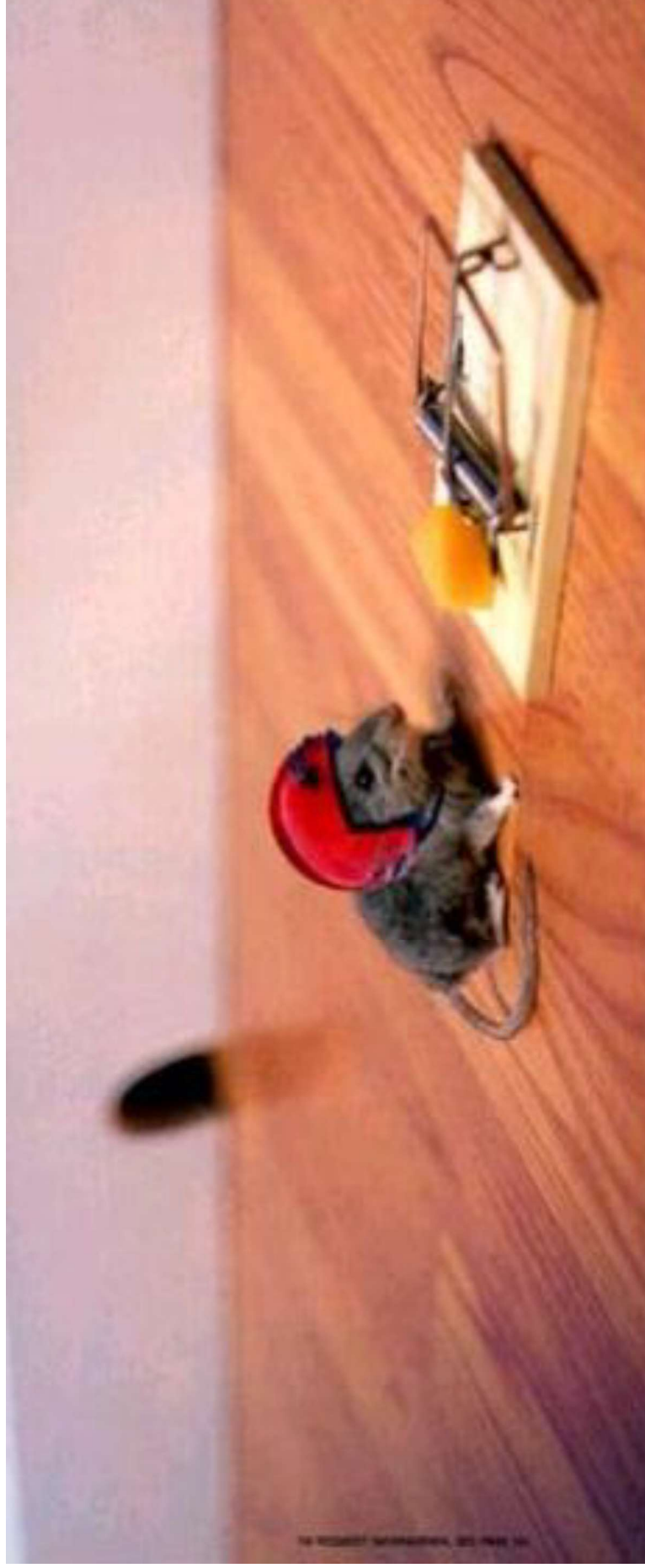


Anticoagulant Rodenticides

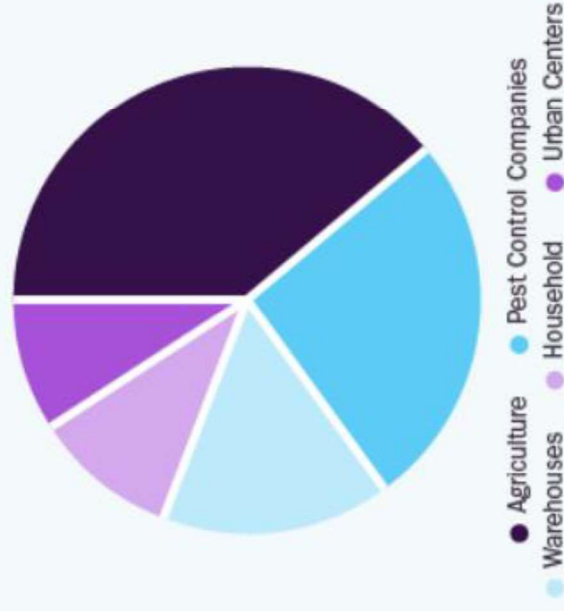


Thanks to Gretchen Fowles and Kathy Clark

Rodenticide Market

Global Rodenticides Market

Share, by Application, 2022 (%)

