Rabies Surveillance in California

Annual Report 2022

Veterinary Public Health Section
Infectious Diseases Branch
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Introduction

Rabies is a severe zoönotic encephalitis caused by a Rhabdovirus of the genus *Lyssavirus*. Following an incubation period that can range from a few days to several years, early clinical signs and symptoms of rabies--including headache, fever, chills, cough or sore throat, anorexia, nausea, vomiting, and malaise--are non-specific and can be mistaken for more common conditions. Symptoms progress rapidly (within 1-2 weeks) to central and peripheral neurologic manifestations including irritation at the site where the virus was introduced, altered mental status (e.g., hyperactivity and agitation), hydrophobia, excessive salivation, and difficulty swallowing due to laryngeal spasms. Ultimately, autonomic instability, coma, and death occur, due mainly to cardiac or respiratory failure. No treatment protocol has proven consistently effective for clinical rabies and reports of patients surviving are exceedingly rare. If a person is exposed to the virus, prompt post-exposure prophylaxis (PEP) by administration of rabies immune globulin and vaccine can prevent progression to clinical rabies.

Rabies virus variants (RVV) are maintained in certain mammalian species, but all rabies viruses are capable of infecting any mammal, including humans. In California, bat RVVs exist throughout the state, while the California skunk RVV is found mostly north of the Tehachapi mountain range. Domestic animals (dogs, cats, and livestock) can be infected with these RVVs through contact with rabid wildlife; but the rarity of domestic animal rabies in California limits the potential for the virus to evolve and sustain transmission in these species. Each year since 1957, the Director of the California Department of Public Health (CDPH) has identified counties in California where rabies constitutes a public health hazard. The Director has declared all 58 counties in California as rabies areas every year since 1987.

Since the early 20th century, CDPH has overseen a statewide rabies surveillance and control program. Local departments of public health and environmental health, animal control agencies and shelters, and medical and veterinary practitioners collaborate with CDPH to prevent rabies in California by:

- Providing reliable laboratory services for the diagnosis of rabies in humans and animals,
- Regulating and enforcing rabies vaccination of dogs to provide a protective “firewall” that reduces the potential for human exposure,
- Investigating reports of animals that bite humans,
- Evaluating animals for rabies by confinement and observation for a specified period, or by euthanasia and testing,
- Offering recommendations for PEP to persons following a known or suspected exposure to rabies,
- Developing and disseminating preventive education on rabies, and
- Collecting, collating, and reporting surveillance data on rabies in humans and animals.

Reporting and Analysis

The California Code of Regulations (17 CCR §2500) lists rabies that is diagnosed in either humans or animals as a reportable disease. Health care providers, including physicians and veterinarians, having knowledge of a confirmed or suspected case of rabies are required to report this knowledge immediately to the local health officer. Diagnostic testing of human patients who have signs and symptoms suggestive of rabies is challenging, and no single test can accurately diagnose rabies ante-mortem. Therefore, several tests on multiple tissue samples are typically pursued. Diagnosis can be made by detection of virus antigen in nuchal skin biopsy, brain biopsy, or saliva by direct fluorescent antibody assay (DFA) or polymerase chain reaction; or by demonstration of rabies-specific antibodies in blood or cerebrospinal fluid of previously unvaccinated patients by immunofluorescent antibody assay or Rapid Fluorescent Focus Inhibition Test (RFFIT). Infection with rabies is confirmed post-mortem in humans and animals by detection of rabies virus antigen, typically in central nervous system tissue, by DFA performed by a certified public health microbiologist. In 2022, 30 local public health laboratories in California employed trained microbiologists and maintained resources to perform rabies testing in animals. The CDPH Viral and Rickettsial Diseases Laboratory (VRDL) provides primary and confirmatory testing for rabies in animals, diagnostic testing of human patients suspected to have rabies, and characterization of rabies viruses to RVV type. Local public health departments report confirmed cases of rabies in humans and animals to CDPH. This surveillance report summarizes information on confirmed cases of rabies in humans and animals reported to CDPH in 2022.

Rabies in Animals

In 2022, specimens from 4,411 animals were tested for rabies in California – approximately 17 percent fewer than the annual average of 5,326 specimens tested during the previous ten years, 2012-2021. Of the 55 counties that submitted at least one animal for rabies testing, the number of animals tested per county ranged from 2 to 538.

Rabies was confirmed in 241 animals, roughly 10 percent more than the 220 cases confirmed in 2021 and slightly above the annual average of 231 cases in 2012-2021 (Table A). One or more rabid animals were identified in 38 counties, which reported between 1 and 50 rabid animals each.

In 2022, rabies was confirmed in California in 189 bats, 40 skunks, 9 foxes, 1 bobcat, 1 domestic cat, and 1 domestic dog.

Wild Animals

Rabies was diagnosed in 239 wild animals in 2022, accounting for 99 percent of all rabid animals reported to CDPH. Bats (189, 78.4%) were the wild animal most frequently reported rabid, followed by skunks (40, 16.6%), foxes (9, 3.7%), and a bobcat (1, <1.0%).

