Assessing Some Potential Environmental Impacts from Agricultural Anticoagulant Uses

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ABSTRACT: This study was designed to give us a better understanding of the relationship between agricultural anticoagulant rodenticide uses and related occurrence of these materials in raptor tissues. The project utilized data from raptor carcasses collected, both in urban San Diego County and in largely agricultural Fresno, Kern, and Madera Counties, as part of the public health surveillance programs of the County Veterinarian(s) and/or Departments of Environmental Health. Most raptors contained detectible levels of second-generation anticoagulants, which are registered only for commensal rodent control in and around structures; very few contained first-generation anticoagulants, which are the only anticoagulants registered for use in agricultural production in California. This suggests that secondary hazards to raptors and other wildlife from anticoagulants stems primarily from retail sale of commensal rodent baits, particularly in residential areas, and not from anticoagulant rodenticide uses in agricultural regions.

KEY WORDS: agriculture, anticoagulants, California, non-target hazard, potential environmental impact, raptor exposure, rodent control, rodenticides, secondary hazard, urban wildlife

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INTRODUCTION

Anticoagulant rodenticides are the most common baits used in agricultural and domestic areas to manage rodent pests (Litovitz et al. 1998, Maroni et al. 2000). They are generally classified as first or second-generation anticoagulants based on their toxicity relative to the amount of bait a rodent must eat. The first-generation anticoagulants such as chlorophacinone, diphacinone, and warfarin usually require multiple feedings over several days to be lethal. The second-generation anticoagulants, such as bromadiolone, brodifacoum, and difethialone, are more persistent in animal tissues and in many situations can be lethal from only one feeding. In California, only first-generation anticoagulants are registered for agricultural uses. Almost 1 million pounds of formulated chlorophacinone and diphacinone baits are sold annually by California Agricultural Commissioners (CDPR 2007, CDPR 2009) to control agricultural ground squirrels, voles, and some other rodent pests. Additional first-generation anticoagulant bait is sold by commercial outlets for agricultural protection and some commensal use, but use data are not readily available. A much larger quantity of second-generation anticoagulants is sold to homeowners, structural pest control operators, and others for control of commensal rodents (Norway and roof rats, *Rattus norvegicus* and *R. rattus*, and house mice, *Mus musculus*) in and around structures (CDPR 2007). All of these uses have the potential of creating primary and secondary poisoning risks to pets, domestic animals, and wildlife including birds of prey.

Various predators and scavengers in California have tested positive for second-generation anticoagulants, while a much lower number of first-generation exposures have been detected (Redig and Arent 2008). However, without information on anticoagulant use patterns in the areas where these animals were collected, we cannot paint a complete picture of the exposure risks and impacts of anticoagulant use in agricultural production areas. Yet, in the absence of such data, persons concerned about pesticide residues in wildlife often assume that anticoagulant rodenticides used in agriculture cause widespread risk to non-target wildlife, particularly predators and scavengers of rodents.

BACKGROUND

There are two main classes of anticoagulants, first-generation and second-generation. These first-generation chemicals are the only anticoagulants registered for use in agricultural operations in California and consist of Chlorophacinone, Diphacinone, and Warfarin (CDPR, 2009). Even though Coumachlor is no longer registered for use in California, the chemical was tested for as a control for the labs purpose. Second-generation anticoagulants are mostly used in and around homes, consisting of Brodifacoum, Bromadiolone, and Difethialone (CDPR, 2009). The chemicals listed above are the most common rodenticide used in agricultural and domestic areas to deal with rodent pest problems (Litovitz et al., 1998; Maroni et al., 2000; Morrissey et al., 1995; Murphy, 2002; O'Connor and Eason, 2000; Stone et al., 1999; Towns and Broome, 2003). Little is known about the fate of these anticoagulants in the food system, but these toxicants are commonly found through sophisticated chemical analysis and can be detect at extremely low levels.