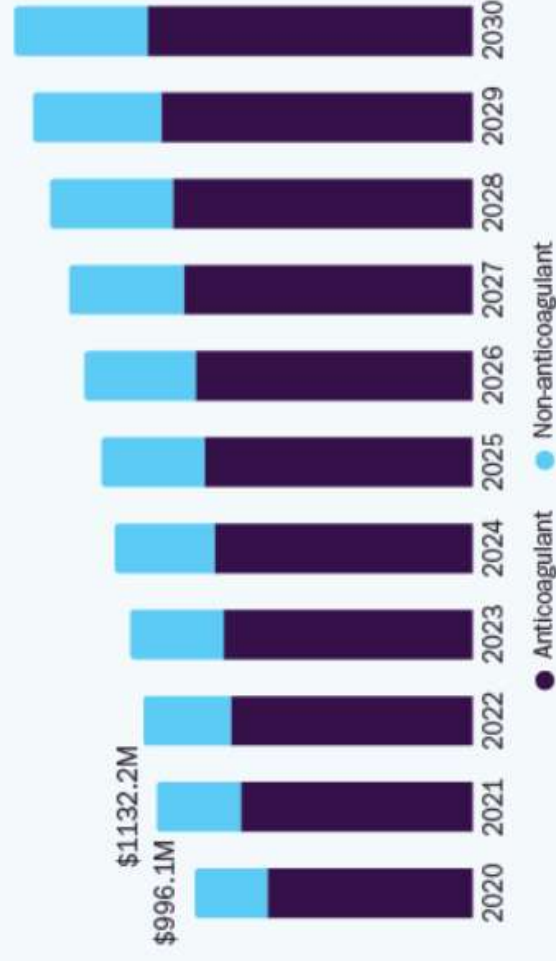


\$5.3B

Global Market Size,
2022

U.S. Rodenticides Market

Size, by Product, 2020 - 2030 (USD Million)



<https://www.grandviewresearch.com/industry-analysis/rodenticides-market>

Rodenticides



The growth of this market can be attributed to the increasing vector-based disease outbreak which encourage adoption of rodenticides.



Increasing infestation of rodenticides in agricultural fields, warehouses are leading to crop losses and high demand for sustainable agriculture are important factors which drives the rodenticides market



The global rodenticides market is expected worth USD 6.6 billion by 2026, growing at CAGR of 5.0% during the forecast period



The increased demand from residential and commercial segment has attributed to the increasing adoption of rodenticides for effective rodent control.



