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

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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

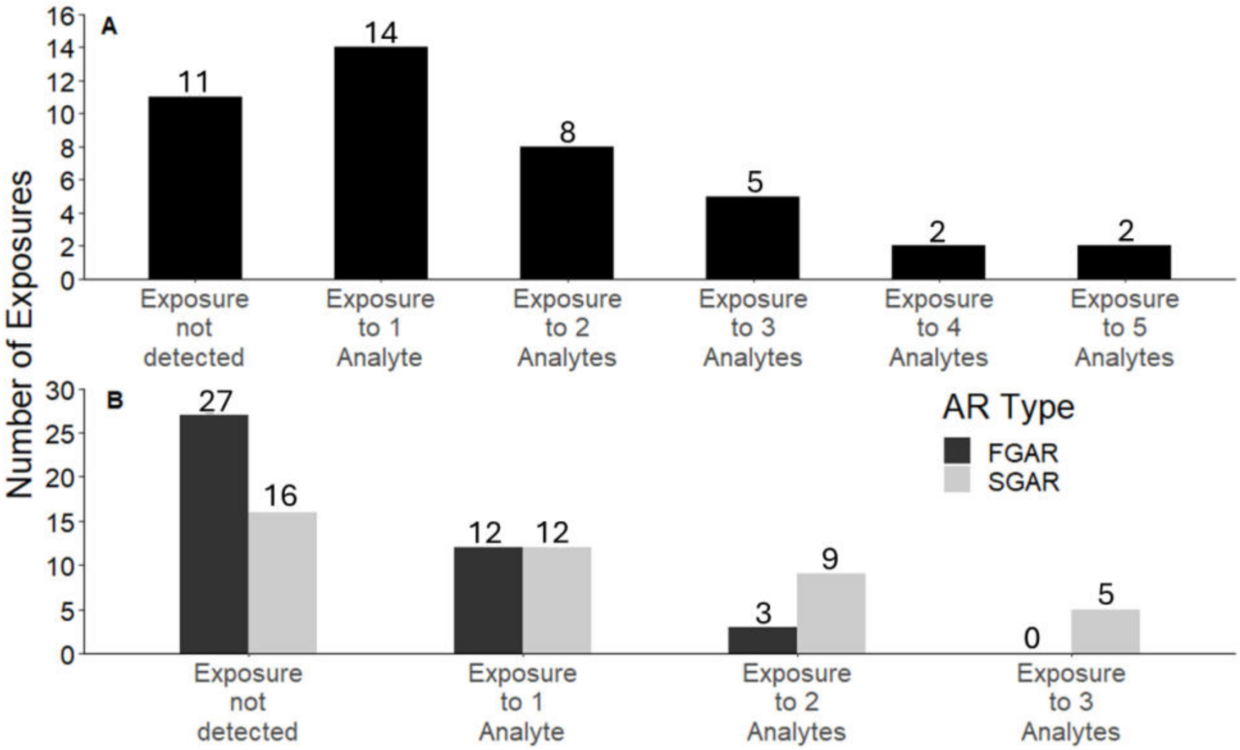


Figure 1. **(A)** Number of anticoagulant rodenticide residues detected in the livers of 31 wild birds in 2023. **(B)** Number of anticoagulant residues detected in the livers of 31 wild birds separated by SGAR and FGAR.

