LMAC Final Report
Anticoagulant Rodenticide Surveillance in Game Animals in California
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Project Summary
Anticoagulant rodenticides (ARs) are used to control rodents around homes, buildings, and in agriculture. They have been found widely in predatory and scavenging wildlife as a result of secondary exposure and less commonly in herbivores and omnivores from primary exposure. While predators and scavengers have been monitored for AR exposure, no monitoring data had been collected for game animals in California. In particular, very little information is available about AR residues in edible muscle tissue of game animals.

Game animals may be exposed to ARs through direct consumption of bait, ingestion of contaminated food or vegetation, or consumption of contaminated prey items. Deer would most likely to be exposed directly through consumption of bait as was observed in New York (Stone et al 1999) or through intentional poisoning (Gabriel et al 2013). Wild pigs and bear, being opportunistic omnivores, could be exposed through additional routes, including consumption of contaminated rodents or small invertebrates (Gabriel unpublished data; Booth et al. 2003) and consumption of refuse.

ARs fall into two categories based on toxicological characteristics and use patterns. Older, first-generation ARs (FGARs) were developed and made available in the 1950s. Products with these ingredients are less toxic than second-generation anticoagulants (SGARs) and require consecutive days of intake to achieve a lethal dose. They also have a lower ability to accumulate in biological tissue and clear more rapidly, with liver half-lives (depending on the particular compound) of 2 to 26 days (Erickson and Urban 2004; Fisher et al. 2003). FGARs are used both for commensal and field rodent control.

Carcasses of three kinds of game animals; black bear, wild pigs, and deer; were collected opportunistically for this study. Causes of death were mainly depredation, vehicular trauma, or hunter harvest. Sampling kits were provided CDFW scientific and enforcement staff in Regions 1, 2, and 4, and USDA Wildlife Services staff. Tissue samples (liver, muscle, and blood) were extracted in the field and sent with accompanying collection data into the Wildlife Investigations Laboratory. Samples were kept frozen until they could be submitted to the California Animal Health and Food

Safety Laboratory (CAHFS) in Davis for AR analysis. Four SGAR and four FGAR compounds were analyzed (Table 1). Unforeseen workload issues at CAHFS delayed analysis of samples, causing some of the expenditures to take place after the predicted end of the project.

Findings

Sampling kits were returned for a total of 17 black bears, 37 deer, and 123 pigs (Table 2). Not all sampling kits were returned with all requested tissues. Sampling kits containing liver samples were analyzed.

Black bear:

Sampling kits for 17 black bears from eight counties were returned. Of these, 12 kits contained liver samples (Table 3). Eight of these bears were killed for depredation, three were hit by vehicles and one appeared to die of illness. Ten of twelve liver samples were positive for ARs, with brodifacoum being detected most frequently (42% of total). Of the positive liver samples, the average number of ARs detected per individual was 1.6. For positive liver samples, eight kits containing muscle samples were tested. All were negative. Serum samples were tested for five of the kits with positive liver samples. A trace of brodifacoum was found in one serum sample.

Deer:

Sampling kits for 37 deer from 11 counties were returned, all containing liver samples. For the 37 deer, 22 died from physical trauma (typically vehicular), five had unknown cause of death, five were hunter harvested, and five died from illness. None of the liver samples tested positive for ARs. Corresponding serum samples were tested for 16 deer and were all negative for ARs.

Wild pigs:

Sampling kits for 123 wild pigs were returned with 120 containing liver samples. Samples were submitted from 10 counties but 84% came from Mariposa and San Luis Obispo Counties (Table 4). Cause of death for all pigs was depredation. Ten liver samples were positive for ARs (8.3% of total) with the compound most frequently detected being chlorophacinone (5% of total) (Table 5). Of the positive liver samples, the average number of ARs detected per individual was 1.1. For the ten positive liver samples, corresponding muscle samples were available for nine of them. Four of the nine muscle samples also tested positive for ARs. Chlorophacinone was the most likely to be found in muscle tissue, with 50% of muscle tissue samples with corresponding chlorophacinone-containing liver samples also testing positive. Chlorophacinone is commonly used to control field rodents on agricultural crops and rangeland.

Preliminary Conclusions

- The highest prevalence of AR exposure was found in bears, with 83% of tested livers positive. Prevalence of exposure in wild pigs was 8.3%. None of the deer livers tested positive for ARs.

- Bear were most likely to be exposed to brodifacoum, a SGAR used primarily in and around residences. Pigs were most likely to be exposed to chlorophacinone, used in agriculture.
- More than half of pigs with AR residues in their liver also had AR residues in their muscle tissue.

Future Work
It would be useful to monitor ARs in edible tissues of wild pigs throughout the state to determine public health implications of consumption of harvested wild pigs.

Data
All data collected in this study will be available to LMAC.

