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Poster Presentation

Ecological Risk Assessment for Use of Agricultural Rodenticides in California

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ABSTRACT: The California Department of Food and Agriculture holds registrations for four grain-based anticoagulant rodenticides used in agricultural areas in California to control the California ground squirrel. These rodenticides contain either chlorophacinone or diphacinone as the active ingredient at 0.005% or 0.01% by weight, and are applied by either broadcast or spot baiting techniques. Using residue data from recent field studies, an ecological risk assessment was performed for non-target species potentially receiving secondary exposure through consumption of squirrel carcasses. The species of concern included five birds (American kestrel, burrowing owl, common raven, golden eagle, red-tailed hawk) and one highly sensitive mammal, the coyote. Risks to nontarget species were estimated using a risk quotient (RQ) approach, with RQ values calculated using species-specific daily exposure estimates and levels of concern derived from subchronic toxicity studies. Exposure estimates for the birds of concern ranged from 0.05-0.21 mg/kg bw/day for chlorophacinone and from 0.04-0.16 mg/kg bw/day for diphacinone. For chlorophacinone uses, RQs for birds ranged from 0.172-0.724. RQ values for diphacinone were 16-18 times lower. Based on the methodology used and using EPA risk criteria, the RQ data indicate *de minimus* risks for all avian receptors of concern. Exposure estimates for adult and subadult coyotes spanned a range from 0.009-0.028 mg a.i./kg bw/day depending on the use pattern. RQs for mortality and blood coagulation were generally near, or slightly above, a value of 1.0 for all of the use patterns evaluated; however, because of the conservative exposure assumptions and other factors, it is highly unlikely that ecologically significant effects on coyotes does or could occur due to use of CDFA's anticoagulant baits. Wildlife incidence data and population modeling studies corroborate this. Based on the weight of evidence, it is concluded that use of CDFA's rodenticides for spot and broadcast baiting will not cause "unreasonable adverse effects" on coyote populations or those of other predators/scavengers that feed on squirrel carcasses.

KEY WORDS: anticoagulants, California ground squirrel, chlorophacinone, diphacinone, nontarget hazard, predators, risk assessment, rodenticides, scavengers, *Spermophilus beecheyi*

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INTRODUCTION

This ecological risk assessment (Silberhorn *et al.* 2003) covers four grain-based anticoagulant rodenticides registered by the California Department of Food and Agriculture (CDFA) for use in agricultural areas in California. The products are registered under Section 24(c) of FIFRA for Special Local Needs (SLN) within the State of California. Two of the rodent baits evaluated use chlorophacinone as the active ingredients at either 0.005% or 0.01% by weight. The other two products contain diphacinone as the active ingredient at the same concentrations. The composition of these four products is almost identical except for the active ingredient and its percentage in the product. The primary species targeted for control by all four of these rodenticides is the California ground squirrel (*Spermophilus beecheyi*), although other ground squirrels, deer mice, and meadow mice (voles) are also major target species. Depending on the specific bait and target species, application methods include: 1) broadcast baiting, 2) spot (hand broadcast/scatter/bait spoon) baiting, 3) hand or placement baiting, and 4) use in bait stations. On a statewide basis, annual agricultural use of all of CDFA's anticoagulant rodenticides is limited to less than 300,000 total acres, or approximately 1% of the 27.7 million total agricultural acreage in the state.

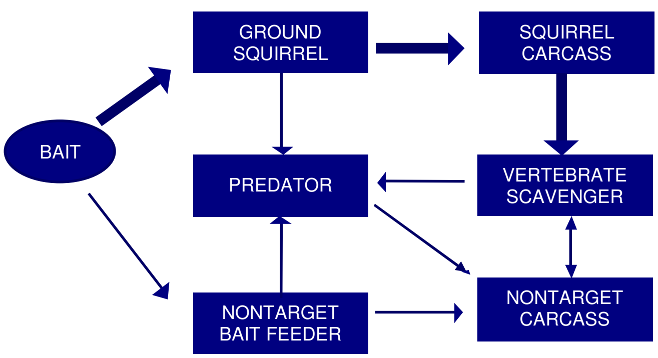
When the Rodenticide Cluster Reregistration Eligibility Decision (RED) document was issued in 1998, the U.S. Environmental Protection Agency determined that above ground field-bait uses for rodenticides containing more than 0.005% of either chlorophacinone or diphacinone may have the potential to cause unreasonable secondary poisonings to avian and mammalian consumers as defined under the Federal Insecticide, Fungicide and Rodenticide Act (FIFRA). This ecological risk assessment was conducted with the primary objective of determining the potential risks of the primary uses of CDFA's four anticoagulant rodent baits to birds and nontarget mammals through secondary exposure.