Bats

A total of 1,533 bats from 54 counties was tested for rabies in 2022 (Figure A). The 189 rabid bats reported in 2022 were 5 percent lower than the annual average of 199 reported in the preceding ten years, 2012-2021 (Figure B). The greatest number of rabid bats (50) was reported in Los Angeles County, which reported the most rabid bats in each of the past ten years (Table A, Figure C). The six southern California counties of Los Angeles, Orange, Riverside, San Bernardino, San Diego, and Ventura collectively accounted for 107 (57%) of all rabid bats detected in California in 2022. Rabid bats were most frequently reported during the spring and autumn months; approximately four fifths (154, 81%) of all rabid bats were reported in the six months of May through October (Figure D). Species were identified for 117 rabid bats: 53 Mexican free-tailed bats (*Tadarida brasiliensis*), 28 western pipistrelle (*Parastrellus hesperus*), 14 California myotis (*Myotis californicus*), 7 Yuma myotis (*Myotis yumanensis*), 7 big brown bats (*Eptesicus fuscus*), 3 pallid bats (*Antrozous pallidus),* 2 Hoary bats (*Laisurus cinereus*), 1 Western yellow bat (*Lasiurus xanthinus*), 1 long-eared myotis bat (*Myotis evotis*), and 1 silver-haired bat (*Lasionycteris noctivagans*); 1 bat was identified to genus only (*Myotis* sp.).

Skunks

A total of 250 skunks (*Mephitis mephitis*) from 32 counties were tested for rabies in 2022, of which 40 from 10 counties were confirmed rabid (Figure A, B). The 40 rabid skunks in 2022 was more than the annual average of 26 in the preceding ten years, 2012-2021. The greatest number of rabid skunks was reported in El Dorado County (17).

Foxes

A total of 54 foxes from 26 counties were tested for rabies in 2022. The nine confirmed rabid foxes in 2022 were more than the annual average of three foxes reported in the previous 10 years, 2012-2021 (Figure B). Rabies virus variants were characterized for seven foxes: *Myotis californicus* (3), *Myotis yumanensis*, *Lasionycteris noctivagans*, California skunk, and Arizona fox.

Other wild animals

Rabies was detected in a single bobcat from Trinity County in 2022. The RVV was consistent with the *Myotis californicus* bat RVV.

Domestic Animals

In 2022, 2,248 domestic animals (dogs, cats, horses, cattle, goats, sheep, and swine) were tested for rabies. Rabies was confirmed in two domestic animals in California in 2022.

In June 2022, a free-roaming Australian Cattle dog was observed to be disoriented and to have difficulty walking on a public street in Sacramento County. The dog was presented to a veterinary clinic and noted to be recumbent with possible hypersalivation and hypersensitivity to stimuli. The dog was euthanized and submitted to the Sacramento County Public Health Laboratory who confirmed rabies virus in brain tissue.

The CDPH VRDL identified the virus that infected the dog as consistent with the California skunk RVV. Three of four veterinary clinic staff were referred for rabies PEP.

A 1.5-year-old spayed female domestic shorthair cat in El Dorado County was noted to have onset of neurological signs in late June 2022. The cat was presented to a veterinary clinic and euthanized. Testing performed at the Sacramento County Public Health Laboratory confirmed rabies infection. The CDPH VRDL identified the virus that infected the cat as consistent with the California skunk RVV. Approximately one month earlier, a domestic dog that resided at the same property had contact with a rabid skunk and was placed under a rabies exposure quarantine. The unvaccinated cat was not known to have had contact with the skunk.

Rabies in Humans

Rabies was not diagnosed in any California resident in 2022. One case of rabies was diagnosed in California in the previous ten years (2012-2021) in a resident of Contra Costa County in 2012.

Rabies in the United States

At the time of this report, United States rabies surveillance data for 2022 have not been published.

Discussion

In each of the last 20 years, bats have accounted for 62 to 95 percent of all rabid animals identified in California. Approximately 24 species of bats are permanent or seasonal residents of California. Unique RVVs have been identified for at least 10 of these species, with RVVs occasionally passed between bat species. While some bat species are rare, reclusive, and have limited geographic distribution, others such as the Mexican free-tailed bat are abundant and are present throughout all of California. In addition, migratory species may be found in different parts of the state during different times of the year. Finally, some species may forage up to 50 miles around their roosts each night. It is because of the broad distribution of bat populations and expansive home ranges of individual bats, combined with the numerous RVVs adapted to efficient transmission between bats, that the CDPH Director has declared all of California endemic for rabies each year since 1987.

> Rabid bats are the predominant cause of rare human rabies in the U.S. and have been the most frequently reported rabid animal in California since 2000.

Bat RVVs are the predominant cause of human rabies in the United States. Of the 38 U.S. cases of human rabies between 2000 and 2020 that could be attributed to indigenous transmission (case-patient had no history of travel outside the U.S. during the incubation period), exposure to bats or bat RVVs was responsible for 31 (86%) — including California's most recent human rabies case in 2012 [Ma 2021]. The

disproportionate representation of bat RVVs in human rabies epidemiology is likely partly attributable to exposed persons failing to recognize that they sustained a bite—owing to the often imperceptible wounds left by a bat's teeth—and lacking a health impetus to seek medical care and initiate rabies PEP.

Skunks continued to be the second most frequently reported rabid mammal in California in 2022. A RVV circulates in California skunks that is distinct from the North Central and South Central skunk RVVs present throughout the central U.S., from Texas to North Dakota. The California skunk RVV is maintained chiefly along the western Sierra Nevada foothills from Madera County northward to Placer County. These seven counties, plus neighboring Sacramento and San Joaquin counties, accounted for 33 (82%) of 40 rabid skunks in 2022, and 253 (88%) of 287 rabid skunks detected in the last ten years (2013-2022). Sporadic cases of skunk rabies are also occasionally identified in the coastal counties of Monterey and Santa Barbara. In 2021, nearly 700 rabid skunks were reported nationwide—second only to raccoons (1030) as the most commonly identified terrestrial mammal with rabies [Ma 2023].

Foxes are the most commonly identified rabid animal species in California for which there is not an adapted RVV. Rabies cases in California foxes represent transmission of virus from other maintenance species, most likely via oral mucous membrane during predation. The nine rabid foxes in California in 2022 were infected with three different bat RVVs, the California skunk RVV, and one wild canid RVV.