Recent publications have indicated that various predators and scavengers in California test positive for second-generation anticoagulants (Redig and Arent, 2008), while a much lower number of first-generation exposures were detected. While a significant number of raptors and other carnivores have been tested and proved to contain low quantities of anticoagulants in tissue samples (particularly in liver specimen) the route of exposure, rate of introduction and overall impact of these levels in individuals and populations is basically unknown. This compounded with the fact that no published data exists that indicates the short-term or long-term risks associated with low-level detections of anticoagulants in these non-target animals.

Without information on anticoagulant use patterns in the areas where these animals were collected, we cannot paint a picture of the exposure risks and impacts of anticoagulants utilized in agricultural production areas. While deficient in this data, many regulators including the EPA assume these levels have some negative impact on non-target animals and conclude that all anticoagulants pose an undue secondary hazard to predators. Since this deduction has been accepted, secondary poisoning of raptors by anticoagulants has been identified as a significant concern and, therefore all should be restricted in their use and application. As a result of this, under the EPA's Reregistration Eligibility Decision (RED proposal): Rodenticide Cluster which states that "all pesticides sold or distributed in the United States must be registered by EPA, based on scientific studies showing that they can be used without posing unreasonable risks to people or the environment" (US EPA, 2000). This would make all anticoagulants, including chlorophacinone and diphacinone, Restricted Use Materials changing the dynamic of ground squirrel and other rodent control programs in agricultural areas. Growers and other private applicators would have to obtain an applicators license or certificate to implement any of the current control and application protocols.

OBJECTIVES

This study was undertaken to help understand the extent of raptor exposure to anticoagulants, particularly in relation to anticoagulant uses for protecting agriculture. Data were utilized from raptors that were collected as part of the public health surveillance programs of the County Veterinarian(s) and/or Departments of Environmental Health, as well as by submission from other organizations such as California Fish and Game and the United States Department of Agriculture – Wildlife Services. None of the raptors analyzed were initially suspected of having anticoagulant exposure or poisoning.

The ultimate goal was to determine possible raptor exposure to first and second-generation anticoagulants by evaluating the relationship between the use of these materials in agricultural versus urban settings and the presence/absence of residues in raptor tissues collected from each region.

A second objective was to determine if wild rodents captured as part of a county Hantavirus surveillance program would show any signs of exposure to anticoagulants. While anticoagulant residues have been found in many carnivores, few reported data exist demonstrating the occurrence of residues in rodents found in areas where anticoagulant materials are used. The data that are available originates from rodents targeted by specific baiting programs. It is likely that some of these rodents survive baiting by consuming a sub lethal dose. In turn, these survivors could have some anticoagulant residue remaining in their tissues, providing a possible exposure route for raptors and carnivores.

METHODS

San Diego County has a robust public health surveillance program that includes testing of raptors and other birds found dead throughout the County. This provided a large number of raptors for potential analysis. Since San Diego County is fairly urban, we wanted to compare data from these birds with birds from more rural and agricultural counties. The top 5 agricultural counties with the highest quantity of total agricultural pesticide use in California in 2007 were Fresno, Kern, Tulare, San Joaquin, and Madera (Brooks 2008). Of these, Fresno, Kern, and Tulare Counties were selected because we have worked on extensive ground squirrel problems in these areas for the past 30 years. We sought to compare anticoagulant residue data from raptors collected in these counties to those from the more urban San Diego County, where we assume most rodenticides applied are used by homeowners for the control of commensal rodents.

Anticoagulant Use

In order to better understand the information gathered, we estimated how much anticoagulant was used in each county. Table 1 provides the total amount of active ingredient of each of the 7 anticoagulants sold by all entities in counties comprising our study sites, in 2007. We assume that materials purchased would be used in the county of purchase within a 1-year period.

For example, 2.92 lbs of diphacinone (as active ingredient) reported for San Diego County would, when formulated at 0.005% a.i. in rodent baits, represents a total of 58,400 lbs of ready-to-use bait.

Table 1. Pounds of anticoagulants (active ingredient) use for each included county as reported by rodenticide manufactures or through the required applicator pesticide use reports (CDPR 2007).