METHODS

Problem Formulation / Conceptual Model

The conceptual model for the risk assessment included evaluation of exposure to predators and scavengers through consumption of ground squirrels carcasses containing residues of chlorophacinone or diphacinone due to ingestion of CDFA bait (Figure 1). This exposure route was selected because the California ground squirrel is the primary target species for the four products evaluated and there is adequate carcass residue data for this species. In addition, the available data indicate that this species has residues that are generally equal to or greater than those in the other target species. The nontarget species of concern selected for risk assessment included five birds (American kestrel, *Falco sparverius*; burrowing owl, *Speotyto cunicularia*; common raven, *Corvus corax*; golden eagle, *Aquila chrysaetos*; red-tailed hawk, *Buteo jamaicensis*) and one sensitive mammal, the coyote, *Canis latrans*. These receptors were selected based primarily on their occurrence at field sites in California where CDFA's rodent baits are used and the availability of relevant toxicity and/or secondary hazard data for these, or closely related, species.

Figure 1. Conceptual model for residue exposure.



Exposure Analysis / Squirrel Carcass Residues

The spatial and temporal aspects of exposure to rodenticide residues are limited in California following spot and broadcast applications of CDFA's anticoagulant baits. Exposures from these uses typically occur in the late spring and early summer durations when control operations take place. Exposures are confined to the immediate areas where control operations occur, which are typically in rangelands, orchards/groves, rights-of-ways, and non-crop borders. Because individual squirrel carcasses are quickly desiccated and/or consumed by insects under field conditions, exposure is basically limited to the period of time over which squirrels die, which is generally less than 2 weeks. Exposure is further limited due to the fact that the vast majority of ground squirrels die below ground in their burrows and thus are not available to most scavengers. In addition, ground squirrels are typically wary of predators and usually remain near their burrows, thus they are unlikely to die very far from where they live.

Analyses of squirrel carcasses recovered in field efficacy studies indicate that residues of chlorophacinone and diphacinone, as measured by mean whole body concentrations, range from about 0.23 to 1.4 mg/kg for different combinations of bait strengths and application methods. Residues expressed as skinned carcass concentrations were slightly higher (Table 1). Across all of the bait strength and treatment combinations, there was no general trend for one of the active ingredients to consistently produce higher residues than the other. However, when using 0.01% a.i. baits (either active ingredient), ground squirrel carcass residues were generally higher, or much higher after spot baiting than those occurring after broadcast applications. This was true regardless of the number and frequency of spot baiting applications. In contrast, when using 0.005% a.i. baits, residues from spot baiting were generally similar to, or even less than, those from broadcast baiting when the treatment conditions were the same. Residues of chlorophacinone and diphacinone in squirrel carcasses increased with increased under different methods of application and increased concentration in baits.

Risk Characterization

Risks to avian and mammalian nontarget species through secondary exposure were estimated using a risk quotient approach based on several conservative assumptions. Quantitative risk estimates were made for the two primary uses of CDFA's anticoagulant baits: mechanical broadcast of 0.01% a.i. baits, and spot (hand scatter) baiting of 0.005% a.i. baits. The risk quotient (RQ) values were calculated using species-specific daily exposure estimates and levels of concern (LOC) derived from toxicity studies with extended exposure durations (5 days for bird studies and 14 days for mammalian studies) (Tables 2 and 4). Exposures estimates were conservatively calculated using skinned carcass concentrations, rather than the lower whole body concentrations, and also assumed consumption of carcasses (residues) over an extended period. Risks were characterized based on the total weight of evidence taking into account RQ values, data from secondary hazard studies (when available), incidence data, and other species-specific information that may affect exposure and risk.

Table 1. Residues of anticoagulants in ground squirrel carcasses*.

Active Ingredient	Bait Application Method	0.005% A.I.		0.01% A.I.	
		N	mg/kg ± SD	N	mg/kg ± SD
Chlorophacinone	Spot	21	0.45 ± 0.28	16	1.96 ± 1.11
	Broadcast	12	0.44 ± 0.50	14	0.83 ± 0.65
Diphacinone	Spot	8	0.35 ± 0.27	16	1.11 ± 0.89
	Broadcast	16	0.48 ± 0.29	34	0.63 ± 0.45

*values are concentration means from skinned carcasses

Table 2. Derivation of avian Level of Concern (LOC).

