A California without Rodenticides: Challenges for Commensal Rodent Management in the Future

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ABSTRACT: Rodenticides are an essential tool in the integrated pest management (IPM) of infestations of commensal rodents. With the introduction of Assembly Bill 2422 *California Natural Predator Protection Act*, the State of California is potentially facing a future with serious restrictions on the use of anticoagulant rodenticides to manage commensal rodents in urban areas. Assembly Bill 2422 has been proposed to protect predators from rodenticide poisoning and seeks to significantly restrict the application of first and second generation anticoagulant rodenticides for use in many urban and no-urban areas of California. Exclusion and cultural practices, such as landscape management and sanitation, are important and successful tools for managing rodent populations. However, quick and efficient control of commensal rodent infestations often necessitates the use of rodenticides. While rodenticide is an important tool, exposure of wildlife to anticoagulant rodenticides has been evident for many years in the state of California. When rodents are consumed by predators, second generation anticoagulant rodenticides can be detected as residues in the livers of predators. Many species of animals are documented as having succumbed to rodenticide toxicosis, however the effects of chronic, sub-lethal exposure to predators are not well understood. This paper will discuss the current and proposed changes to rodenticide legislation in California, impacts of the legislation on communities across California, and gaps in research preventing the adoption of evidence-based best management strategies for rodent control. In order to improve the success of commensal rodent control programs in California, effective strategies for rodent management must be developed.

KEY WORDS: anticoagulant, California, commensal rodent, legislation, management, mouse, Norway rat, rodenticides, roof rat

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INTRODUCTION

Commensal rodents (rats and mice) are considered some of the most economically significant pests in the world. Three species of commensal rodents (*Rattus rattus*, *R. norvegicus*, and *Mus musculus*) are known to persist in almost all cities across California. These rodents exist in close proximity to human populations and are regularly found in homes, schools, restaurants and other commercial settings as well as food processing plants and storage areas and warehouses. In the United States, the need for rodent focused integrated pest management (IPM) strategies is increasing (Bell Laboratories Inc. 2016). Studies have shown that climate change has the ability to affect fecundity, litter sizes, and the survivability of adults in some mammalian species (Post et al. 1997, Forchhammer et al. 2001, Walther et al. 2002). It is also thought that climate change is most likely to affect the free living, intermediate, or vector stages of pathogens, such as those that infect commensal rodents (Harvell et al. 2002).

The presence of commensal rodents around homes, food facilities, schools, and agricultural is associated with human risks of exposure to allergens that can trigger asthma, exposure to potentially infectious organisms, i.e. Salmonella, and parasites like tropical rat mites and fleas that may vector other diseases. However, little is known about the ecology of wild commensal rodents and the pathogens they can vector in urban, residential communities. Recent studies of urban commensal rodents in Vancouver and New York City, report the presence of pathogens like *Leptospira* and *Bartonella* in commensal rodent populations (Frye et al. 2015, Himsworth et al. 2015, McVea et al. 2018). The Vancouver Rat study has found evidence of *E. coli* in 62.7% of urban rats tested. Not only did they identify a high prevalence of *E. coli* but they also have detected clustering of specific strains. More research is necessary to better elucidate the ecology and life history of rodent populations living in close proximity to humans.

The goal of commensal rodent management is to reduce the population of rodents quickly so that no further damage or exposure to allergens and pathogens occurs. To achieve this goal rodent management needs to be quick and efficient. In urban and residential infestations, this type of management is often referred to as "population knockdown" and is most commonly achieved using a combination of trapping, habitat manipulation, and rodenticide placement. However, habitat manipulation and trapping can be costly and require additional hours of labor to be effective. Pest control operators are tasked with the control of rat populations through trapping and rodenticide bait use, but sanitation, exclusion and the removal of harborage are the responsibility of the property owners. Property owners, the consumers of pest control services, want an economical service. Additional services such as rodent proofing (pest exclusion), habitat modifications and sanitation must be approved by

Table 1. List of first generation anticoagulant rodenticides (FGAR), second generation anticoagulant rodenticide (SGAR), and acute toxicants that were proposed to be prohibited for use in urban areas in California (with some clauses) in AB-2596 and AB-1687. Only FGARs and SGARs have proposed restrictions in AB 2422.