© 2008 - 2020 MarketsandMarkets Research Private Ltd. All rights reserved

<https://www.grandviewresearch.com/industry-analysis/rodenticides-market>

Anticoagulant Rodenticides

1st generation

Warfarin, Pindone

- Multiple feedings
- Less toxic



2nd generation

Brodifacoum, Diphacinone,
Bromadiolone, Difethialone

- “One feeding”
- Persists in tissues

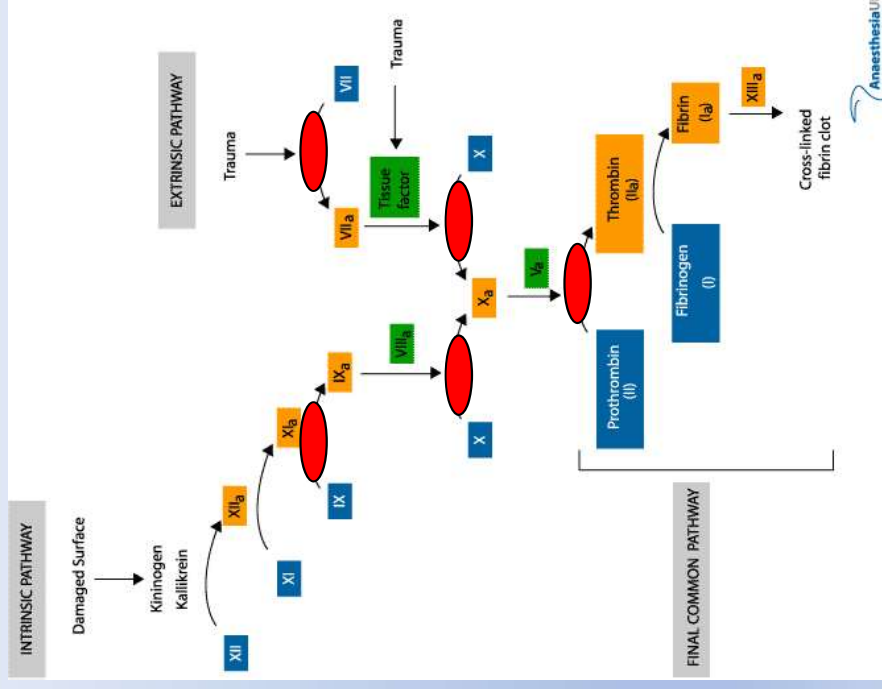


Anticoagulant Rodenticides

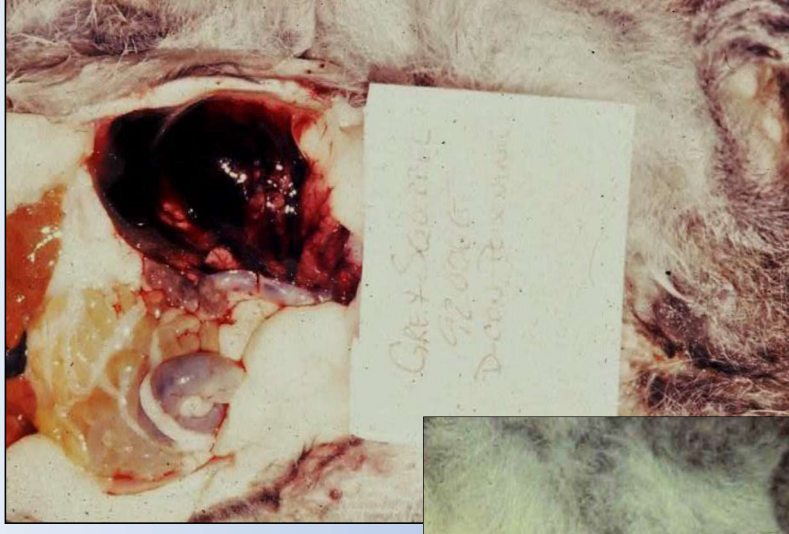
Signs: bruising, internal hemorrhages, profuse bleeding

Dx: failure to clot; response to vit K1 or ARs in liver

Tx: vitamin K1, supportive care and minimal handling; prevent additional absorption



Anti-coagulants: Primary bait ingestion



SGAC Rodenticides in Raptors

Canadian Studies

70% owls found dead 1988-2003: *Arch Environ Contam Toxicol*, 58, 451-459

96% owls found dead 2005-2011: Hindmarch & Elliot, Raptor Research Fndn Mtg 2011

Massachusetts (Tufts)

86% of 161 raptors that died/euth 2006-2010

RTHA, BDOW, EASO, GHOW

Journal of Zoo and Wildlife Medicine, 42, 88-97

PennVet/NJDFW Study 2011:

5/23 (22%) BAEA, BDOW, GHOW, PEFA, RTHA blood

24/27 (89%) GHOW livers had exposure to SGACR



Project SNOWstorm (2013-23) (Pre-print data)

- 71/196 livers (36%) had quantifiable (>trace) exposure
 - Hemorrhage in 75%
- 52 > 0.03ppm
 - Hemorrhage in 92%; 61% w/no trauma

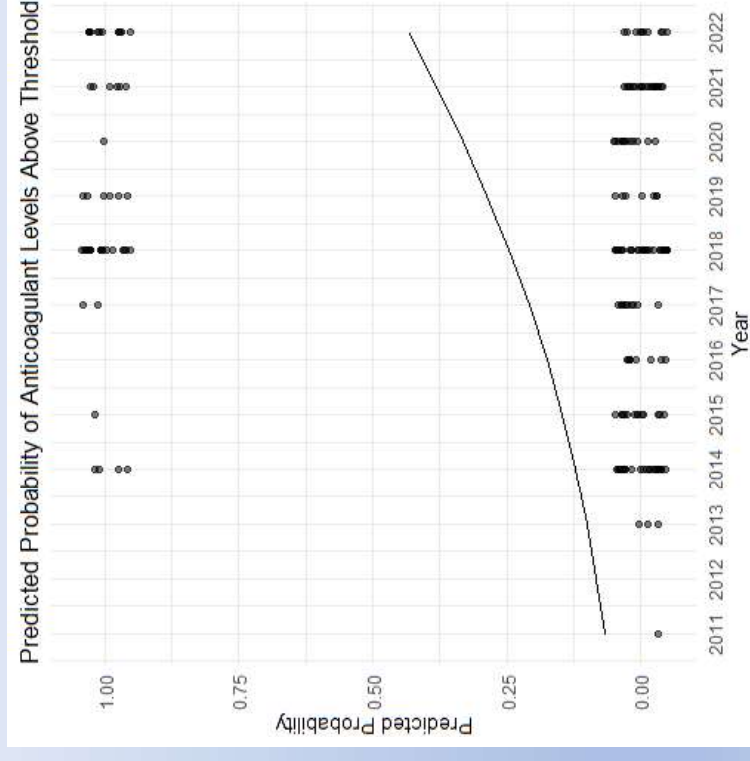
Bull. Environ. Contam. Toxicol. (2003) 70:34–40
© 2003 Springer-Verlag New York Inc.
DOI: 10.1007/s00128-002-0152-0