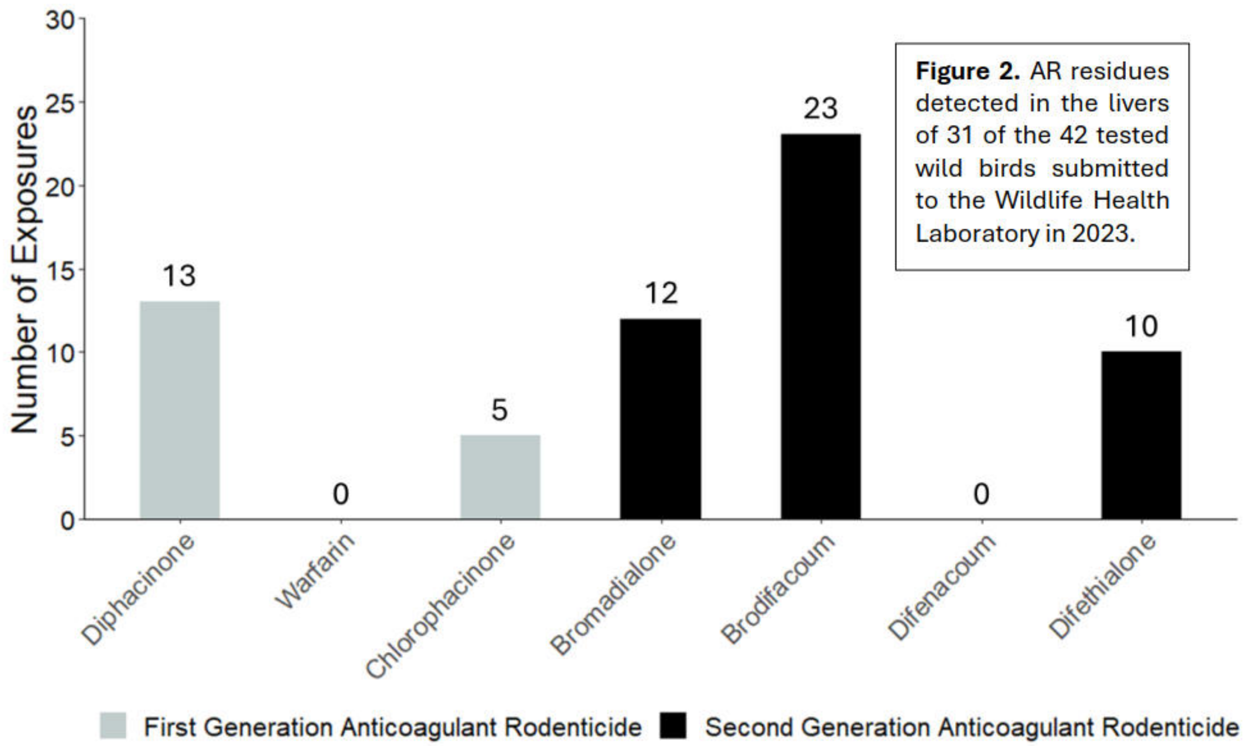


Figure 2. AR residues detected in the livers of 31 of the 42 tested wild birds submitted to the Wildlife Health Laboratory in 2023.

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

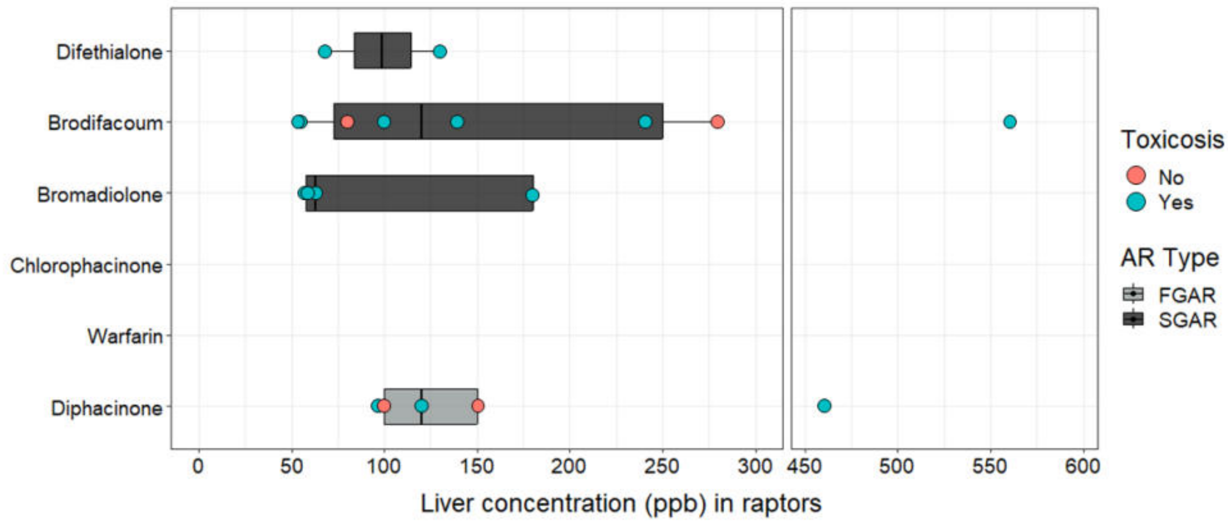


Figure 3. Boxplot to visualize AR concentrations (ppb) quantitated in the livers of 20 of the 31 wild birds that tested positive for AR exposure in 2023. Colored marks indicate concentrations whether or not toxicosis was confirmed. Note that toxicosis can occur at varying levels of AR concentrations 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.