A grey fox in eastern San Bernardino County in 2022 was identified to be infected with a RVV previously recognized only in foxes in Arizona and western New Mexico (Figure F). This fox was the first detection of the Arizona fox RVV within California and the first case of infection with a canine RVV in California since the campaign to control the domestic dog RVV was initiated in the mid-20th century.

A rabies virus maintained in Arizona foxes was identified for the first time in California in 2022.

All canine RVVs circulating today trace ancestry to the period between the late 17th and early 19th centuries when European colonization and transportation of dogs along trade routes helped to disseminate viruses belonging to the Cosmopolitan clade [Troupin 2016]. The domestic dog RVV dominated rabies epidemiology in North America into the 20th century. In the 1920s and 1930s, between 300 and 2000 rabid dogs were identified each year in California. Development and deployment of effective canine rabies vaccines slowed and eventually interrupted transmission of this RVV in the latter 20th century. In 2007, CDC declared the domestic dog RVV eradicated from the United States. Cases of rabies in domestic and wild canids in California and most of the U.S. now chiefly represent incidental spillover of other terrestrial (raccoon, skunk) or volant (bat) RVVs.

Despite the elimination of the domestic dog RVV, other RVVs belonging to the Cosmopolitan dog clade have persisted and adapted to new host species in some areas of the United States. Among these RVVs are a dog-coyote variant in southern

Texas along the U.S.-Mexico border, a grey fox variant in central Texas, and a unique grey fox variant in Arizona. (The Arctic fox RVV present in Alaska and northern Canada does not reflect viral evolutionary adaptation in North America but derives from historical relocation of infected foxes from Asia.). The Texas coyote and grey fox RVVs arose in the 1980s via independent host-shifts from the domestic dog RVV circulating in northern Mexico, which in turn derived from a canine RVV prevalent in Central America [Velasco-Villa 2008]. The Texas fox RVV circulated since at least the 1950s, but an oral rabies vaccination program initiated in 1995 constrained the spread of coyote and fox rabies; the last reported animal (a cow) with the Texas fox RVV occurred in 2013 [Dyer 2014]. Interestingly, the California and North Central skunk RVVs are part of the Cosmopolitan dog clade as well, while the South Central skunk RVV derives from the New World bat lineage. The California skunk RVV demonstrated capacity to host-shift back to canids during an epizootic of rabies in foxes in Humboldt County in 2009.

The Arizona fox RVV is most closely related to, but genetically distinct from, the Texas fox RVV [Velasco-Villa 2017]. The Arizona grey fox RVV has been detected in all but one county in Arizona, precipitates occasional rabies epizootics in fox populations, and is often transmitted to other species including coyotes, bobcats, llamas, horses, javelina, badger, and dogs [Arizona Department of Public Health 2022]. The facility with which these canine lineage RVVs shift among canid species and across non-canid carnivores compels the concession that the domestic dog RVV has been not so much “eradicated” from North America as merely kept at bay. Any of the Cosmopolitan dog RVVs could readily revert to a form efficiently circulated among domestic dogs.

Vaccination, licensure, and control of domestic dogs remain critical to preventing the reemergence of enzootic domestic dog rabies in California.

Canine RVVs could be reintroduced to California through movement of canids across state or international borders. It is assumed that the 2022 rabid fox in California originated in Arizona and was infected with rabies virus prior to its arrival in California. No additional rabid foxes were subsequently identified along the California-Arizona border to suggest ongoing autochthonous transmission. How the fox traveled to California remains unknown. Adult grey foxes have home ranges of only 5-7 miles, but this fox was collected more than 80 miles from the westernmost previous detection of Arizona fox RVV [CDC Rabies and Poxvirus Branch, personal communication]. It is possible that the fox was intentionally or inadvertently carried across the border via human transport. Vigilant and comprehensive rabies vaccination is critical to erect a defensive barricade against canine RVVs regaining a foothold in pet dogs via re-emergence or reintroduction. Thousands of dogs and likely hundreds of people in California died of rabies in the decades preceding enactment of current state laws that mandate vaccination, licensure, and control of domestic dogs.

A single bobcat from Trinity County was identified with rabies in 2022. This is the first rabid bobcat detected in California since 1990 when two rabid bobcats were identified in Mendocino and Monterey counties. Unlike canids, there are no known RVVs that

are specifically adapted to maintenance in wild felids. Bobcats, mountain lions, and other wild felids are susceptible to infection with any volar or terrestrial RVV, such as the *Myotis californicus* bat RVV that infected the 2022 bobcat. Despite being exclusively incidental hosts, bobcats can secondarily transmit rabies virus to other vulnerable mammals, including humans. In 1969, a 2½ year-old boy from San Diego County died of rabies after he sustained multiple severe bites from a rabid bobcat [Emmons et al. 1973]. Between 1966 and 1969, 25 rabid bobcats were detected in San Diego County. The RVVs were not characterized for these cats; but despite the domestic dog RVV having been largely eliminated from California by the 1960s, rabid dogs from Mexico continued to cross into border counties, contributing to increased incidence of rabies in domestic canids in San Diego and Imperial counties in the latter 1960s. (The World Health Organization declared Mexico free of canine rabies in 2019.) It is likely that most or all of the rabid bobcats observed in San Diego during this time, including the one implicated in the human case, were infected with the Mexican dog RVV.

In the last ten years, 23 dogs and cats in California were infected with rabies from wild animals.