**Subsidiary of
Environmental
Contamination
and Toxicology**

Anticoagulant Rodenticides and Raptors: Recent Findings from New York, 1998–2001

W. B. Stone,¹ J. C. Okoniewski,¹ J. R. Stedelin²

Threshold of 0.03 ppm is associated with potential mortality



Trend in the predicted probability of anticoagulant levels to exceed 0.03ppm

NJ BAEA data(2013-23)

- 100 eagles tested
 - 54 had some exposure
 - 50 were brodifacoum
- 12 had $>0.03\text{ppm}$



Repeated exposures

Environmental Toxicology and Chemistry—Volume 39, Number 2—pp. 468–481, 2020

Received: 5 August 2019 | Revised: 24 September 2019 | Accepted: 28 October 2019

468

Hazard/Risk Assessment



Brodifacoum Toxicity in American Kestrels (*Falco sparverius*) with Evidence of Increased Hazard on Subsequent Anticoagulant Rodenticide Exposure

Barnett A. Rattner,^{a,*} Steven F. Volker,^b Julia S. Lankton,^c Thomas G. Bean,^d Rebecca S. Lazarus,^a and Katherine E. Horak^b

^aPatuxent Wildlife Research Center, US Geological Survey, Beltsville, Maryland, USA

^bNational Wildlife Research Center, Animal and Plant Health Inspection Service, US Department of Agriculture, Fort Collins, Colorado, USA

^cNational Wildlife Health Center, US Geological Survey, Madison, Wisconsin, USA

^dDepartment of Environmental Science and Technology, University of Maryland, College Park, Maryland, USA

AR Exposure in Eagles

Percent exposure and number of AR compounds detected in eagles

	≥1 AR		1 AR		≥ 2 AR	
	Exposed/ tested	% Exposed	Exposed/ tested	% Exposed	Exposed/ tested	% Exposed
BAEA	96/116	82.7%	56/116	48.3%	40/116	34.5%
GOEA	13/17	76.5%	4/17	23.5%	9/17	52.9%
Total	109/133	81.9%	60/133	45.1%	49/133	36.8%

Specific AR compounds detected in eagles

	Compound	% AR Exposure (n)		
		BAEA (n=116)	GOEA (n=17)	Total (n=133)
First-generation AR	Chlorophacinone	0.9% (1)	5.9% (1)	1.5% (2)
	Coumachlor	0%	0%	0%
	Warfarin	0%	0	0%
	Diphacinone	0.9% (1)	11.8% (2)	2.3% (3)
Second-generation AR	Brodifacoum	84.5% (98)	64.7% (11)	80.5% (107)
	Bromadiolone	21.6% (25)	47.1% (8)	24.8% (33)
	Difethialone	18.1% (21)	5.9% (1)	16.5% (22)
	Difenacoum	9.6% (11)	11.8% (2)	9.8% (13)

Slide from a presentation by
Bob Sargent of Georgia
Wildlife Resources

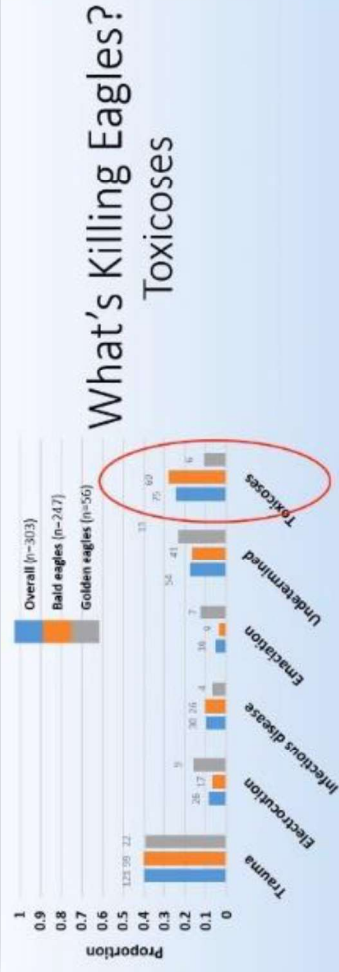
at the

Atlantic Flyway's Nongame
Technical Section, Raptor
committee.

Data from Georgia bald
eagles treated in
rehabilitation centers.