A.I.	5-day Dietary LC_{50} (ppm)	Food Ingestion Rate	LC_{50} Daily Dose (mg/kg/d)	Geometric Mean (mg/kg/d)	Avian LOC* (mg/kg/d)
Chlorophacinone	56-bobwhite	0.09	5.04	7.21	0.29
	172-mallard	0.06	10.32		
Diphacinone	2057-bobwhite	0.09	185.13	100.35	4.01
	906-mallard	0.06	54.36		

*derived using assessment factor of 25 per ECOFRAM (1999)

RESULTS and DISCUSSION

Avian Risk Characterization

Daily exposure dose estimates for the five bird species of concern ranged from 0.05 to 0.21 mg/kg bw/day for chlorophacinone and from 0.04 to 0.16 mg/kg bw/day for, diphacinone. Exposure doses were highest for broadcast baiting of 0.01% a.i. baits. For chlorophacinone uses RQs ranged from 0.172 to 0.724. RQ values for diphacinone were approximately 16 to 18 times lower (Table 3). The estimated risks for the species with the highest predicted exposures (burrowing owl) and those for the species with the lowest estimated exposures (red-tailed hawk) differed only by a factor of slightly greater than 2 for the same use pattern. Based on the methodology used, an RQ value of 1.0 indicates that one would expect a mortality of 0.1% (or 1 in 1,000) in the typical population of this avian species under the exposure conditions specified, assuming this species is more sensitive to the toxicity of the active ingredient than 95% of all avian species (i.e., 95th percentile sensitivity). An RQ value greater than 1.0 indicates a greater risk, while a value of less than 1.0 indicates a lesser risk, of mortality at the 0.1% level. Per EPA guidance, the 0.1% mortality level (RQ = 1.0) for birds represents a "presumption of no risk" from a regulatory perspective with no required mitigation.

Table 3. Risk quotients for avian receptors.

Species	Chlorophacinone		Diphacinone	
	Broadcast 0.01%	Spot 0.005%	Broadcast 0.01%	Spot 0.005%
American kestrel	0.448	0.241	0.025	0.015
Burrowing owl	0.724	0.379	0.040	0.022
Common raven	0.448	0.241	0.025	0.015
Golden eagle	0.345	0.172	0.020	0.010
Red-tailed hawk	0.310	0.172	0.017	0.010

Taking into account EPA risk criteria, the RQ data indicate that potential risks to all five of the avian receptors of concern for all of the CDFA use patterns evaluated are de minimus and below a level that would require a restricted use classification or other mitigation measures. The quantitative risk estimates are consistent with state incident data and the results of secondary toxicity studies, which indicate that avian species are not significantly at risk due to chlorophacinone or diphacinone exposures (EPA 2002, Hosea 2000). It is concluded that individual birds that feed exclusively on ground squirrels or their carcasses for extended periods may show increased clotting times and other sublethal effects related to blood coagulation; however, these effects are unlikely to be life threatening except in very rare cases. Based on the types and magnitude of predicted effects, no population level changes are expected for avian species in California.

Mammalian Risk Characterization

Because of the high sensitivity of canid species to anticoagulants, the mammalian risk assessment focused on potential risks to the coyote, a common predator/ scavenger in many areas of California. Daily exposure estimates for adult and subadult coyotes spanned a range from 0.009 to 0.028 mg a.i./kg bw/day depending on the rodenticide/application method/age group combination evaluated. RQs were developed for both mortality and effects on blood coagulation (i.e., clotting time). RQ values for both endpoints were generally near, or above, a value of one for all active ingredient/bait/application method combinations evaluated. Because subadults are smaller and receive higher exposures than adults (assuming both eat one carcass per day), RQs were higher for this age group by a factor of about 1.6. Chlorophacinone RQs were larger than those for diphacinone by a factor of 1.6 to 2.6 depending on the bait and application method (Table 5). The difference in RQs for the two active ingredients was largely reflective of the 2-fold difference in the level of concern (LOC) values derived for the two active ingredients. Because the mammalian LOCs were derived from no observed effect levels (NOELs), one would expect to see no mortality or effects on clotting time in coyotes when corresponding RQs are at or below a value of 1.0; therefore, an RQ of 1.0 or less would also indicate a "presumption of no risk" from a regulatory perspective.

Table 4. Derivation of mammalian Level of Concern (LOC).

A.I.	Endpoint	Rat Subchronic NOEL (mg/kg bw/d)	Assessment Factor	Mammalian LOC (mg/kg bw/d)
Chlorophacinone	Mortality	0.040	5	0.008
	Coagulation	ND		ND
Diphacinone	Mortality	0.085	5	0.017
	Coagulation	0.040		0.008

Table 5. Risk quotients for mammals (coyote).