Rabies in domestic animals is rare in California with zero to six cases reported each of the last 10 years (2013-2022). All rabid domestic animals represented spillover of virus from wildlife species. Both the rabid dog and rabid cat identified in California in 2022 were infected with the California skunk RVV. Skunks are among the generalist, opportunistic mammals that can survive and frequently thrive on anthropogenic resources emergent from human development and habitation (e.g., food provisioning) [Becker 2015]. The proximal juxtaposition of this "urban wildlife" in and around human residences increases the frequency of encounters between wild mammals and domestic animals that could facilitate transmission of infectious disease agents such as rabies virus. The rabid dog identified in Sacramento County in 2022 was observed behaving abnormally while unconfined in the public right-of-way. The veterinarian to which the dog was presented astutely considered rabies and promptly euthanized the dog and submitted the brain for testing. While the general risk to humans of contracting rabies from a domestic dog bite in California is very low, any bite from a dog that lacks an identifiable owner and known medical history, including vaccination, should precipitate a heightened concern for rabies and urgency for initiating rabies PEP, until/unless testing or quarantine of the dog excludes the possibility of rabies infection.

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Table A. Reported cases of rabies in animals, California, 2022.

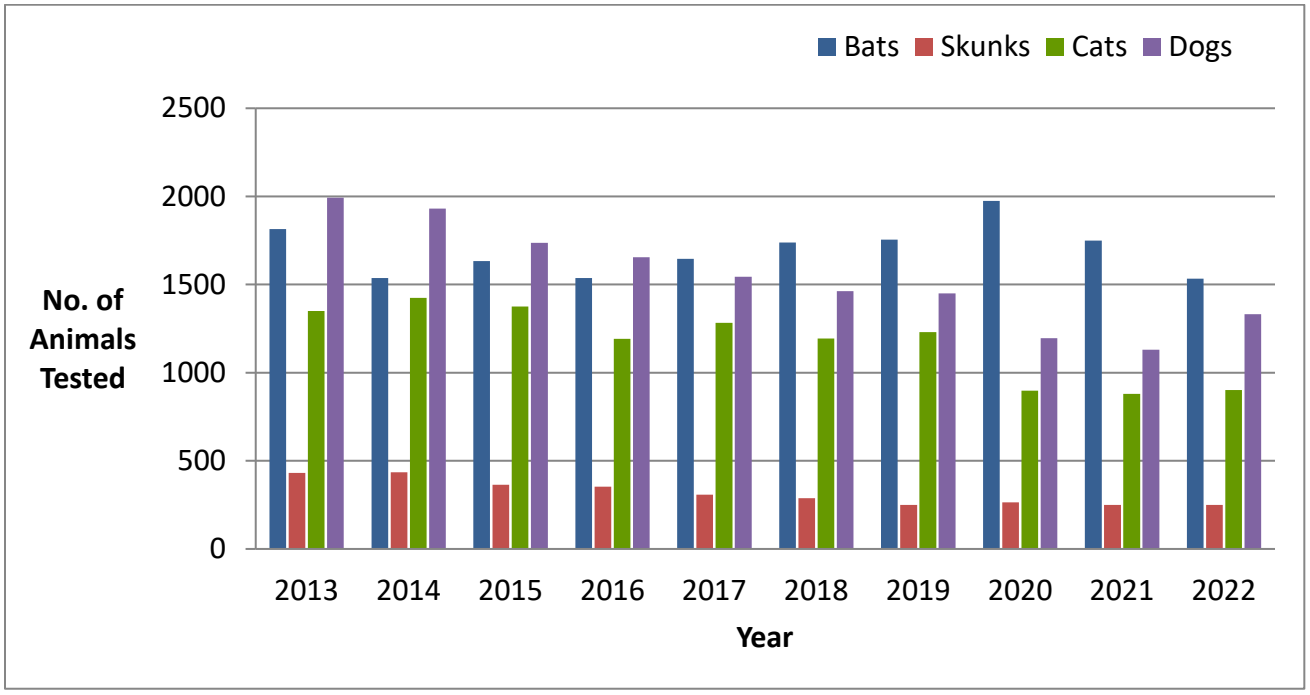
COUNTY	BAT	SKUNK	CAT	DOG	BOBCAT	FOX	HORSE	SHEEP	CATTLE	RACCOON	TOTAL
TOTAL	189	40	1	1	1	9	0	0	0	0	241
Alameda	2	0	0	0	0	0	0	0	0	0	2
-Berkeley City	0	0	0	0	0	0	0	0	0	0	0
Alpine	0	0	0	0	0	0	0	0	0	0	0
Amador	1	2	0	0	0	1	0	0	0	0	4
Butte	3	6	0	0	0	0	0	0	0	0	9
Calaveras	3	2	0	0	0	1	0	0	0	0	6
Colusa	0	0	0	0	0	0	0	0	0	0	0
Contra Costa	2	0	0	0	0	0	0	0	0	0	2
Del Norte	1	0	0	0	0	0	0	0	0	0	1
El Dorado	2	17	1	0	0	0	0	0	0	0	20
Fresno	2	0	0	0	0	0	0	0	0	0	2
Glenn	0	0	0	0	0	0	0	0	0	0	0
Humboldt	0	0	0	0	0	2	0	0	0	0	2
Imperial	0	0	0	0	0	0	0	0	0	0	0
Inyo	0	0	0	0	0	0	0	0	0	0	0
Kern	0	0	0	0	0	0	0	0	0	0	0
Kings	0	0	0	0	0	0	0	0	0	0	0
Lake	0	0	0	0	0	0	0	0	0	0	0
Lassen	0	0	0	0	0	0	0	0	0	0	0
Los Angeles	50	0	0	0	0	0	0	0	0	0	50
-Long Beach City	0	0	0	0	0	0	0	0	0	0	0
-Pasadena City	0	0	0	0	0	0	0	0	0	0	0
Madera	3	0	0	0	0	0	0	0	0	0	3
Marin	11	0	0	0	0	0	0	0	0	0	11
Mariposa	0	1	0	0	0	0	0	0	0	0	1
Mendocino	0	0	0	0	0	0	0	0	0	0	0
Merced	0	0	0	0	0	0	0	0	0	0	0
Modoc	0	0	0	0	0	0	0	0	0	0	0
Mono	0	0	0	0	0	0	0	0	0	0	0
Monterey	3	1	0	0	0	0	0	0	0	0	4
Napa	2	0	0	0	0	0	0	0	0	0	2
Nevada	1	1	0	0	0	0	0	0	0	0	2
Orange	18	0	0	0	0	0	0	0	0	0	18
Placer	0	2	0	0	0	0	0	0	0	0	2
Plumas	0	0	0	0	0	1	0	0	0	0	1
Riverside	13	0	0	0	0	0	0	0	0	0	13
Sacramento	3	6	0	1	0	0	0	0	0	0	10