Slides from a presentation by Bob Sargent
of Georgia Wildlife Resources
at the

Atlantic Flyway's Nongame Technical
Section, Raptor committee.



Compound	Intoxication		
	Total	Bald eagle	Golden eagle
Lead	15.8% (48)	17.9% (44)	7.1% (4)
Anticoagulant rodenticide	4.0% (12)	4.5% (11)	1.8% (1)
OP/Carbamate	≤1% (3)	≤1% (2)	1.8% (1)
Avian vacuolar myelinopathy	2.3% (7)	2.8% (7)	0
Pentobarbital	1.3% (4)	1.6% (4)	0
Zinc	≤1% (1)	≤1% (1)	0
Toxicant exposure			
Lead	15	13	2
Anticoagulant rodenticide	109	96	13

SCWDS Study Summary

- SGAR exposure among bald and golden eagles is common and widespread despite use restrictions
 - Primary, secondary, and tertiary poisoning reported
 - Brodifacoum detected in 80% of eagles tested and 100% of intoxicated eagles
 - Although intoxication appears uncommon, the high prevalence of exposure is concerning
 - The impacts of subclinical SGAR exposure to eagle population health remain unclear

SCWDS = Southeast Cooperative Wildlife Disease Study



Lethal Dose: Rat Poison & Local Wildlife

Local residents may inadvertently be poisoning wildlife. National Park Service researchers have found a direct link between exposure to anticoagulant rodenticides, commonly known as rat poison, and the deaths of wildlife in and around the Santa Monica Mountains. How rodenticide works its way through the food chain:

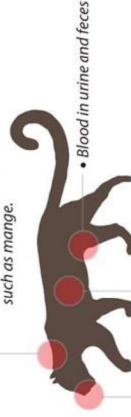


How anticoagulant rodenticide kills

These compounds interrupt blood-clotting, which leads to uncontrolled bleeding and death. They may also suppress the animal's immune system, making it susceptible to other diseases. **Symptoms include:**

- Nosebleeds
- Bleeding gums
- Ruptured blood vessels, causing bruising
- Internal hemorrhaging

Secondary disease, such as mange.



Blood in urine and feces

What is mange?

A microscopic mite that burrows into the skin and causes...

1. Extreme Itchiness and skin lesions.
2. Fluid and nutrient loss through the skin.
3. Infection, starvation, hypothermia or other complications, eventually leading to death.



Check the label

Here are the most common anticoagulant compounds:

- Diphacinone
- Bromadiolone
- Brodifacoum
- Difethialone



SOURCES: Santa Monica Mountains National Recreation Area research, L.E.K. Serriels, UrbanCarnivores.com

CREDIT: National Park Service
<http://1.usa.gov/1SuhsXv>

Anticoagulant Exposure and Notoedric Mange in Bobcats and Mountain Lions in Urban Southern California

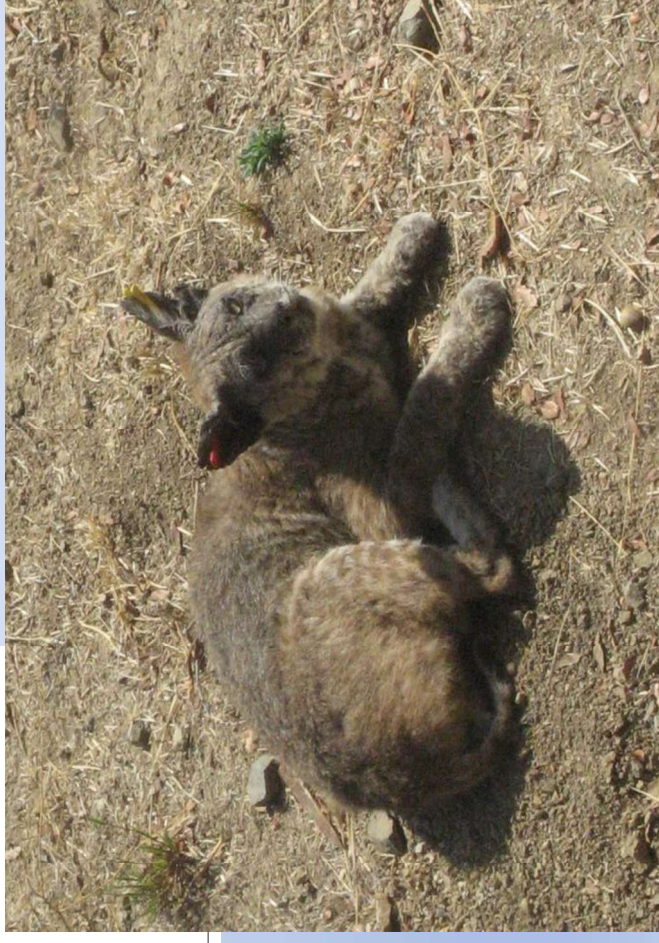
Author(s): SETH P. D. RILEY, CASSITY BROMLEY, ROBERT H. POPPENG, FRANCISCO A. UZAL, LYNN WHITED, and RAYMOND M. SAUVAJOT

Source: Journal of Wildlife Management, 71(6):1874-1884. 2007.