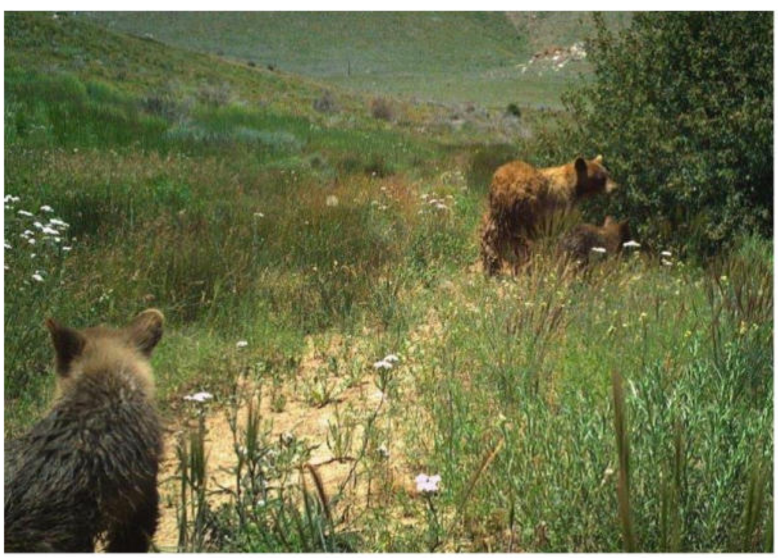
Black-tailed Deer at Upper Butte Wildlife Area. Photo: Ryan Bourbour, CDFW