Source: California Department of Public Health, Veterinary Public Health Section

Table A (continued). Reported cases of rabies in animals, California, 2022.

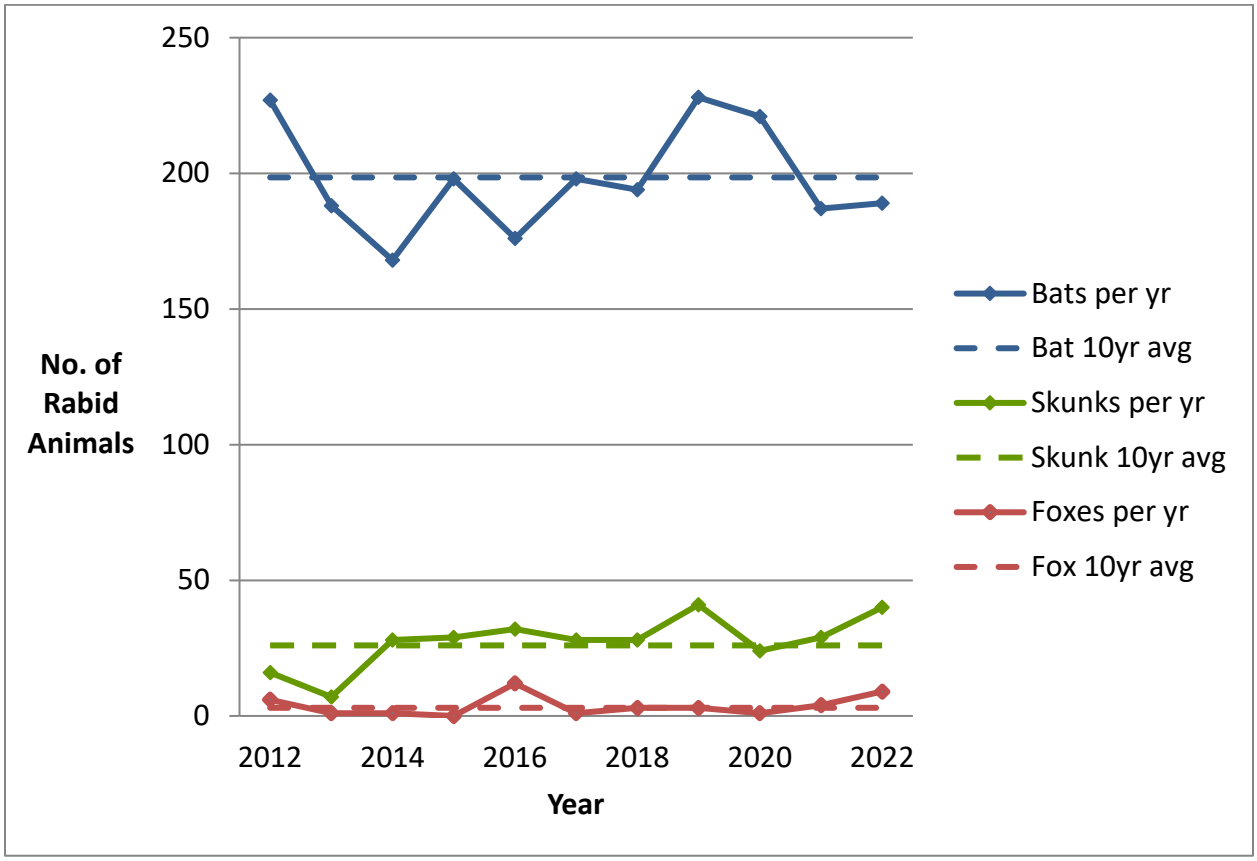
COUNTY	BAT	SKUNK	CAT	DOG	BOBCAT	FOX	HORSE	SHEEP	CATTLE	RACCOON	TOTAL
San Benito	0	0	0	0	0	0	0	0	0	0	0
San Bernardino	16	0	0	0	0	1	0	0	0	0	17
San Diego	3	0	0	0	0	0	0	0	0	0	3
San Francisco	2	0	0	0	0	0	0	0	0	0	2
San Joaquin	1	2	0	0	0	0	0	0	0	0	3
San Luis Obispo	1	0	0	0	0	0	0	0	0	0	1
San Mateo	2	0	0	0	0	0	0	0	0	0	2
Santa Barbara	4	0	0	0	0	0	0	0	0	0	4
Santa Clara	7	0	0	0	0	0	0	0	0	0	7
Santa Cruz	2	0	0	0	0	0	0	0	0	0	2
Shasta	2	0	0	0	0	0	0	0	0	0	2
Sierra	0	0	0	0	0	0	0	0	0	0	0
Siskiyou	0	0	0	0	0	0	0	0	0	0	0
Solano	3	0	0	0	0	0	0	0	0	0	3
Sonoma	4	0	0	0	0	0	0	0	0	0	4
Stanislaus	0	0	0	0	0	0	0	0	0	0	0
Sutter	1	0	0	0	0	0	0	0	0	0	1
Tehama	0	0	0	0	0	0	0	0	0	0	0
Trinity	0	0	0	0	1	3	0	0	0	0	4
Tulare	0	0	0	0	0	0	0	0	0	0	0
Tuolumne	0	0	0	0	0	0	0	0	0	0	0
Ventura	6	0	0	0	0	0	0	0	0	0	6
Yolo	11	0	0	0	0	0	0	0	0	0	11
Yuba	4	0	0	0	0	0	0	0	0	0	4