Budget Summary
A total of $27,294.90 was spent on laboratory analysis at CAHFS (Table 6). This was roughly half of the proposed budget of $60,750. The proposed budget was for 405 samples and allowed for half of all muscle samples to be analyzed. However, fewer AR detections in the liver samples meant that fewer muscle samples were analyzed. In addition, CDFW and USDA field staff submitted less than the estimated number of samples. The estimated cost per sample was $150 and the actual cost per sample averaged $121.31. The difference in sample cost is due to fewer detections that required quantification.

References:

Booth, L.H., P. Fisher, V. Heppelthwaite, and C.T. Eason. 2003. Toxicity and residues of brodifacoum in snails and earthworms. DOC Science Internal Series 143, Published by the New Zealand Department of Conservation.

Erickson, W. and D. Urban. 2004. Potential Risks of Nine Rodenticides to Birds and Nontarget Mammals: a Comparative Approach. USEPA Office of Pesticide Programs. Pages 21-29.

Fisher, P., C. O'Connor, G. Wright, and C.T. Easton. 2003. Persistence of four anticoagulant rodenticides in livers of laboratory rats. DOC Science Internal Series 139. New Zealand Department of Conservation.

Gabriel, M.W., G.Wengert, J.M. Higley, S. Krogan, et al. 2013. Silent forests? Rodenticides on illegal marijuana crops harm wildlife. The Wildlife Professional Spring 2013.

Stone, W.B., Okoniewski, J.C. Stedelin, J.R. 1999. Poisoning of wildlife with anticoagulant rodenticides in New York. Journal of Wildlife Disease 35:187-193.

Table 1. Compounds Analyzed in Anticoagulant Rodenticide Scan with Reporting Limits

SGAR/FGAR	Compound	Reporting Limit (ppm), Muscle and Liver	Reporting Limit (ppm), Serum
FGAR	Chlorophacinone	0.020	0.001
	Coumachlor[1]	0.020	0.001
	Diphacinone	0.020	0.001
	Warfarin	0.020	0.001
SGAR	Brodifacoum	0.020	0.001
	Bromadiolone	0.020	0.001
	Difenacoum	0.020	0.001
	Difethialone	0.020	0.001

[1]Coumachlor is not legally used in the U.S.

Table 2. Summary of Anticoagulant Rodenticide Detections from Bear, Deer, and Pig

	Bear			Pig		Deer	
	Liver	**Muscle**	**Serum**	**Liver**	**Muscle**	**Liver**	**Serum**
Brodifacoum	8/12	0/7	1/4	4/120	1/9	0/37	0/16
Bromadiolone	2/12	0/7	0/4	0/120	0/9	0/37	0/16
Difethialone	1/12	0/7	0/4	0/120	0/9	0/37	0/16
Difenacoum	1/12	0/7	0/4	0/120	0/9	0/37	0/16
Chlorophacinone	3/12	0/7	0/4	6/120	3/9	0/37	0/16
Diphacinone	1/12	0/7	0/4	1/120	0/9	0/37	0/16
Warfarin	0/12	0/7	0/4	0/120	0/9	0/37	0/16

Table 3. Black Bear Anticoagulant Rodenticide Results

Date	County	COD	Liver AR (ppm)	Muscle AR	Serum AR
7/12/13	El Dorado	Illness	BROD 0.046 BROM 0.67	ND	NT
8/8/13	Madera	Hit by car	BROD trace	ND	NT
9/13/13	Tehama	Hit by car	ND	NT	NT
12/3/13	Mendocino	Hit by car	ND	NT	NT
7/8/14	Kern	Depredation	CHLOR trace	ND	ND
7/9/14	Tuolumne	Depredation	BROD trace	ND	NT
7/22/14	Tuolumne	Depredation	CHLOR trace	ND	NT
7/30/14	SLO	Depredation	BROD trace, CHLOR trace	ND	NT
10/7/14	Kern	Depredation	BROD trace, DIPH 1.1	ND	trace
10/8/14	Kern	Depredation	BROD 0.61	NT	ND
1/5/15	Placer	Depredation	BROD 1.5 BROM 1.5 DIFETH 5.7 DIFEN trace	NT	ND
9/17/15	Madera	Hit by car	BROD trace	ND	ND

Table 4. Wild Pig Anticoagulant Rodenticide Detections by County

County	Number of Samples	Percent Positive
Humboldt	1	0
Kern	2	0
Mariposa	42	5
Mendocino	2	0
Nevada	4	0
Placer	2	0
San Luis Obispo	61	13
Sonoma	2	0
Sutter	2	0
Tuolumne	2	0