Published By: The Wildlife Society

DOI: <http://dx.doi.org/10.2193/2005-615>

URL: <http://www.bioone.org/doi/full/10.2193/2005-615>



<http://www.urband carnivores.com>

ACR Effects on Immune Function?

PROCEEDINGS B

rsbp.royalsocietypublishing.org



Research

Cite this article: Serieys LEK *et al.* 2018

Urbanization and anticoagulant poisons promote immune dysfunction in bobcats.

Proc. R. Soc. B **285**: 20172533.

<http://dx.doi.org/10.1098/rspb.2017.2533>

Received: 12 November 2017

Accepted: 8 December 2017

Urbanization and anticoagulant poisons promote immune dysfunction in bobcats

Laurel E. K. Serieys^{1,4,5}, Amanda J. Lea⁶, Marta Epeldegui³, Tiffany C. Armenta¹, Joanne Moriarty⁷, Sue VandeWoude⁸, Scott Caner⁹, Janet Foley¹⁰, Robert K. Wayne¹, Seth P. D. Riley³ and Christel H. Uittenbogaart^{2,3}

¹Department of Ecology and Evolutionary Biology, ²Departments of Pediatrics and Microbiology, Immunology & Molecular Genetics, and ³UCLA AIDS Institute and Jonsson Comprehensive Cancer Center, University of California, Los Angeles, CA, USA

⁴Institute for Communities and Wildlife in Africa, Biological Sciences, University of Cape Town, Cape Town, South Africa

⁵Environmental Studies, University of California, Santa Cruz, CA, USA

⁶Department of Biology, Duke University, Box 90338, Durham, NC, USA

⁷Santa Monica Mountains National Recreation Area, National Park Service, 401 West Hillcrest Drive, Thousand Oaks, CA 91360, USA

⁸Department of Microbiology, Immunology, and Pathology, Colorado State University, Fort Collins, CO, USA

⁹School of Biological Sciences, University of Tasmania, Tasmania, Australia

¹⁰Department of Medicine and Epidemiology, School of Veterinary Medicine, University of California, Davis, CA, USA

LEKS, 0000-0002-0399-6646

“We find evidence of both inflammatory response and immune suppression associated with urban land use and rat poison exposure that could influence susceptibility to opportunistic infections.”

SCIENTIFIC REPORTS

OPEN

Effects of Low-level Brodifacoum Exposure on the Feline Immune Response

Jennifer H. Kopanke¹, Katherine E. Horak², Esther Musselman¹, Craig A. Miller¹, Kristine Bennett³, Christine S. Oliver¹, Steven F. Volker², Sue VandeWoude¹ & Sarah N. Bevins²

Received: 18 December 2017

Accepted: 11 May 2018

Published online: 25 May 2018

Anticoagulant rodenticides have been implicated as a potential inciting factor in the development of *manno* in wild felids, but a causal association between anticoagulant rodenticide exposure and

“This study indicates that cats may be more resistant to clinical effects of brodifacoum exposure than other species and suggests that the gross impacts of environmentally realistic brodifacoum exposure on humoral and cell-mediated immunity against foreign antigen exposures in domestic cats are minimal.”

ACRs lead to poor fitness

Received: 17 July 2017 | Revised: 18 December 2017 | Accepted: 4 January 2018

DOI: 10.1111/mec.14531

ORIGINAL ARTICLE

WILEY **MOLECULAR ECOLOGY**

Genome-wide expression reveals multiple systemic effects associated with detection of anticoagulant poisons in bobcats (*Lynx rufus*)

Devaughn Fraser^{1*}  | Alice Mouton^{1*} | Laurel E. K. Serieys^{1,2,3}  | Steve Cole⁴ | Scott Carver⁵ | Sue Vandewoude⁶ | Michael Lappin⁷ | Seth P.D. Riley⁸ | Robert Wayne¹

¹Department of Ecology and Evolutionary Biology, University of California, Los Angeles, CA, USA

²Institute for Communities and Wildlife in Africa, Biological Sciences, University of Cape Town, Cape Town, South Africa