FGAR	SGAR	Acute toxicants
Warfarin	Brodifacoum	Cholecalciferol
Chlorophacinone	Difenacoum	Bromethalin
Diphacinone	Bromodiolone	
	Difethialone	

property owners and these services are more costly than a pest management strategy based on rodenticide applications. A rodent management program based on rodenticide continues to be the most economically feasible service provided as part of a rodent management program.

The use of rodenticides to control commensal rodents, whether by pest control operators or homeowners, is considered the easiest, cheapest, and quickest method to knock down rodent populations. Second generation anticoagulant rodenticides have been recognized as being very effective because they typically take days before lethal effects occur (Fisher 2005). This means that there is little opportunity for bait shyness to develop. Other reasons for their popularity include, but are not limited to:

- High oral toxicity
- Toxic effects after a single feeding
- High palatability
- Economic
- Ease of use by professional applicator

If the use of rodenticides in Table 1 are further restricted or prohibited, there may be significant implications for Californian residents, particularly those residing in urban, economically-stressed communities.

Current and Proposed Changes to Rodenticide Legislation in California

Pesticides applied in California are applied under some of the strictest regulations in the United States. The Federal Insecticide, Fungicide and Rodenticide Act, passed in 1972, provides for federal regulation of pesticide distribution, sale, and use. In 1996, the legislation was further amended by the Food Quality Protection Act, and again in 2012 by the Pesticide Registration and Improvement Extension Act of 2012. California has a separate registration system that requires additional review of pesticides registered by the US EPA, prior to registration of products in California, thus further limiting or restricting use of federally registered pesticides prior to being offered for sale in the state. In 2008, the US EPA revised a risk mitigation decision for ten rodenticides that led to tightened safety standards that aimed to reduce risks to humans, pets, and nontarget wildlife. In response to evidence of wildlife weakened or killed by second generation anticoagulants, the California Department of Pesticide Regulation further restricted the use and sale of second generation anticoagulants. These restrictions came into effect in July 2014.

These recent risk mitigation measures for anticoagulant rodenticides in California include:

1) The classification of second generation anticoagulants as restricted use so they are only permitted to be applied by professional, licensed applicators;
2) Restriction on sale of second generation anticoagulant rodenticides to the public;
3) Restriction of rodenticide placement to within 50 feet of man-made structures, unless the placement limit on the label extends the bait placement footage (or there is a harborage present);
4) Determination that SGAR's are not labeled for controlling ornamental, plant or turf pests.

Information on applications of anticoagulant rodenticides by professional applicators in urban environments is lacking as this information is protected generally under privacy laws (Rattner et al. 2014). However, in California, pesticide use data (PUR) is reported in aggregate annually by the Department of Pesticide Regulation (CDPR). The restrictions on use and placement of second generation anticoagulants appear to have not significantly reduced the annual total amount of pounds of second generation of active ingredient of second generation anticoagulant rodenticide reported as used for structural pest control in California from 2012 to 2015 (PURs for 2016 and 2017 are not available). At the time of publication several inaccuracies were discovered in the CDPR's PUR database. However, even with these inaccuracies, it does not appear that the amount of applied SGAR has been significantly reduced. While the restrictions imposed in 2014 were intended to restrict the access of the homeowner to these products, the pesticide use data suggests that the restrictions on sites, species and applicator for application of second generation anticoagulant rodenticides, has not reduced the amount of these products placed around structures in California.

In 2016, the Food and Agricultural Code was further amended to restrict the placement of the four second generation anticoagulants in any wildlife habitat area defined as a state park, state wildlife refuge, or state conservancy (CA Food & Ag Codes 12978.7). In February 2016, AB-2596 Pesticides: Use of Anticoagulants was introduced to the California Assembly by Assembly Member Bloom. A year later, AB 1687 replaced AB2596 and was cited as the California Natural Predator Protection Act of 2017. This legislation aimed to prohibit the use of the active ingredients listed in Table 1 in the State of California. AB 1687 was amended to provide exemptions for use in agricultural production and in the event of public

health emergencies. Ab 2422 was subsequently introduced with similar language.

A review of City ordinances in California found that 26 cities enacted ordinances that further restricted the sale and use of rodenticides. Of the 26 local ordinances identified by the authors (Table 2), 15% of the cities are below the State of California's median household income. The remaining 85% of cities range from 3% to 286% above the State of California's median household income. The data indicates that communities with higher median household income are more likely to enact local ordinances discouraging the sale and use or rodenticides. The local communities restricting rodenticide sales may also advocate for changes in rodenticide policy at the state level. In this situation, the communities requesting restrictions on rodenticide use may be communities that are impacted the least by damage and diseases of rodents or have sufficient income to pay for higher cost rodent management services such as trapping and rodent-proofing.