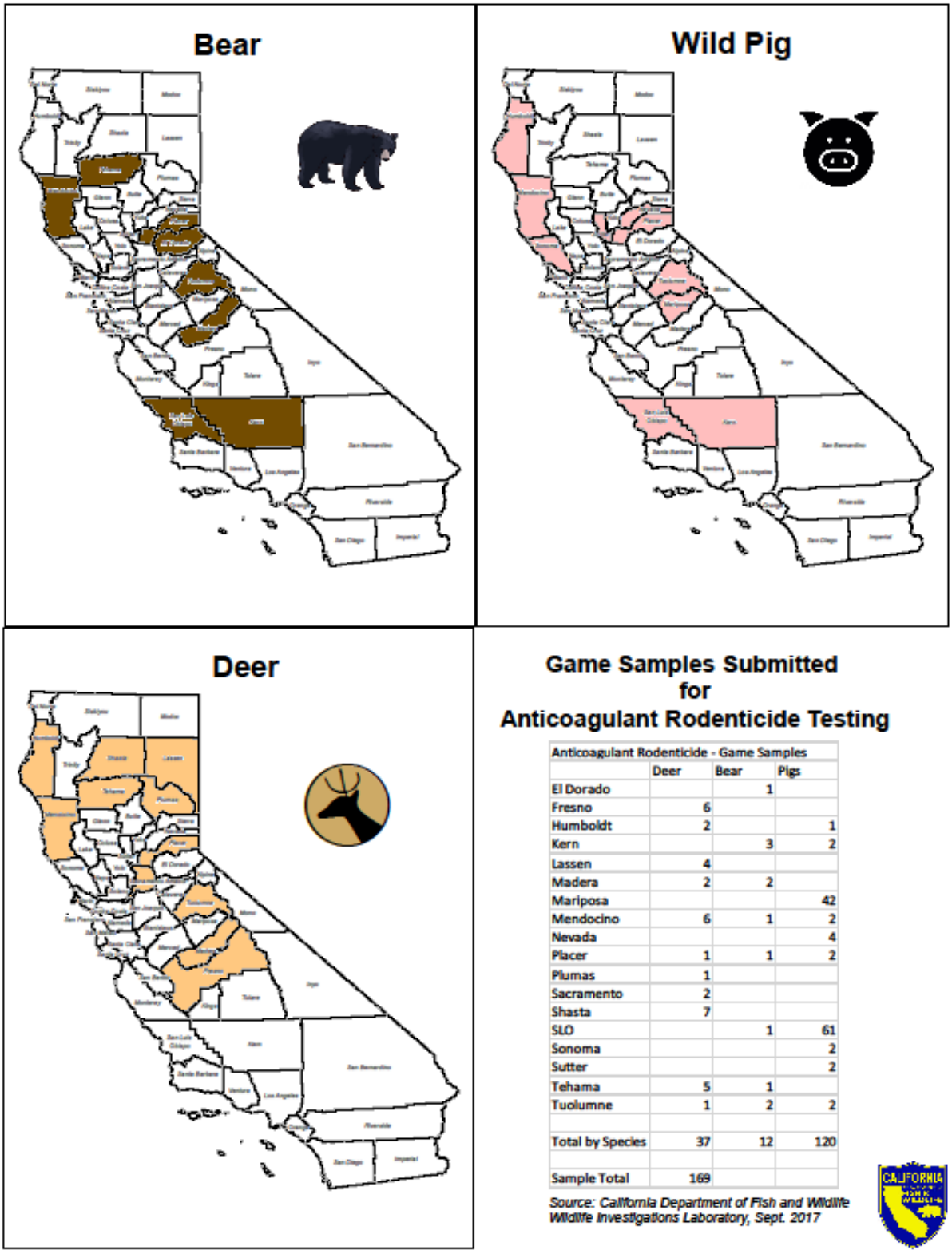
Table 5. Wild Pig Anticoagulant Rodenticide Results

Sample no	Date	County	Liver AR	Muscle AR
ID0022238	7/9/14	SLO	CHLOR 0.32	ND
ID0022242	7/11/14	SLO	CHLOR 0.077	CHLOR trace
ID0022243	7/11/14	SLO	CHLOR trace	CHLOR trace
ID0022244	7/11/14	SLO	CHLOR trace	ND
ID0022245	7/11/14	SLO	CHLOR 0.15	CHLOR trace
ID0019560	7/17/14	SLO	BROD trace	ND
ID0022246	7/30/14	SLO	BROD trace DIPH 0.069	BROD trace
ID0022416	8/21/14	SLO	CHLOR trace	ND
ID0022423	9/17/14	Mariposa	BROD trace	NT
ID00024290	4/1/15	Mariposa	BROD trace	ND

Table 6. Budget Summary

Month/Year	Amount Spent	Number of Samples
5/7/14	2877.90	30
8/4/14	1406.30	15
8/4/15	583.09	6
2/1/16	13247.61	106
2/7/17	9180.00	68
Total	27,294.90	225

Figure 1. Counties where Samples were Collected



Game Samples Submitted for Anticoagulant Rodenticide Testing

Anticoagulant Rodenticide - Game Samples			
	Deer	Bear	Pigs
El Dorado		1	
Fresno	6		
Humboldt	2		1
Kern		3	2
Lassen	4		
Madera	2	2	
Mariposa			42
Mendocino	6	1	2
Nevada			4
Placer	1	1	2
Plumas	1		
Sacramento	2		
Shasta	7		
SLO		1	61
Sonoma			2
Sutter			2
Tehama	5	1	
Tuolumne	1	2	2
Total by Species	37	12	120
Sample Total	169		

Source: California Department of Fish and Wildlife Wildlife Investigations Laboratory, Sept. 2017