³Environmental Studies Department, University of California, Santa Cruz, CA, USA

⁴Department of Medicine, University of California, Los Angeles, CA, USA

⁵School of Biological Sciences, University of Tasmania, Hobart, TAS, Australia

Abstract

“Overall, our results show that the focus on the lethal effects of toxicants developed for pest control which cause a failure of blood to clot in target species may be misplaced. Individual fitness and population persistence may be critically impacted without signs of the target effects of ARs”

Reduced Escape Response; Transplacental Exposure

Ecotoxicology (2015) 24:844–862
DOI 10.1007/s10646-015-1429-5

Anticoagulant rodenticides in urban bobcats: exposure, risk factors and potential effects based on a 16-year study

L. E. K. Serieys · T. C. Armenta · J. G. Moriarty ·
E. E. Boydston · L. M. Lyren · R. H. Poppenga ·
K. R. Crooks · R. K. Wayne · S. P. D. Riley

Accepted: 6 February 2015 / Published online: 25 February 2015
© Springer Science+Business Media New York 2015

Abstract Anticoagulant rodenticides (ARs) are increas- bobcats sampled over a 16-year period (1997–2012) and a

- A reduced escape response has been observed in rats dosed with ARs (Cox and Smith 1992), and if carnivores secondarily exposed to ARs have a similarly reduced response to threats, they may be more vulnerable to vehicle collisions or predation
- Reproductive consequences associated with AR exposure in other species have included increased miscarriage, fetal toxiosis, fetal congenital deformities, and decreased sperm counts

Bobcats in NJ Exposure to ARs

YEAR	tested	AR found	% w/exposure	
2013	3	0	0.0	
2014	4	2	50.0	
2015	9	5	55.6	
2016	12	3	25.0	
2017	15	3	20.0	
2018	13	5	38.5	
2019	20	9	45.0	
2020	9	4	44.4	Covid....
2021	26	17	65.4	
2022	29	20	69.0	
2023	34	25	73.5	
2024	14	9	64.3	as of 16 June
'13-24	188	102	54.2	

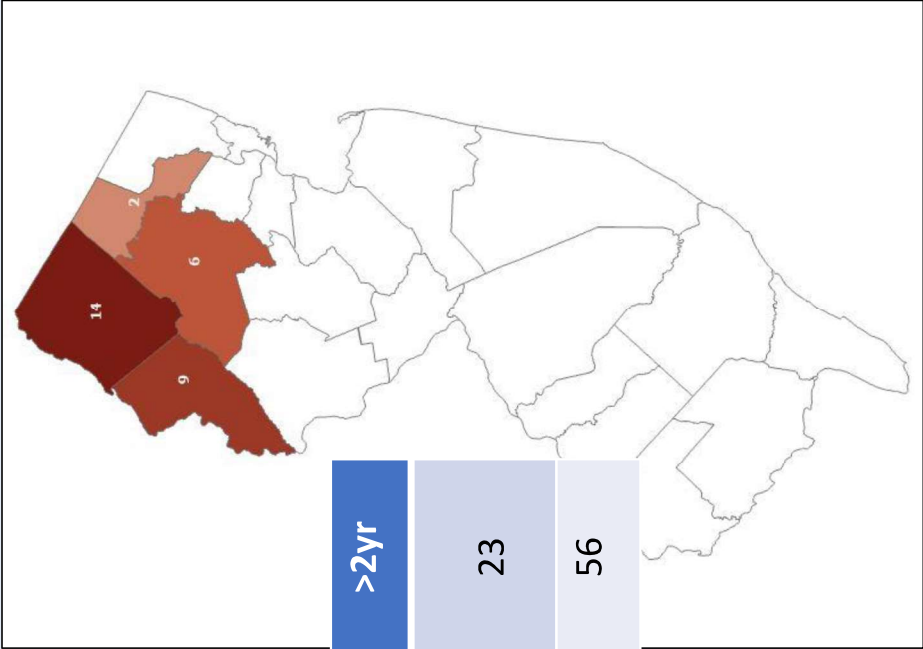


[Felids in CA study with mange had much higher SGACR levels]

Year	# bobcats tested	No ACR	Diphacinone ppm	Brodifacoum ppm	Bromadiolone ppm	Difethialone ppm	Rodenticides found	Frequency (any)	Frequency (>trace)
2013	3	3						0%	0%
2014	4	2	1	1			None (2) Brodifacoum (1) Diphacinone (1)	50% (2)	50% (2)
2015	9	4		5	4	1	None (4) Brodifacoum (1) Bromadiolone +Brodifacoum (3) Brodifacoum + Bromadiolone + Difethialone (1)	56% (5)	56% (5)
2016	12	9	3				None (9) Diphacinone (3)	25% (3)	17% (2)
2017	15	12	1	1	2		None (12) Brodifacoum (1) Bromadiolone (1) Diphacinone + Bromadiolone (1)	20% (3)	7% (1)
2018	13	8	2	3	3		None (8) Brodifacoum (1) Bromadiolone (1) Bromadiolone +Brodifacoum (1) Diphacinone + Bromadiolone (1) Diphacinone + Brodifacoum (1)	38% (5)	31% (4)
2019	20	11	7	1	2	1	None (11) Diphacinone (6) Bromadiolone (1) Difethialone (1) Diphacinone + Brodifacoum + Bromadiolone (1)	45% (9)	10% (2)
2020	9	5	3		3		None (5) Diphacinone (1) Bromadiolone (1) Diphacinone + Bromadiolone (2)	44% (4)	33% (3)
Total	85	54	17	11	14	2	None (54); one compound (20); two compounds (9); three compounds (2)	36% (31)	22% (19)