Rodenticide and Wildlife

The potential risk of rodenticides to nontarget animals and the secondary poisoning of predators is well documented in California and anticoagulant rodenticides have been shown to persist in many nontarget species. Anticoagulant rodenticide has been detected in 70% of nontarget wildlife collected by the California's Depart-

Table 2. List of cities (with region and county) that have been identified as having local ordinances pertaining to the use and sale of rodenticides. The cities median household income (US Dollars) has also been listed. The percentage above or below (-) the state median household income as identified from the US Census Bureau is also listed.

Region	City	County	Median Household Income ($)	% above/below
Bay Area	Albany	Alameda	78,769	24
	Berkeley	Alameda	65,283	3
	Emeryville	Alameda	69,329	9
	El Cerrito	Contra Costa	88,380	39
	Richmond	Contra Costa	54,857	-14
	Fairfax	Marin	93,354	47
	San Anselmo	Marin	100,681	58
	San Francisco	San Francisco	78,378	23
	Belmont	San Mateo	106,287	67
	Brisbane	San Mateo	80,233	26
	Foster City	San Mateo	11,4651	80
	Menlo Park	San Mateo	115,650	82
	Portola Valley	San Mateo	182,381	187
	Santa Cruz	Santa Cruz	61,533	-3
Southern California	Agoura Hills	Los Angeles	107,268	69
	Calabasas	Los Angeles	117,176	84
	Hidden Hills	Los Angeles	245,694	286
	Malibu	Los Angeles	130,432	105
	Westlake Village	Los Angeles	115,550	82
	Whittier	Los Angeles	65,583	3
	Camarillo	Ventura	87,120	37
	Moorpark	Ventura	99,353	56
	Ojai	Ventura	60,714	-5
	Simi Valley	Ventura	89,595	41
	Thousand Oaks	Ventura	99,115	56
Other	Davis	Yolo	57,454	-10

ment of Fish and Wildlife (Hosea 2000). High levels of regional detection have also been reported from single species populations in Southern California (Riley et al. 2007), as well as multiple raptor species (Krueger et al 2016). It is possibly that the exposure of wildlife to other pesticides is widespread, however, anticoagulant rodenticides are persistent and have the potential to be detected at higher rates for longer periods of time than less persistent compounds (Thompson et al. 2014). One of the major issues with wildlife exposure to rodenticide is understanding how nontarget prey are being exposed to rodenticides. While some research exists on this issue, it has been identified by several researchers as a major research gap (Hoare and Hare 2006, Elliott et al. 2014, Rattner et al. 2014). Exposure of nontarget species is likely occurring from both legal and illegal applications of anticoagulant rodenticide.

A study of rodenticide placement on residential properties by a southern California mosquito and vector control district concluded that rodenticide was being placed in lieu of habitat modifications such as source reduction and harborage removal by property owners (Krueger et al 2015). Illegal applications of rodenticides in natural resource areas and the pathways of rodenticide to nontarget animals are better understood. For example, it is known that female fisher survival is related to the numbers of marijuana cultivation sites they are likely to encounter (Thompson et al. 2014). If the process by which nontarget animals get exposed to rodenticides was better understood, the potential for applicators to mitigate for the exposure could be implemented so that exposure of nontarget species could be reduced. In urban areas of Southern California, anticoagulant rodenticides not registered in the United Sates (coumatetralyl), as well as active ingredients (difenacoum) that are not readily used (but registered) are being detected in urban coyotes (Quinn, unpublished data). If urban residences are able to purchase rodenticides from outside the United States, or on the internet, restrictions on purchasing these banned products may reduce nontarget exposure.

Perhaps a more significant issue is the ability for researches to understand if there are any population-level effects on nontarget species' populations' exposure to rodenticides. Little is known about the sub-lethal effects of rodenticide exposure and if this translates to significant decreases in the population densities of nontarget species in urban environments. This knowledge gap has also been identified (Kramer et al. 2011, Rattner et al. 2014, Rattner and Mastrota 2018, Shore and Coeurdassier 2018, van den Brink et al. 2018) and solutions to this problem have been suggested (Quinn and Swift 2018).