Active Ingredient (lbs)	San Diego County	Fresno County	Kern County	Tulare County
Chlorophacinone	0.0795	0.3927	0.8932	0.3235
Diphacinone	3.2941	1.8605	2.3378	3.523
Warfarin	0.1056	0.0903	0.0376	0.0024
Brodifacoum	0.0998	0.0647	0.045	0.0269
Bromadiolone	3.1664	0.8124	0.296	0.1553
Difethialone	0.2825	0.0378	0.0197	0.0159

Raptor Tissue Collection

San Diego County has a robust public health surveillance program to detect the presence of West Nile virus in wild birds, and dead birds are routinely submitted to the County Veterinarian for testing. We partnered with the County Veterinarian to have the liver tissue removed and sent to UC Davis to test for the presence of anticoagulants. The Central Valley does not have a systematic raptor collection program. The birds that are submitted are generally obtained as a result of chance collection by members of the general public. Liver tissues from this region were provided by the Pesticide Investigations Unit of the California Department of Fish and Game. Our project did not capture or handle raptors, nor did it cause any birds to be captured.

Residue Analysis

Corresponding liver tissue samples from each animal were frozen and shipped to the California Animal Health & Food Safety Laboratory System at the University of California, Davis for anticoagulant residue analysis. If detected, the quantity in parts per million (ppm) was determined. When possible, the location where each bird specimen was found was entered into a GIS layer.

RESULTS

Of 176 raptors available to us, 80 had no information on the specific site of collection, so we did not subject these to residue analysis. The remaining 96 were necropsied and liver tissues were sent for testing. Of these, 53 came from San Diego County and 43 from the three Central Valley counties.

The tested group consisted of 10 common raptor species: American kestrel, Falco sparverius (4); barn owl, Tyto alba (21); burrowing owl, Athene cunicularia (1); Cooper's hawk, Accipiter cooperii (12); great horned owl, Bubo virginianus (7); northern harrier, Circus cyaneus (1); red-tailed hawk, Buteo jamaicensis (22); red-shoulder hawk, B. lineatus (15); sharp shinned hawk, A. striatus (9); and Swainson's hawk, B. swainsoni (1).

Of the 53 birds tested from San Diego County, 92% (n = 49) had anticoagulant detections. Some birds had multiple anticoagulant detections but all were of second-generation materials. Thirty-four of the 43 birds (69%) tested from the Central Valley counties also had anticoagulant detections. Detections included residues at levels above the limit of detection and residues in trace amounts (Tables 2, 3).

Table 2. The reportable limit in parts per million for each anticoagulant included in this study.