Source: California Department of Public Health, Veterinary Public Health Section



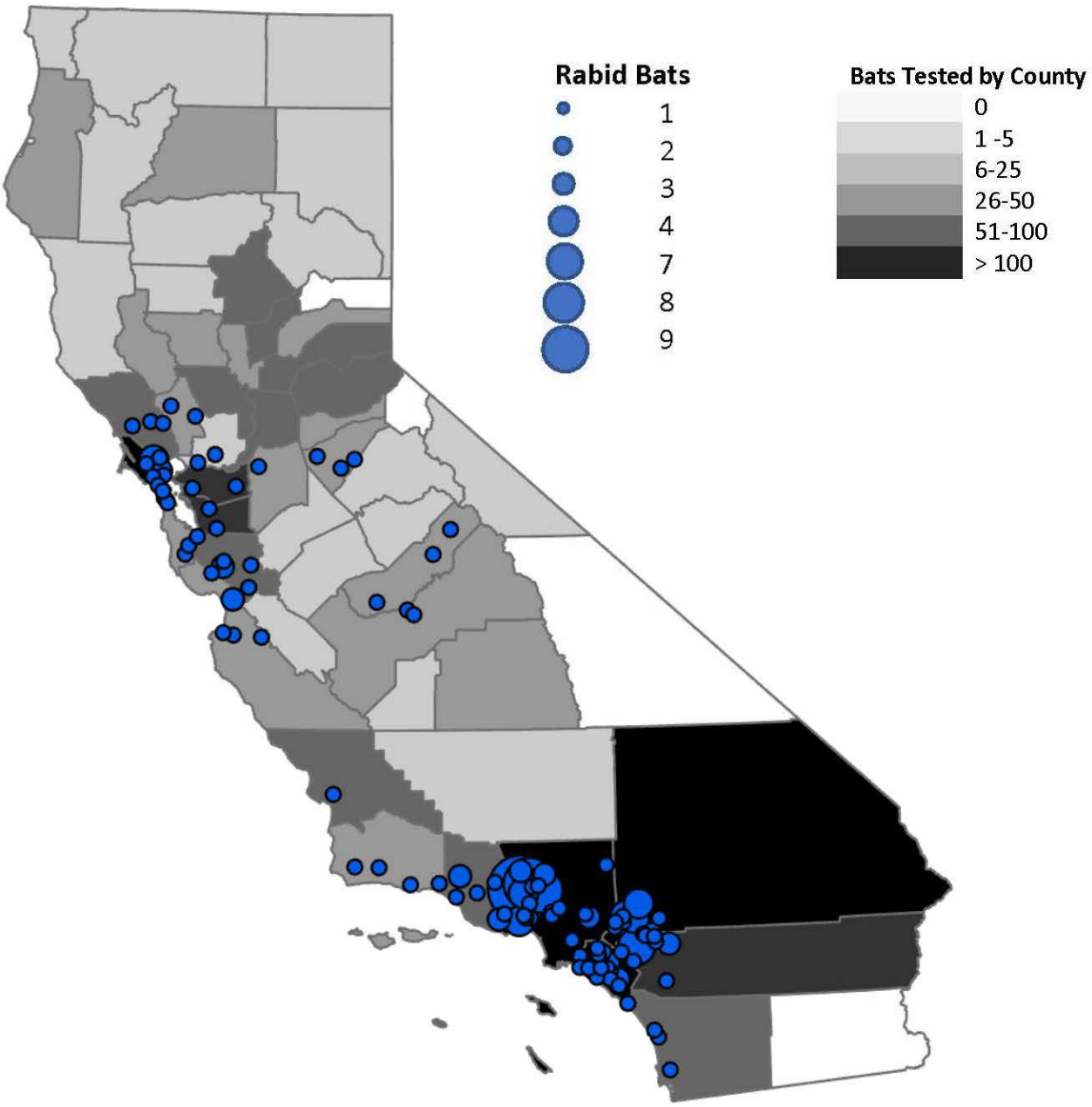
Source: California Department of Public Health, Veterinary Public Health Section

Figure A. Selected wild and domestic animals tested for rabies in California, 2013-2022.