Managing Rodents without Rodenticide or with Further Rodenticide Restrictions

The management of rodents has been recognized as a "wicked problem" (Parsons et al. 2017). This term is used to describe problems that are often unique and have no definite solution. Among other things, wicked problems are considered to be a symptom of other problems (Head 2008). Additionally, pest control operators recognize that every rodent management job is unique, as infestation presents unique challenges for control. Currently there is a lack of cost-effective alternatives to the use of rodenticide. Rodent proofing, harborage removal, and trapping programs are more costly than rodenticide placement.

Integrated pest management is an important process in the management of urban commensal rodents. It incorporates multiple management options to create cost-effective and efficacious management. It has been suggested that a holistic IPM approach that includes all action levels (habitat modification, sanitation, non-toxic management etc.) is probably unattainable (Stenberg 2017). Stenberg (2017) has also suggested that the timeline for achieving the holistic IPM rodent management program is unknown, and likely far in the future. In the agricultural and food industry, the fact that growers are constrained by economic factors and other business realities has been linked to the inability to really have a choice in what pest management option they participate in (Hokkanen 2015). It is likely that this lack of choice, due to economic constraints and other business pressure, may also be experienced by private citizens and professional applicators who manage commensal rodents in urban settings.

While the importance of monitoring rodents has been identified (Langton et al. 2001), few tools are available to pest management professionals to determine the population densities of the rodents they are managing. Better understanding of rodent population dynamics could lead to mitigations on rodenticide placement that could lead to a reduction in nontarget exposure to anticoagulant rodenticide.

The direct impact of area-wide sanitation programs on managing rodents is not well understood in urban environments (Williams et al. 2015). Although frequently recognized as an important element in the success of rodent management programs (Corrigan 2001, Bonwitt et al. 2017), there appears to be little research on the effects of area-wide rodent sanitation programs in urban, residential neighborhoods. Cities can invest considerable resources into sanitation practices such as the city of Chicago's free garbage cart initiative, whereby the city provides free garbage carts in an effort to containerize their street waste. However, research has shown that properties with drain blockages had higher levels of mice and rats inside properties, and higher levels of rats outside (Langton et al. 2001). The Centers for Disease Control also places heavy emphasis on sanitation practices for Integrated Pest Management (Centers for Disease Control and Prevention 2006), although publically funded rodent abatement programs that could implement area-wide sanitation initiatives are in decline in most major urban centers. In 2018, The County of Los Angeles voted to disband the rodent abatement program, and other jurisdictions such as Orange County, only provide service to individual property owners, not area-wide campaigns. While sanitation is an important part of an integrated management program, its adoption in urban environments is hard to attain due to dense aggregations of homes and the lack of government agencies providing targeted, area-wide residential rodent abatement. It is important to identify ways in which pest management professionals can encourage their customers to adopt sanitation practices as a way to permanently reduce rodent harborage and food sources.

The lack of cost-effective alternatives to rodenticide use, as well as property owner's resistance to make structural changes to their properties, combined with the pressure on the applicator to rapidly remediate the rodent infestation proves challenging for all involved in rodent management. Exclusion programs, while proven effective at excluding commensal rodents from the inside of structures, are often cost-prohibitive and do not impact the population of rodents surviving outside the property. Without scientifically-proven management options that impact commensal rodent populations both inside and outside properties, it is difficult to provide evidence-based solutions to homeowners and pest control operators.

Modifications have been made to anticoagulant rodenticide application procedures in different parts of the world. In Canada, as of January 1, 2013, select active ingredients' application (brodifacoum and difethialone) are now restricted to indoor applications only. It is difficult to know if such restrictions would have any impact on nontarget exposure. House mice are known to make less frequent outdoor excursions (compared to rats) so their roles in vectoring anticoagulant rodenticide are probably limited at best. The fate of rodents exposed to anticoagulant rodenticides indoors is unknown. Since they frequent both indoors and outdoors, it is likely that they could still be vectors of anticoagulant rodenticide to nontarget species despite these restrictions. It is unclear whether changing from the traditional continuous "preventative" baiting strategies to evidence-driven rodenticide applications will have any impact on the rate of nontarget species exposures (Elliott et al. 2016). Others have shown that the way anticoagulant rodenticides are used can reduce the risks of secondary poisoning of nontargets (Shore et al. 2006, Jacquot et al. 2013) albeit outside of urban areas.