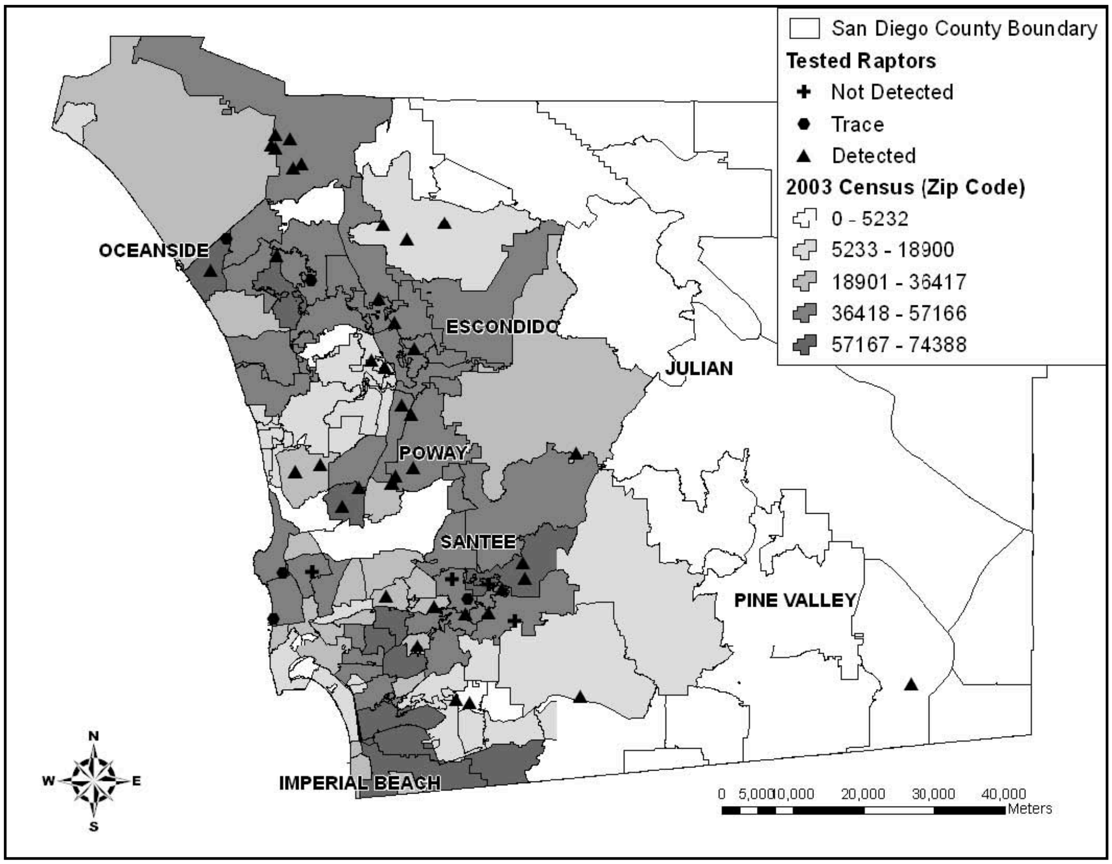
	Anticoagulant	Reportable Limit (ppm)
FirstGeneration	Chlorophacinone	0.25
	Coumachlor	0.05
	Diphacinone	0.25
	Warfarin	0.05
SecondGeneration	Brodifacoum	0.01
	Bromadiolone	0.05
	Difethialone	0.25

For birds collected in San Diego Co., we plotted the pickup location (Figure 1). We define "rural birds" as those recovered within zip codes containing low human populations (≥36,417 individuals), and "urban birds" were those occurring in highly populated zip codes (≤36,418 individuals). Most birds came from "urban" areas, likely because more people were present and freshly dead birds were more likely to be seen and submitted. We see a trend of birds with detectable levels of anticoagulants occurring in the most highly populated areas, although this could be from a greater detection probability. No birds from San Diego Co., either "urban" or "rural", contained any first-generation anticoagulants.

Table 3. Number of detections by chemical and location.

		San Diego County		Central Valley	
		Detectable Level	Trace Amount	Detectable Level	Trace Amount
FirstGeneration	Chlorophacinone	0	0	0	2
	Coumachlor	0	0	0	0
	Diphacinone	0	0	0	0
	Warfarin	0	0	0	0
SecondGeneration	Brodifacoum	44	5	5	1
	Bromadiolone	12	10	23	8
	Difethialone	5	3	0	0

Figure 1. Locations of tested raptor carcasses within San Diego County in reference to human population.



Of the 43 raptors submitted from the Central Valley, there were 34 individuals with anticoagulant residues. Only 2 birds contained residues of a first-generation anticoagulant (chlorophacinone), and in both cases it was present only in trace amounts. The other residues found were all second-generation anticoagulants.

DISCUSSION

Figure 2 shows the results of raptor collection site in relation to human population and agricultural commodity areas. It appears that raptors with detectable second-generation anticoagulants were more common in areas with higher population densities, although this could be the result of increased detection probability. This finding would make sense, because exposure to second-generation anticoagulants is likely originating from commensal rodent pest control programs in and around buildings.

Due to the nature of the sample carcass collection in the Central Valley, we did not have specific collection location information for most of the birds. In these cases, the location was coded as the county where the bird was collected. When evaluating the potential anticoagulant exposure of raptors in the selected Central Valley counties (see Figure 3), it appears that agricultural areas are much more dominant than urban areas. Because of the heavy agricultural production in these counties, we would expect more detection of first-generation anticoagulants in raptors collected in these counties if exposure simply relates to amount of material used. However, this is not supported by the data collected in this study. This finding could be from exposure rates but also could result for the shorter half-life of first generation anticoagulants in poisoned rodents.