Rodenticide Exposure in Bobcats 2013-2020

	Male	Female	RK	Snare	<1yr	~1-1.5yr	>2yr
ACR Exposure	17	14	16	15	3	5	23
Total (85)	47	38	51	33	18	11	56



Regulation change

- Restricted use of products since 2014-15:
 - Commercial use only
 - Tamper-resistant packaging



Bromethalin

Misc. Rodenticides

Cholecalciferol

- Vitamin D3
- Causes calcification of tissues

Strychnine

- Blocks glycine, an inhibitory neurotransmitter
- Causes neurotransmission in spinal cord → seizures

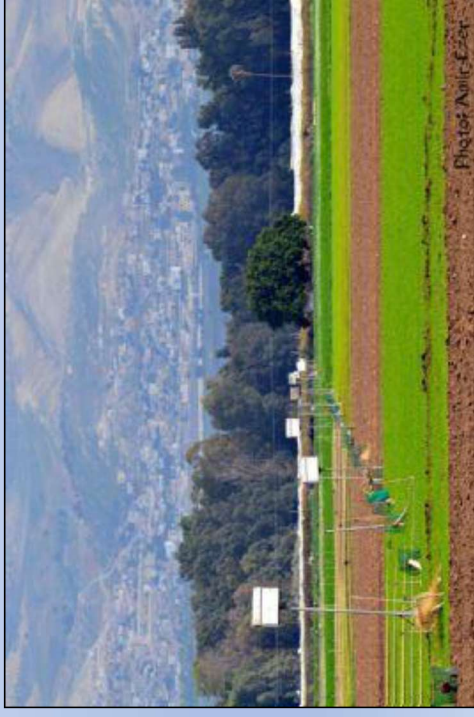


Bromethalin

- uncouples oxidative phosphorylation in mitochondria in CNS and liver
- Cerebral edema in 2-24hrs
- Main metabolite is bromethalin....

Barn Owls www.birdboxisrael.org

- >3000 boxes in Israel
- Barn Owls & Kestrels
- Owls: up to 11 young/yr





Scientific Studies on Rodenticides, Wildlife, and Pets

On this regularly-updated page we provide links to articles, presentations, and scientific and regulatory studies about the impacts of rodenticides on wildlife and pets.

Anticoagulant rodenticides (ARs) continue to be widely used, affecting raptors and other non-target animals. These products can cause both the prey and the animal that eats it to bleed to death internally. They can also cause minor injuries to be much more severe than they would be normally—for example, a poisoned animal might hemorrhage from a wound that would not ordinarily cause death. These terrible poisons also cause “sublethal” impacts, including suppression of an animal’s immune system, and affect overall health, behavior, and survivability.

♦ = Recently added

Wildlife:

- ♦ Sensitivity of turtles to anticoagulant rodenticides: Risk assessment in the Ogasawara Islands (Japan, 2021)
- ♦ Temporal Persistence of Bromadiolone in Decomposing Bodies of Common Kestrel (*Falco tinnunculus*) (Spain, 2020)
- Accumulation of anticoagulant rodenticides in suburban wild boar: implications for human consumers (Spain, 2020)
- Heavy rainfall releases anticoagulant rodenticides from baited sewer systems and outdoor surfaces into streams (Germany, 2020)
- Toxic time bombs: Frequent detection of anticoagulant rodenticides in urban reptiles (Australia, 2020)
- Frequent detection of anticoagulant rodenticides in raptors reflects government rodent control policy (Taiwan, 2019)
- Survival and competing mortality risks: rodenticides are second-leading cause of death of mountain lions in greater Los Angeles area (2010)

<https://www.raptorsarethesolution.org/science-on-ars/>

Thank you

I like my meals poison free.

Rat poison kills more than rats.

www.raptorsarethesolution.org | A Project of Earth Island Institute





PHOTO: KIMBERLY L. GILSON

www.raptorsarethesolution.org