Age Group	Endpoint	Chlorophacinone		Diphacinone	
		Broadcast 0.01%	Spot 0.005%	Broadcast 0.01%	Spot 0.005%
Adult	Mortality	2.25	1.13	0.88	0.71
	Coagulation	ND	ND	1.88	1.50
Sub-adult	Mortality	3.50	1.75	1.35	1.12
	Coagulation	ND	ND	2.88	2.38

Because most of the RQs were greater than 1.0, it cannot be concluded outright that no adverse effects would be expected on coyotes due to use of CDFA's anticoagulant baits. In particular, one cannot completely rule out the possibility of sublethal effects related to blood clotting or the possibility of death in hypersensitive individuals. However, for several reasons it is highly unlikely that significant mortality of coyotes does or would occur due to use of CDFA's anticoagulant baits. Toxicity data from 14-day subchronic studies were used to derive the mammalian LOCs for chlorophacinone and diphacinone. Exposures for this length of time in the field are unlikely, as most squirrels die over a 5- to 8-day period in the field after exposure to baits and carcasses are typically desiccated or consumed by insects within 2 days. As was done in the avian risk assessment, it would be more appropriate to use toxicity data from shorter studies; however, these data were not available, so the analysis is considered to be highly conservative.

There are several additional reasons why the daily exposures for coyotes are likely to be less than were estimated in the assessment. Coyotes prefer to catch and feed on fresh-killed rodents and rabbits, as well as birds and their eggs. The chase and attack is part of their normal feeding behavior. Captive coyotes will sometimes ignore squirrel carcasses, even in the absence of food, until they get very hungry (Marsh and Howard 1986). In the wild, there are many alternate foods available including mice, voles, rats, and rabbits. This makes it very unlikely that coyotes would feed exclusively on ground squirrel carcasses or live squirrels for 14 consecutive days, as has been assumed. Furthermore, coyotes typically roam and feed over an area of several square miles, while ground squirrel control operations are normally confined to small, localized areas where squirrel densities are high enough to justify the cost and labor of control efforts. This further limits that possibility that anticoagulant exposures for coyotes would be at the levels assumed in this risk assessment.

To date, there have been only 3 recorded incidents in California in which residues of chlorophacinone and diphacinone have been found in dead coyotes. In one of the 3 dead coyotes, liver residues of brodifacoum were also found. Two of the dead coyotes were found in Los Angeles County, which is not an area that is highly agricultural and thus probably cannot be attributed to use of CDFA's baits if, in fact, mortality was related to the anticoagulant residues that were found. Field research and population models indicate that coyote populations are very resilient and able to withstand an annual control level of 50 to 70% through compensatory reproduction (Connolly and Longhurst 1975, Sterling *et al.* 1983). In recent decades, coyotes have even extended their range despite the use of intensive long-term control measures in many locations. The loss of a few individuals through use of anticoagulants, should it occur, would not jeopardize California coyote populations. In fact, as a result of the many recent label and use pattern changes that have reduced potential exposure, fewer effects on nontarget wildlife are expected in the future.

CONCLUSIONS / SUMMARY

Based on the weight of evidence, including conservative exposure and quantitative risk analyses, it is concluded that use of CDFA's anticoagulant rodenticides for spot and broadcast baiting will not cause "unreasonable adverse effects" on populations of birds or nontarget mammals that feed on the target species of these products. The risk assessment also indicates that broadcast applications of CDFA's baits containing 0.01% a.i. will not result in significantly higher risks than those due to use of 0.005% a.i. baits and that these risks are acceptable under FIFRA when considering the risk and benefits of these products.

Use of CDFA's rodent baits is not likely to cause in excess of 0.1% mortality in populations of any of the avian species of concern that were evaluated. Individual birds that feed exclusively on ground squirrels or their carcasses for extended periods (e.g., 5 days or more) may show increased clotting times and other sublethal effects related to blood coagulation; however, these effects are unlikely to be life threatening except in very rare cases. Based on the types and magnitude of predicted effects, no population level changes would be expected for the birds of concern in California.

Similar conclusions are drawn for nontarget mammals. Based on highly conservative analyses, it is believed that use of CDFA's baits could potentially result in the isolated deaths of a few sensitive coyotes or other predator/scavengers, but this mortality will have no significant overall adverse effect on wildlife populations. Despite the agricultural use of CDFA's anticoagulant rodent baits for many years, widespread and significant adverse effects on wildlife populations in California have not been documented in the past and are not expected in the future.

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