RODENTS

Methods

As part of the Hantavirus surveillance program, San Diego County's Department of Environmental Services set trap lines to capture wild rodents. The lines were set along fence lines radiating from urban areas into adjacent non-developed environments. A total of 131 rodent carcasses were obtained over several months, and all pickup locations were entered into a GIS layer. Due to limited resources, only 26 were selected for analysis to cover a variety of habitats. Necropsies were performed and liver samples were sent to the UC Davis laboratory for testing.

Figure 2. Locations of raptor carcasses in relation to human population and agricultural commodities of San Diego County.

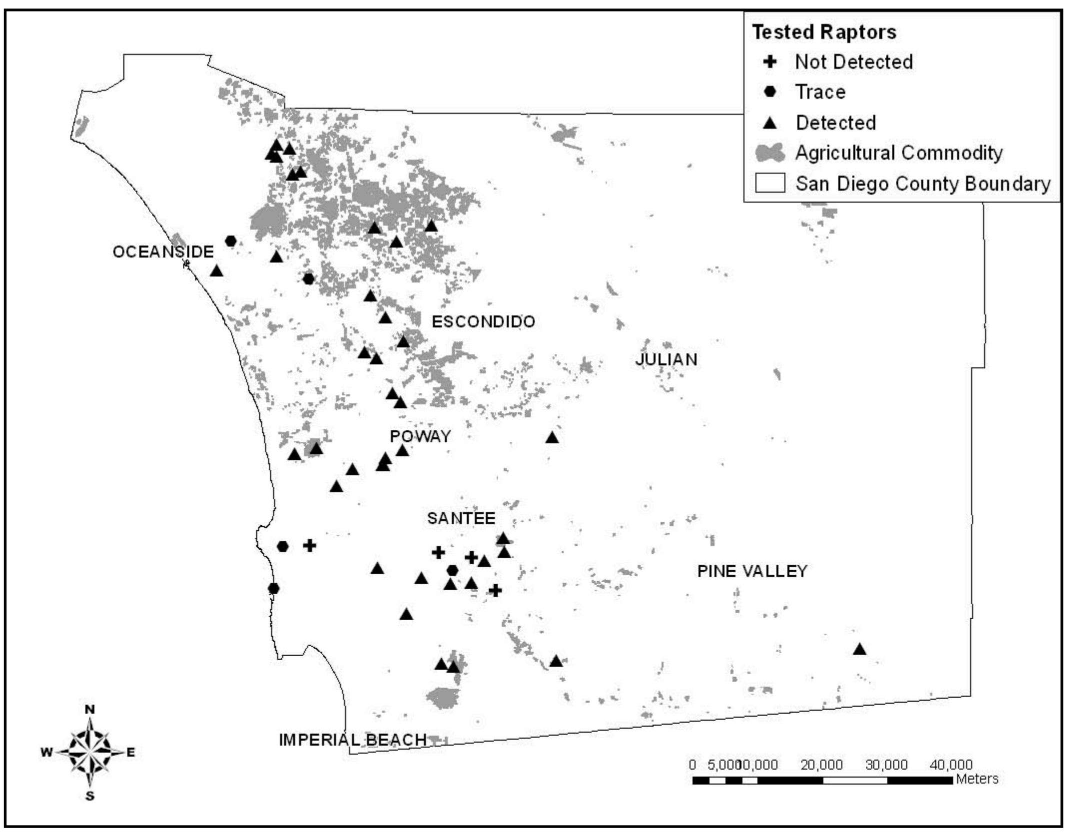
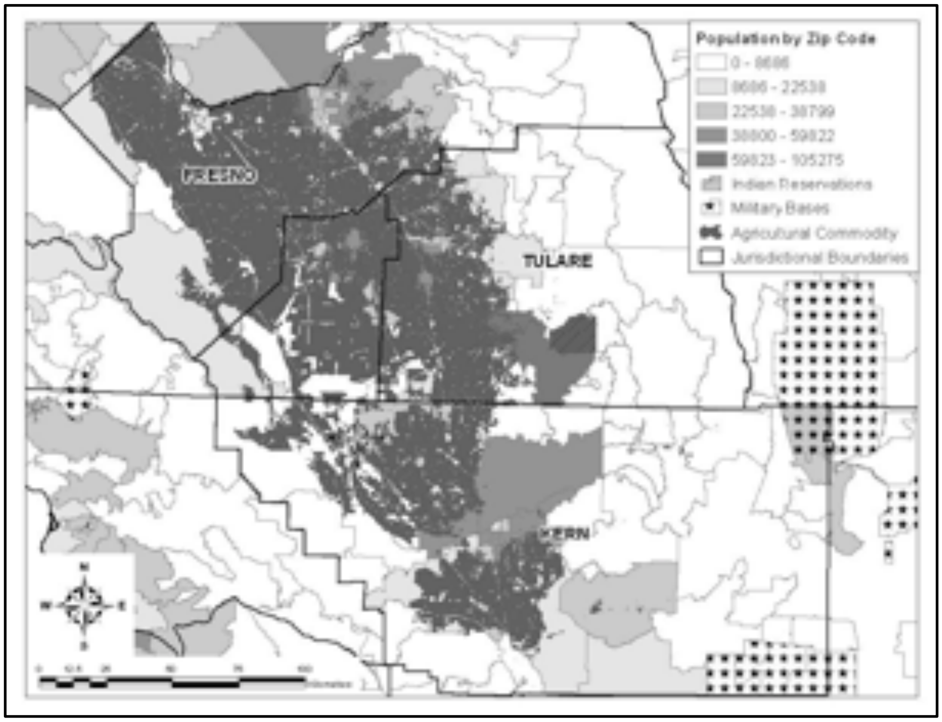