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

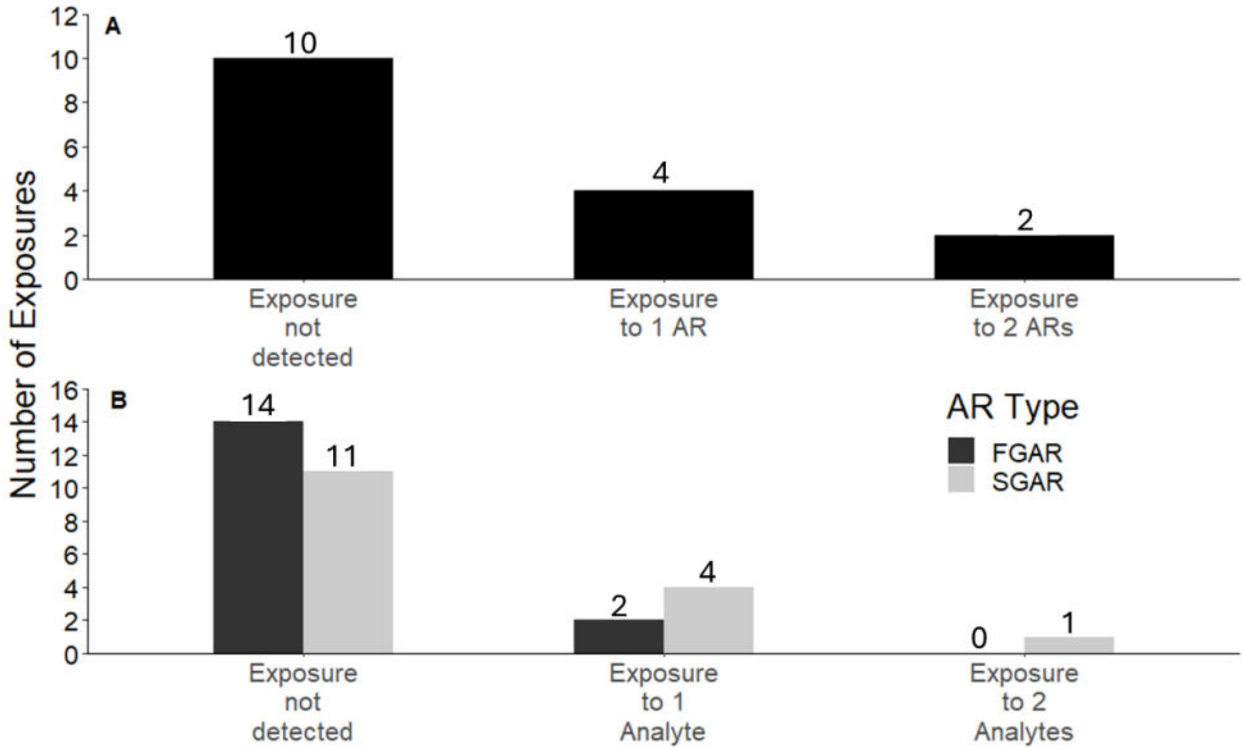


Figure 4. **(A)** Number of AR residues detected in the livers of 16 wild big game mammals in 2023. **(B)** Number of AR residues detected in the livers of 16 wild big game mammals separated by FGAR and SGAR in 2023. After postmortem examination, livers were submitted for toxicology testing to the California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

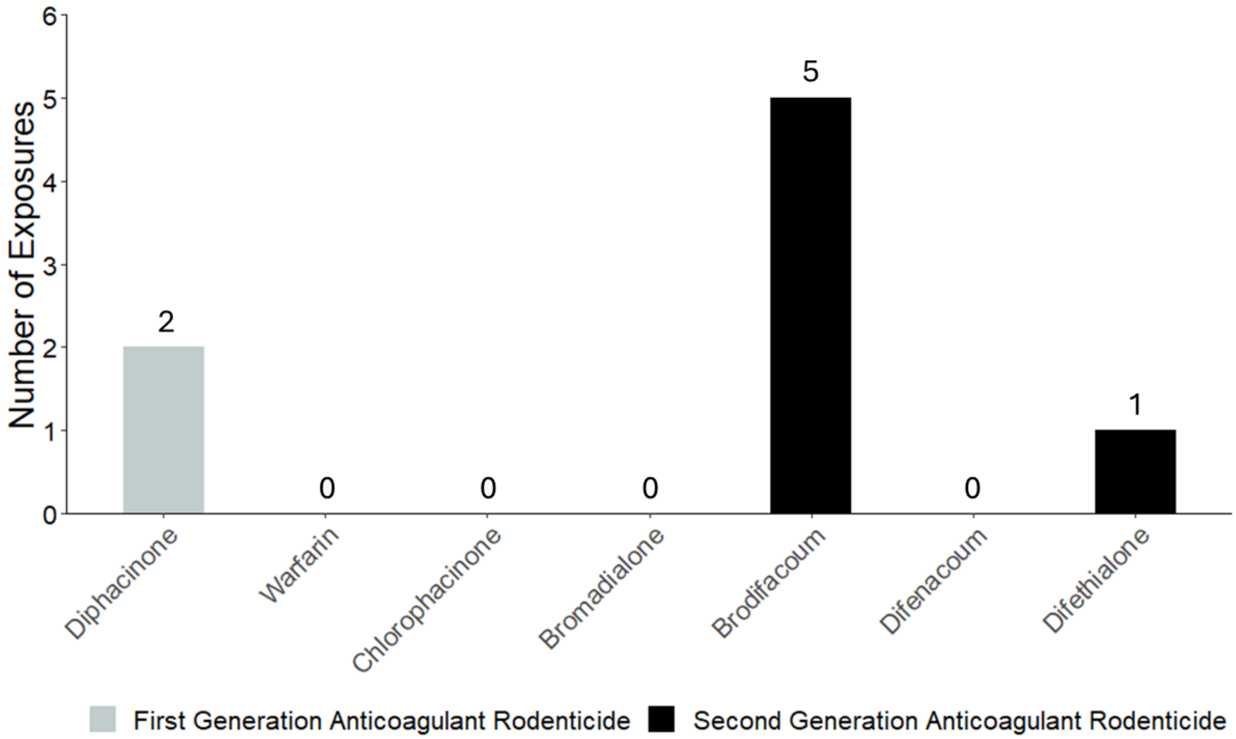


Figure 5: Anticoagulant rodenticide residues detected in the livers of 6 of the 16 tested wild big game mammals submitted to the Wildlife Health Laboratory in 2023.

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.