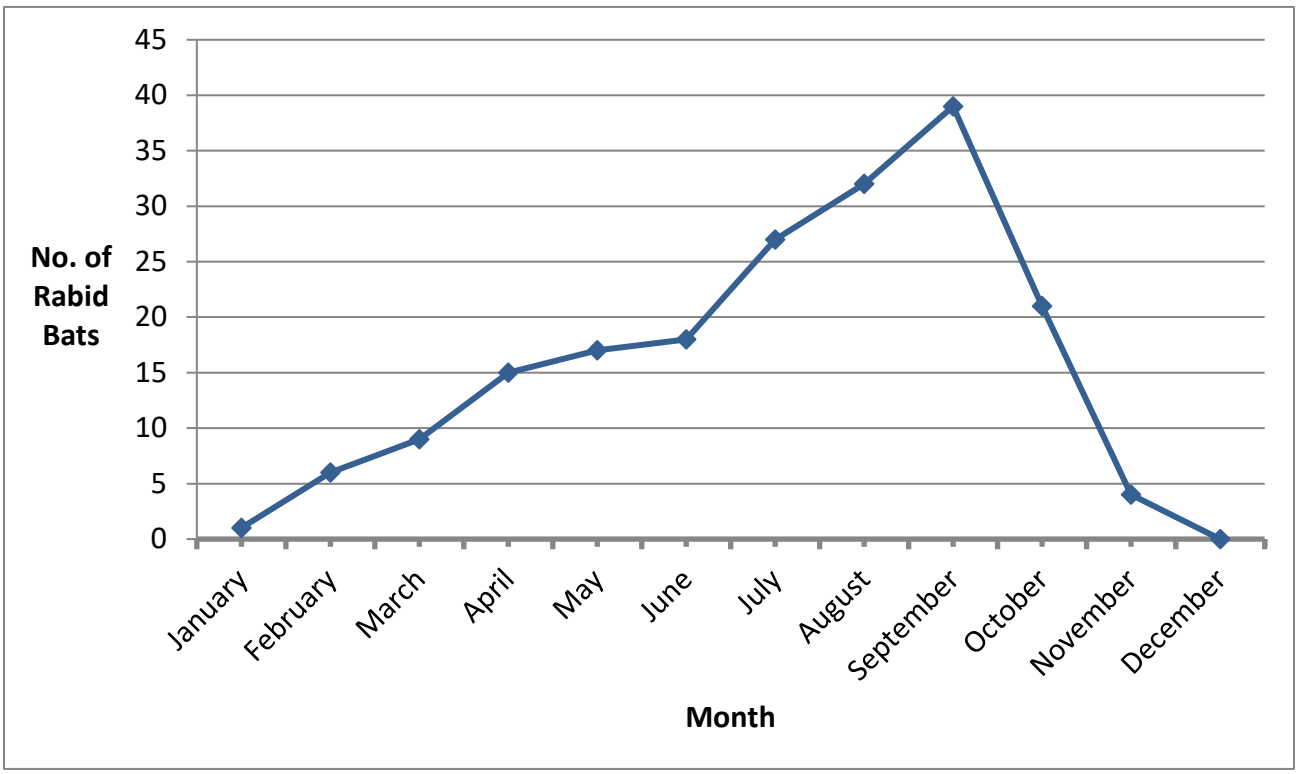
Source: California Department of Public Health, Veterinary Public Health Section

Figure B. Cases of rabies in wild animals in California, 2012-2022.
(Ten-year averages represent 2012-2021 data.)



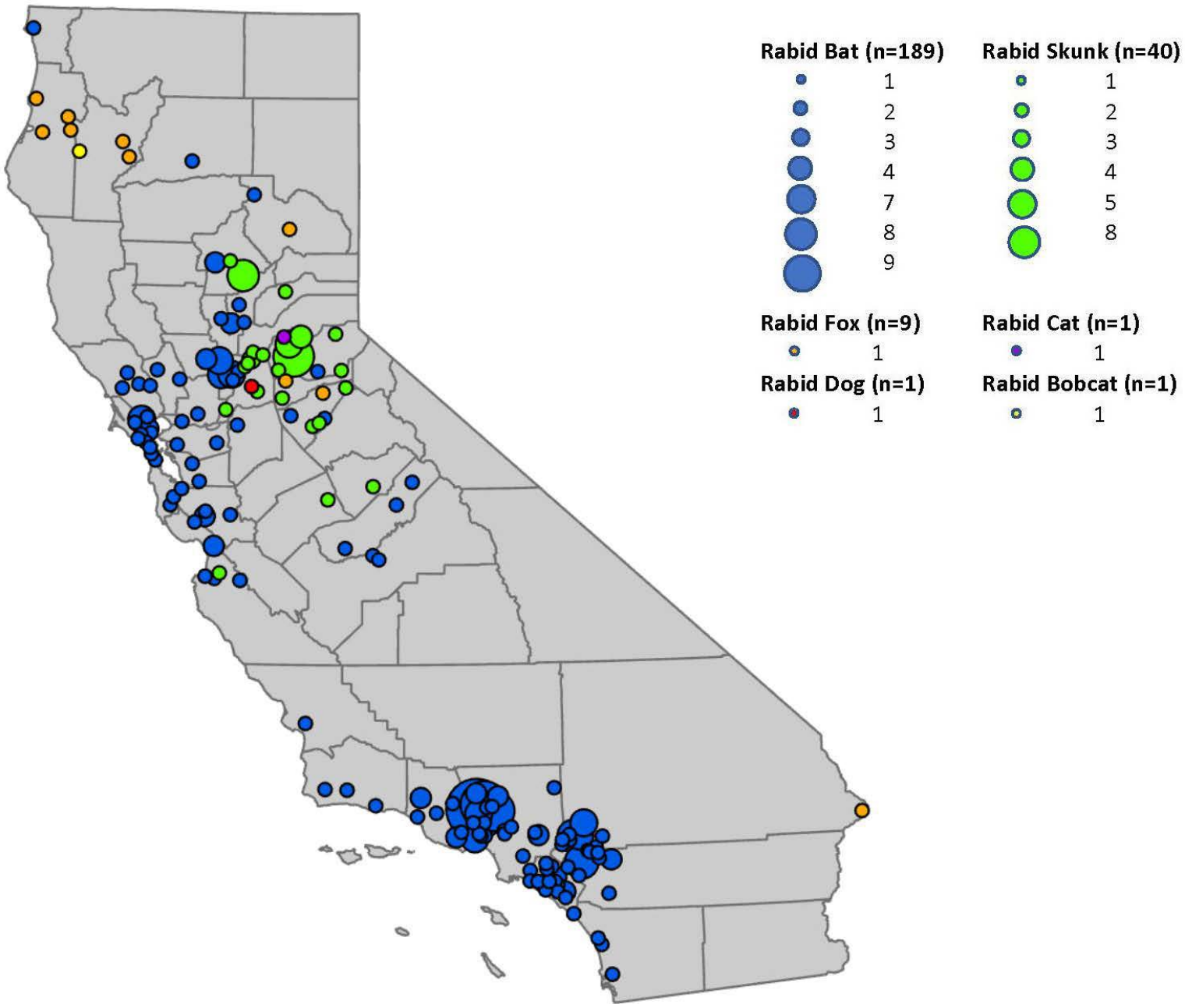
Source: California Department of Public Health, Veterinary Public Health Section

Figure C. Bats tested for rabies by county with positive cases by zip code of collection site, California, 2022.