Figure 3. Human population and agricultural commodities in the Central Valley.



The tested specimens included: deer mouse, Peromyscus maniculatus (5); Baja mouse, P. raterculus (3); California mouse, P. californicus (6); and cactus mouse, P. eremicus (12).

Of the liver tissues submitted, 5 had trace detections of anticoagulants, only 1 of which was a first-generation anticoagulant. Unfortunately, we were unable to process a large enough sample of carcasses to show any real trends, but we were able to determine that measurable amounts of anticoagulants were present in “free-ranging” small rodents. Presumably, these rodents were exposed to anticoagulants from a rodent control program, although none of these species are target animals of the second-generation anticoagulants. Since all of the detections were in trace amounts, the data should only be used to guide future research.

CONCLUSION

With over a million pounds of anticoagulant baits sold annually in California for all target species, these are the most common rodenticides used in agricultural and domestic areas, and this creates potential primary and secondary risks to pets, domestic animals, and wildlife, including birds of prey. Anticoagulant exposure appears to be relatively common, with the predominant anticoagulants detected in this study being the second-generation materials. In this study, 1 in every 1.17 raptors tested containing detectible levels of second-generation anticoagulants. Only 1 in 48 tested positive for first-generation materials. This difference could be from the higher persistence of second-generation materials in exposed animal tissue. Raptors with second-generation anticoagulants in their tissues were more commonly found in urban areas where commensal rodent control is presumably more common; however, this could be the result of more people to detect carcasses in the urban areas. In addition, it could be that the higher number of second-generation detections is from the greater half-life of these materials in carcasses of exposed animals, or because the detection levels for second-generation materials are generally much lower than for first-generation anticoagulants. Raptors were not commonly found in agricultural areas, but those that were tested did not usually contain any first-generation anticoagulant in their tissue.

While second-generation anticoagulant residues were found in many raptors we tested, there was no information available to us on the impact of these residues on the birds. No birds tested displayed symptoms of anticoagulant poisoning, so these levels were not indicative of anticoagulant poisoning. However, these residues could have had sub lethal impacts on the birds or contributed to mortality from other causes. Clearly, more study is needed, particularly on the impacts of specific residue levels on raptors and other non-target wildlife.

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