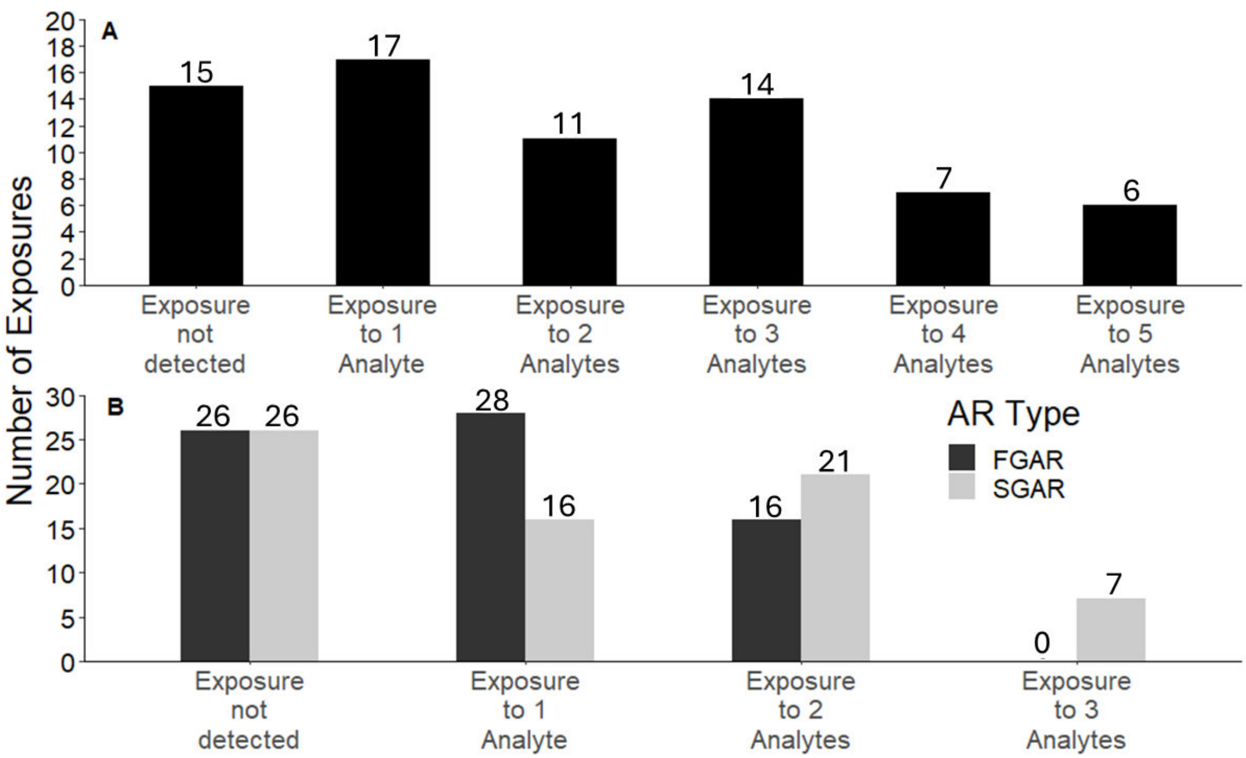


Figure 9. **(A)** Number of anticoagulant rodenticide residues detected in the livers of 70 wild non-game mammals in 2023. **(B)** Number of anticoagulant residues detected in the livers of 70 wild non-game mammals separated by first (FGAR) and second (SGAR) generation anticoagulant rodenticides in 2023.