Development of best management practices may lead to a reduction of nontarget species exposure to anticoagulant rodenticides in agricultural areas (Tosh et al. 2011). Adherence to best management practices for rodenticide placement by a government rat control program in Southern California has been shown to reduce rodenticide placement (OCVCD 2010, Krueger et al. 2015). In this example, the Orange County Mosquito and Vector Control District developed a best management policy for rat control (OCVCD 2010) that outlines specific situations where rodenticide bait may be placed only if one or more of the following conditions exist:

1) Pre-construction habitat removal (e.g., Caltrans work, development projects, etc.)
2) Residential hoarding cases, pre-clean-up
3) Large-scale landscape projects
4) Extreme circumstances observed by a public health professional
5) Confirmed presence of a rodent-borne disease

Adhering to this rodenticide placement policy led to a 9,000 pound per year reduction in the annual amount of rodenticide placed by OCMVCD staff from 2012 to 2017. The effects of these best management practices on rodent densities and the exposure of nontarget species to rodenticide are unknown.

The modification of rodenticide label language, without the elimination of the rodenticide product, has led to success in the past for eliminating deaths of certain species by primary and secondary exposure to anticoagulant rodenticide (McMillin and Finlayson 2010).

Impacts to California and Californians

Californians will be impacted by continued restrictions on rodenticide use in California. Impacts of increased restrictions on rodenticide include: 1) increased expense to property owners for rodent control, 2) increased time from infestation discovery to control, 3) increased need for government rodent abatement programs to conduct area-wide control programs, 4) lack of options for control of rodents on large residential and commercial properties.

Research has suggested that human exposure to rats is common in areas with high population density, such as inner-city economically-challenged neighborhoods (Davis 1953, Childs et al. 1998, Langton et al. 2001, Battersby et al. 2002, Reis et al. 2008, Walsh 2014, Ayral et al. 2015). The effects of rodent management (with or without rodenticide) on the reduction of zoonoses are not well understood. Studies have found that lethal, urban rat management is associated with an increased chance that surviving rats would carry *Leptospira interrogans.* Lee at al. (2018) suggests that human interventions have the potential to increase the prevalence of zoonotic pathogens within rat populations. It is difficult to know if there is a threshold level or population density at which the risk of exposure to rodent-borne zoonoses or allergens is significant. It is very likely that high densities of commensal rodents and people in urban areas can provide opportunities for increased contact between humans and rodents. This could increase the risk of rodent-borne pathogen transmission. However, the prevalence and variation of pathogens between urban and rural rodents is not consistent. Research has shown a lower prevalence of pathogens in urban rodents compared to rural rodents (Inoue et al. 2008, Hsieh et al. 2010), while other studies have noted the opposite (Halliday et al. 2015). A study from an urban center in Southern California shows that the population of fleas on rodents and backyard wildlife has increased significantly since 1967 (Krueger et al. 2016). A study of rat ectoparasites in New York City found the number of fleas on Norway rats to be higher than previously recorded (Frye et al. 2015).

There are many unknowns when predicting the implications to Californians from further rodenticide restrictions. A partial list of these unknowns include: 1) the psychosocial effect of interactions between humans and rats in areas with high rodent populations (German and Latkin 2016); 2) effects of rodent damage on infrastructure such as flood control channels, airports and so on; 3) additional economic costs associated with rodent control that will be passed along to consumers and property owners; and 4) options and effectiveness of area-wide sanitation and harborage removal considering local jurisdictions are reducing publically funded rodent control and abatement programs.

CONCLUSION

The need to identify best management practices for urban commensal rodent management practices is long overdue. Although there continues to be more and more

restrictions for rodenticide applications, the use of rodenticides in California continues to increase. However, without evidence-driven research, or industry-driven best management practices that promote effective rodent management strategies that are both practical and economical, the use of rodenticides will remain a popular choice among pest management professionals for urban-based commensal rodent management programs in California.

In California, there is also a need for increased enforcement of rodenticide applications. There is no mechanism in existence in the state to enforce pesticide applications by homeowners. It is known that unregistered rodenticide products are making their way into the California market. Inspections of professionals applying rodenticides are also limited.

The research gaps on the pathways of anticoagulant exposure of nontarget species are rather large in urban systems. It is unknown if legal rodenticide applications have the ability to even have population-level impacts on nontarget species.

The prohibition of rodenticide in the State of California is not necessary and could have serious repercussions for Californians. However, research is needed to increase the efficacy of rodent management, while limiting potential environmental impacts.

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