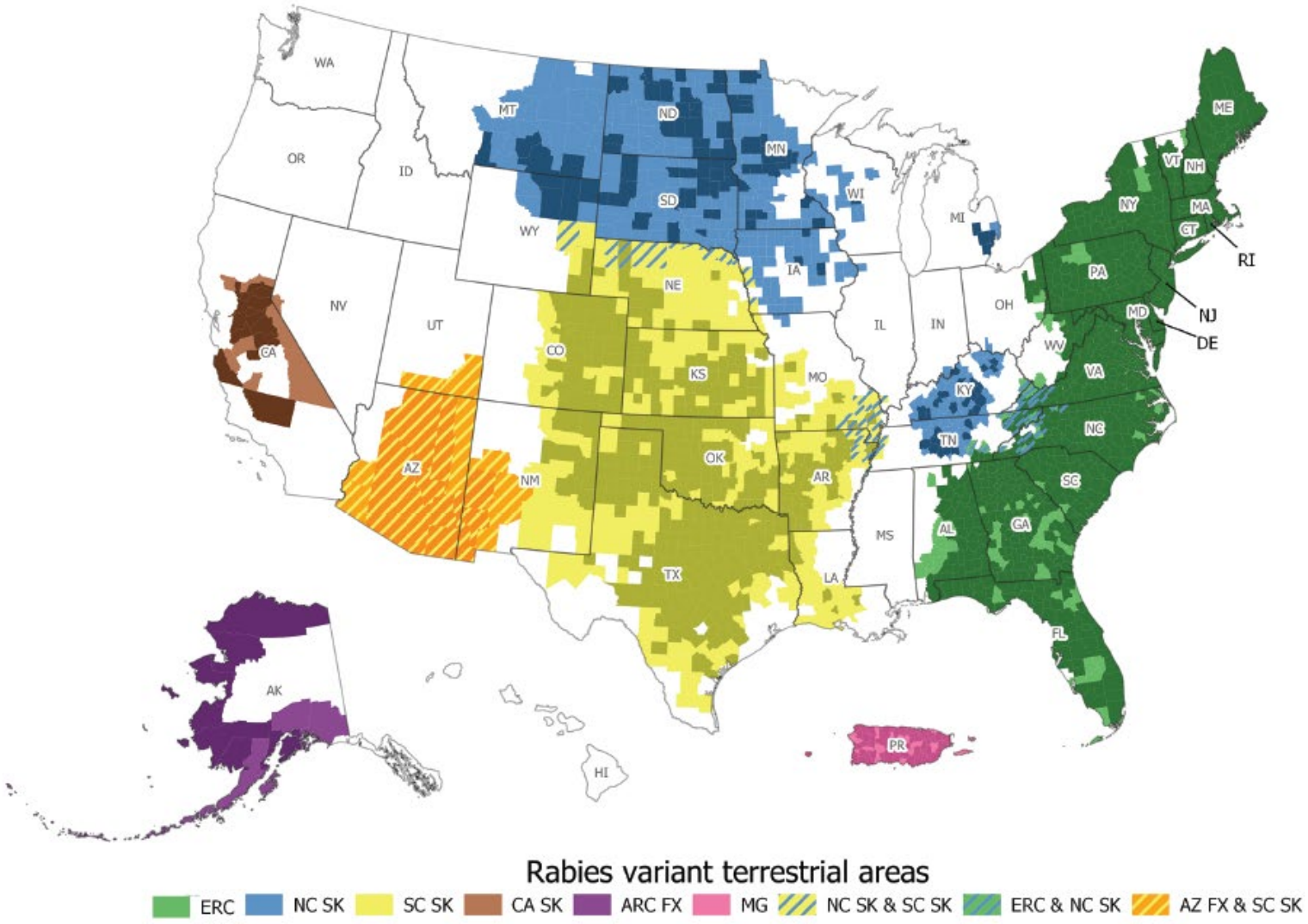
Source: California Department of Public Health, Veterinary Public Health Section

Figure D. Cases of rabies in bats by month of testing, California, 2022.



Source: California Department of Public Health, Veterinary Public Health Section

Figure E. Reported cases of rabies in wild animals by zip code of collection site, California, 2022.



Source: Ma X, Bonaparte S, Corbett P, et al. Rabies surveillance in the United States during 2021. *J Am Vet Med Assoc* 2023; 261:1045-1053.

Figure F. Distribution of major rabies virus variants (RVVs) among mesocarnivores in the U.S., including Puerto Rico, for 2017 through 2021. Darker shading indicates counties with confirmed animal rabies cases in the past 5 years; lighter shading represents counties bordering enzoötic counties with animal rabies cases that did not satisfy criteria for adequate surveillance. Small nonenzoötic areas with no rabies cases reports in the past 15 years are shaded if they are in the vicinity of a known enzoötic counties and do not satisfy criteria for adequate surveillance. ARC FX = Arctic fox RVV, AZ FX = Arizona fox RVV, CA SK = California skunk RVV, ERC = Eastern raccoon RVV, MG = Dog-mongoose RVV, NC SK = North central skunk RVV, SC SK = South central skunk RVV.