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

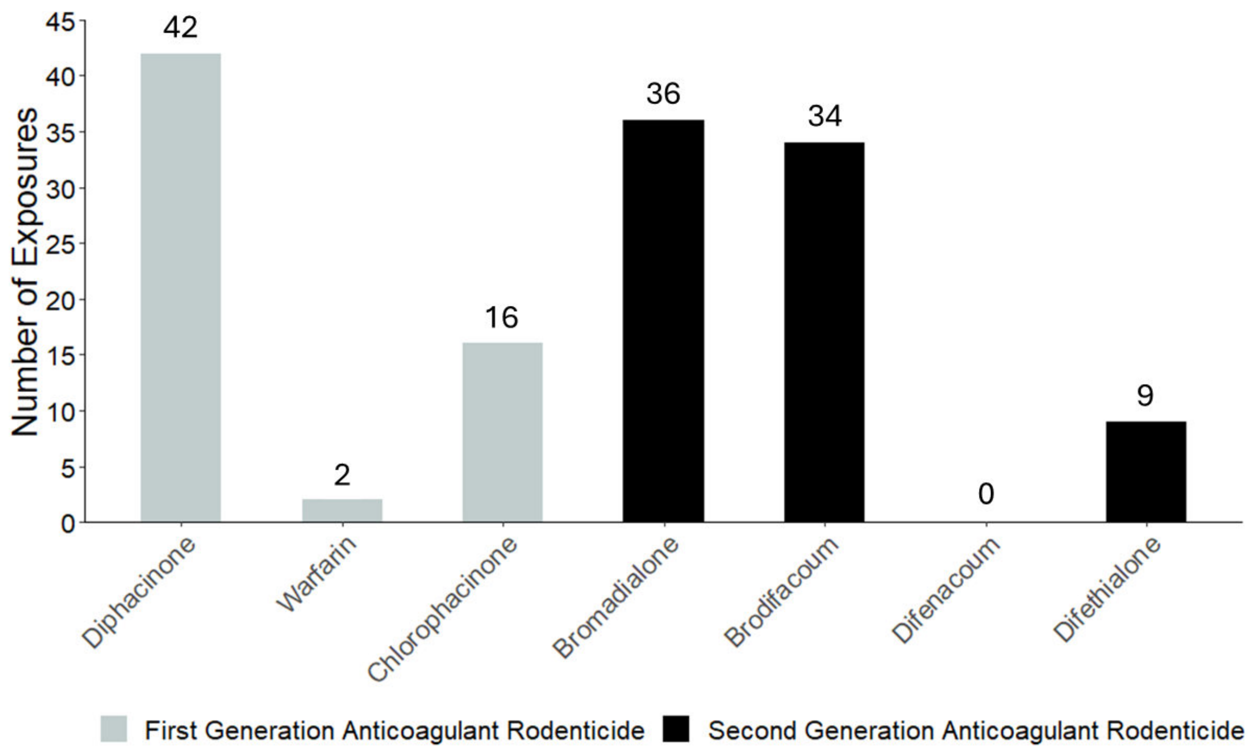


Figure 10. AR residues detected in the livers of 55 of the 70 tested wild non-game mammals submitted to the Wildlife Health Laboratory in 2023. Each bar displays number of exposures at the top.

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**

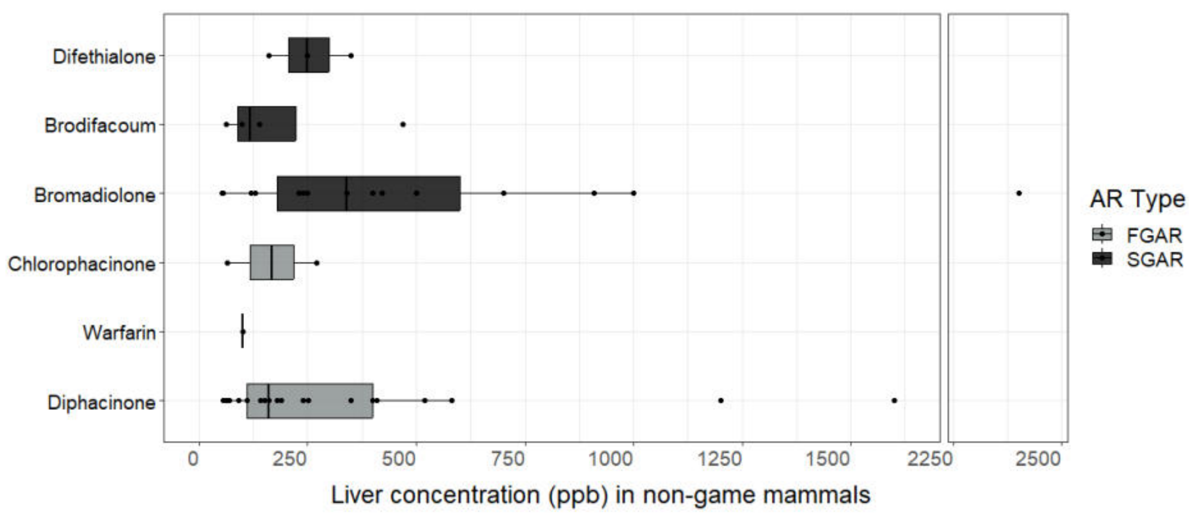


Figure 11. Boxplot to visualize AR concentrations (ppb) in the livers of 50 of the 70 tested wild non-game mammals submitted to the Wildlife Health Laboratory in 2023 where detectable levels were quantitated. This figure does not include instances of trace level detections (see Table 14). Box plot summary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

