistent with all otherwise applicable federal and state laws and regulations.

(5) When used by a governmental agency employee who complies with Section 106925 of the Health and Safety Code to protect public health or by a mosquito abatement and vector control district formed under Chapter 1 (commencing with Section 2000) of Division 3 or Chapter 8 (commencing with Section 2800) of Division 3 of the Health and Safety Code to protect public health.

(6) When FGARs are used at a location with the primary purpose of producing, storing, holding, or packing an agricultural commodity, livestock, poultry, or fish.

(7) For research purposes. Before using a department-registered anticoagulant, a written authorization for research shall be obtained from the director. The director may specify the conditions in the authorization for research under which the research shall be conducted. The director may terminate, amend, or refuse to issue an authorization for research if the director determines any of the following:

(A) The research may involve a hazard to the environment.

(B) The research may be used for purposes unrelated to pesticide data development.

(C) A violation of the authorization for research, prior authorization for research, or Division 6 (commencing with Section 11401) or this division, or a regulation adopted pursuant to either or both of those divisions, has occurred in connection with the research.

§ 6471.5 Sustainable Rodent Management training and plan

For all uses of anticoagulant rodenticides, subsections (a) and (b) apply:

(a) Sustainable Rodent Management Training Course. Commencing one year from the effective date of the regulations, a sustainable rodent management course approved by the Director must be completed each calendar year by every person applying or supervising the application of anticoagulant rodenticides. The course must include Integrated Pest Management and Sustainable Pest Management principles as defined in sections 11401.7 and 11412 of the Food and Agricultural Code respectively, including at a minimum:

(A) Anticoagulant rodenticide non-target effects,
(B) Rodent biology, zoonotic diseases, and identifying target rodents,
(C) Inspection & monitoring,
(F) Sanitation & exclusion,
(E) Anti-rodent landscaping,
(F) Pest management thresholds,
(G) Non-chemical rodent management options,
(H) Rodent management methods & toxicity scales,
(I) Resistance prevention & product rotation,
(J) Safe carcass handling & disposal,
(K) Safe rodenticide storage & disposal site information,
(L) Anticoagulant rodenticides use requirements (CCR Article 5)
(M) Maintaining records

(1) The employer and certified private or commercial applicator as defined in section 6000 must maintain a written record of training course attendance for two years following the date of completion at a central location at the workplace accessible to employees and be provided to the employee, Director, or commissioner upon request. The record must include:

(A) Applicator or handler's name;
(B) License or certificate number if applicable;
(C) Title of the course;
(D) Name of the course provider;
(F) Course completion date;
(G) The applicator or handler's signature confirming attendance.

Other records of course attendance, such as the records required by section 6513, can be used to fulfill this requirement.

(b) Sustainable Rodent Management Plan. Commencing one year from the effective date of the regulations, before using anticoagulant rodenticides, each business location, certified commercial applicator, or operator of the property must have a written general Sustainable Rodent Management Plan and maintain records. This plan can be general (i.e., not required to be site-specific) and must be reviewed each calendar year and updated as necessary.

(A) In instances where anticoagulant rodenticides are not exclusively applied by pest control businesses, the operator of the property is required to develop a general Sustainable Rodent Management Plan and maintain records.

(B) The operator of the property must provide a copy of their general Sustainable Rodent Management Plan and records to any hired business applying anticoagulant rodenticides on their property.

(1) The written general Sustainable Rodent Management Plan must reflect Integrated Pest Management and Sustainable Pest Management as defined in FAC section 11401.7 and section 11412 respectively and must include the following elements at minimum:

(A) Identifying target rodents,
(B) Inspection & monitoring,
(C) Sanitation & exclusion,
(D) Anti-rodent landscaping,
(E) Pest management thresholds,
(F) Non-chemical rodent management options,
(G) Rodent management methods & toxicity scales,
(H) Resistance prevention & product rotation,
(I) Safe carcass handling & disposal,
(J) Safe rodenticide storage & disposal site information,
(K) Maintaining records.

(2) The pest control business, certified commercial applicator or the operator of the property shall maintain records for all locations where anticoagulant rodenticides are applied. These records must list applicator name, location address, dates anticoagulant rodenticides were deployed and collected, number of anticoagulant rodenticide bait boxes deployed, and U.S. Environmental Protection Agency Registration Number and brand name of anticoagulant rodenticide products used. Records shall be maintained at a central location for two years.

(3) The current and prior written general Sustainable Rodent Management Plan must be available for inspection by the Director or commissioner upon request. Prior copies of the plan must be retained for two years.

(4) Pest control businesses and applicators using anticoagulant rodenticides must follow relevant components of the General Rodent Management Plan when making decisions to apply anticoagulant rodenticides.