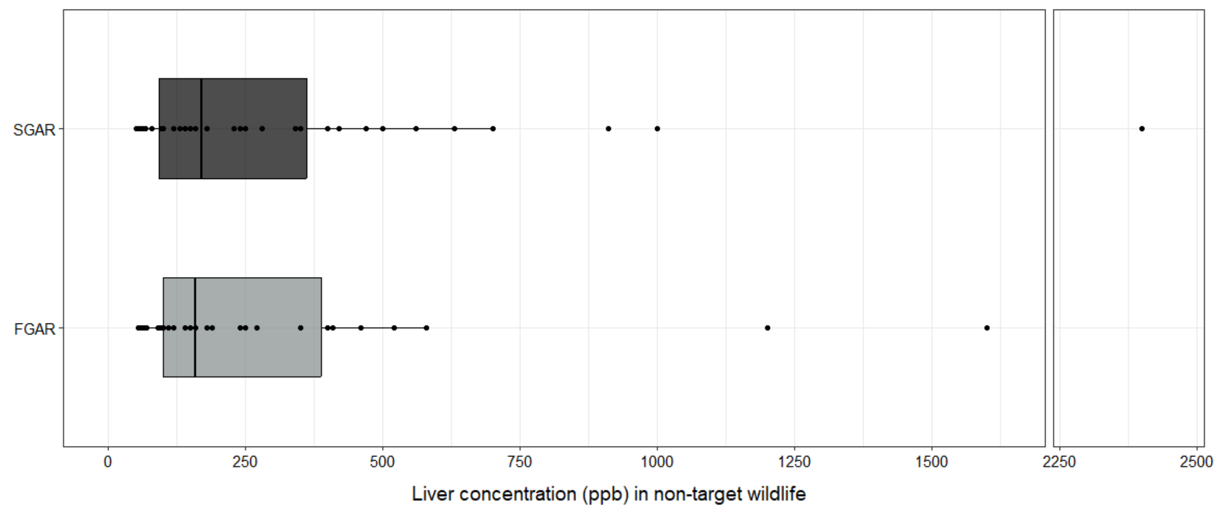


Figure 12. Box plot to visualize FGAR and SGAR concentrations (ppb) in the livers of 74 of the 128 tested wild non-game mammals submitted to the Wildlife Health Laboratory in 2023 where detectable levels were able to be quantitated. This figure does not include instances of trace level detections (see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

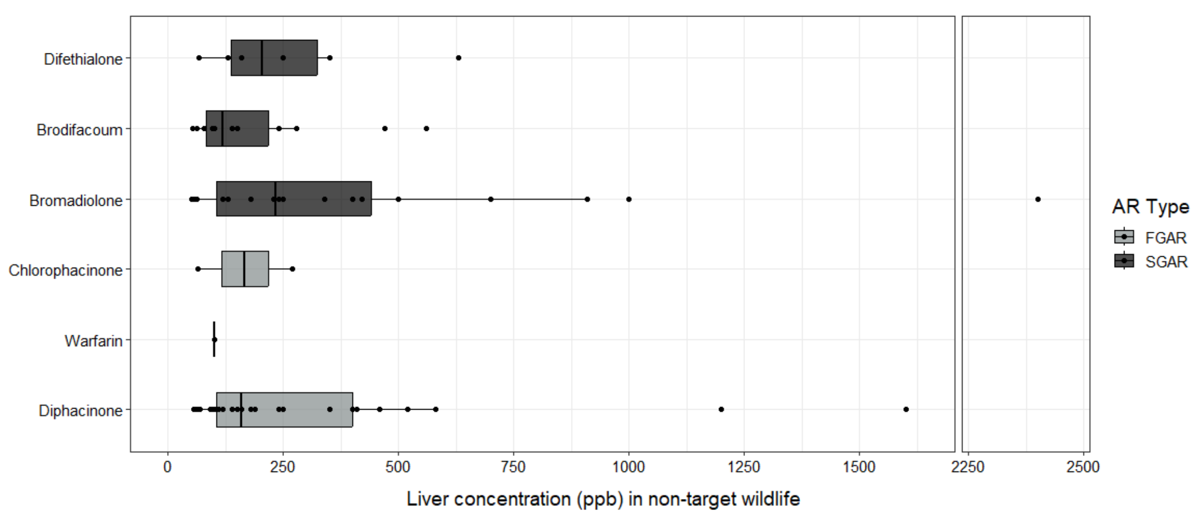


Figure 13. Box plot to visualize AR analyte concentrations (ppb) in the livers of 74 of the 128 tested all non-target avian, game, and non-game wildlife submitted to the Wildlife Health Laboratory in 2023 where detectable levels were able to be quantitated. This figure does not include instances of trace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

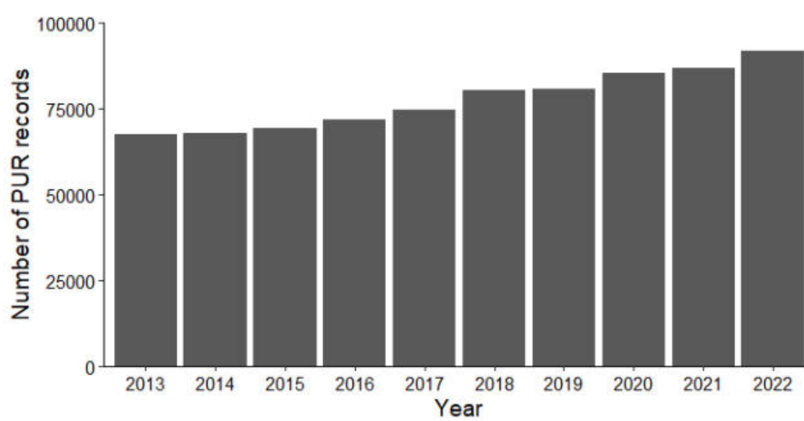


Figure 14. The total number of Pesticide Use Reporting (PUR) records for ARs, bromethalin, and cholecalciferol in California between 2013–2022. PUR data shown in graph was obtained from DPR's California Pesticide Informational Portal; 2023 PUR data was not available when this report was written. The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

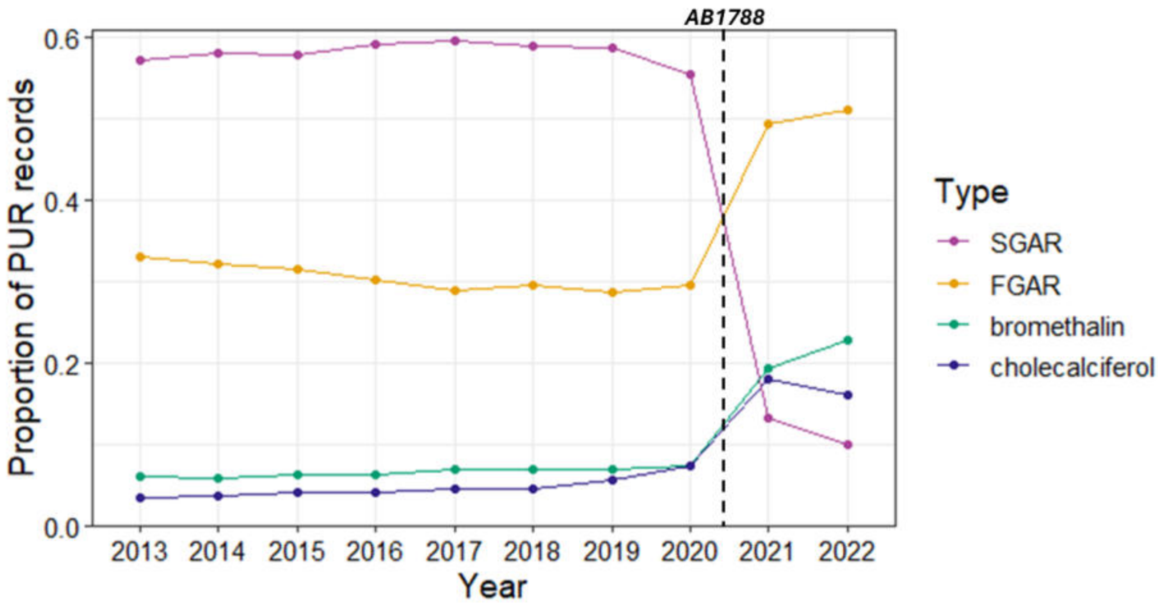


Figure 15. Proportions of the number of rodenticide applications for ARs, bromethalin, and cholecalciferol according to Pesticide Use Reporting (PUR) records in California 2013–2022. PUR data was obtained from DPR's California Pesticide Informational Portal. The black dotted line represents implementation 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