Rabies surveillance in the United States during 2018

Xiaoyue Ma MPH
Ben P. Monroe MPH
Julie M. Cleaton MPH
Lillian A. Orciari MS
Crystal M. Gigante PhD
Jordona D. Kirby MS
Richard B. Chipman MS
Christine Fehlner-Gardiner PhD
Veronica Gutiérrez Cedillo PhD
Brett W. Petersen MD
Victoria Olson PhD
Ryan M. Wallace DVM

From the Poxvirus and Rabies Branch, Division of High-Consequence Pathogens and Pathology, National Center for Emerging and Zoonotic Infectious Diseases, CDC, 1600 Clifton Rd NE, Atlanta, GA 30333 (Ma, Monroe, Cleaton, Orciari, Gigante, Petersen, Olson, Wallace); Wildlife Services, APHIS, USDA, 59 Chenell Dr, Ste 7, Concord, NH 03301 (Kirby, Chipman); Center of Expertise for Rabies, Canadian Food Inspection Agency, 3851 Fallowfield Rd, Nepean, ON K2J 4S1, Canada (Fehlner-Gardiner); Centro Nacional de Programas Preventivos y Control de Enfermedades, Secretaria de Salud de Mexico, Avenida Benjamín Franklin 132, Escandón II Secc, 11800 Miguel Hidalgo, CDMX, Mexico (Gutiérrez Cedillo); and Oak Ridge Institute for Science and Education, 1299 Bethel Valley Rd, Oak Ridge, TN 37830 (Cleaton).

Address correspondence to Ms. Ma (HJV4@cdc.gov).

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OBJECTIVE
To describe rabies and rabies-related events occurring during 2018 in the United States.

ANIMALS
All animals submitted for laboratory diagnosis of rabies in the United States during 2018.

PROCEDURES
State and territorial public health departments provided data on animals submitted for rabies testing in 2018. Data were analyzed temporally and geographically to assess trends in domestic animal and wildlife rabies cases.

RESULTS
During 2018, 54 jurisdictions reported 4,951 rabid animals to the CDC, representing an 11.2% increase from the 4,454 rabid animals reported in 2017. Texas (n = 695 [14.0%]), Virginia (382 [7.7%]), Pennsylvania (356 [7.2%]), North Carolina (332 [6.7%]), Colorado (328 [6.6%]), and New York (320 [6.5%]) together accounted for almost half of all rabid animals reported in 2018. Of the total reported rabies cases, 4,589 (92.7%) involved wildlife, with bats (n = 1,635 [33.0%]), raccoons (1,499 [30.3%]), skunks (1,004 [20.3%]), and foxes (357 [7.2%]) being the major species. Rabid cats (n = 241 [4.9%]) and dogs (63 [1.3%]) accounted for > 80% of rabid domestic animals reported in 2018. There was a 4.6% increase in the number of samples submitted for testing in 2018, compared with the number submitted in 2017. Three human rabies deaths were reported in 2018, compared with 2 in 2017.

CONCLUSIONS AND CLINICAL RELEVANCE
The overall number of animal rabies cases increased from 2017 to 2018. Laboratory diagnosis of rabies in animals is critical to ensure that human rabies postexposure prophylaxis is administered judiciously. (*J Am Vet Med Assoc* 2020;256:195–208)

The present report provides detailed information on the epidemiology of rabies and rabies-associated events in the United States during 2018 as well as a brief update of rabies in 2019. Summaries of 2018 rabies surveillance data for Canada and Mexico are also provided.

Rabies is a viral zoonosis caused by any of the 15 recognized viruses of the genus *Lyssavirus*. Globally, however, the rabies virus is the leading cause of rabies and is responsible for an estimated 59,000 human deaths annually.[1] Although all mammals are susceptible to rabies virus infection, certain reservoir species are responsible for maintaining enzootic transmission. There is great diversity in the global epidemiology of rabies and distribution of rabies virus reservoir species. Rabies and nonrabies lyssaviruses are found in the Americas, Europe, Asia, Africa, and Australia. At least 30 reservoir species have been identified, consisting primarily of terrestrial carnivores, hematophagous bats, and insectivorous bats. Globally, the canine RVV, maintained by domestic dogs, presents the greatest human health risk and has been implicated in > 99% of human rabies deaths.[2]

In the United States, national canine rabies control efforts began in earnest in the early 1940s and led to elimination of the canine RVV from the country during the late 1970s. Since then, wildlife has accounted for > 90% of all rabid animals. The primary reservoir species responsible for maintaining RVVs in the United States are bats (multiple RVVs in multiple species), raccoons (raccoon RVV), striped skunks (south central, north central, and California skunk RVVs), gray foxes (Arizona gray fox RVV), arctic foxes (arctic fox RVV), and mongooses (dog-mongoose RVV

ABBREVIATIONS

CI	Confidence interval
ORV	Oral rabies vaccine
PEP	Postexposure prophylaxis
RVV	Rabies virus variant

in Puerto Rico). With the exception of bat RVVs, circulation of distinct RVVs associated with the major animal reservoir species occurs in geographically distinct regions where transmission is primarily between members of the same species **(Figure 1)**. In contrast, the volant nature of bats has resulted in broader distribution of their associated RVVs and more frequent transmission between closely related bat species.[3–5]

In the United States, the number of human rabies cases has been dramatically reduced through the successful elimination of canine RVVs, animal control programs, vaccination of domestic animals and wildlife, timely administration of PEP, and education of health-care professionals and the public. Despite these advances, human rabies exposures remain relatively common as a result of interactions with wildlife and unvaccinated domestic animals, and an estimated 60,000 people are treated for rabies exposure annually in the United States.[6] In addition, human rabies cases continue to occur and are primarily associated with bat exposures in the United States or exposure to rabid dogs in countries where the canine RVV is still endemic.[7,8] Appropriate risk assessment of potential rabies virus exposures, including observation and testing of animals for rabies, is critical to ensure that rabies PEP is administered judiciously. In the case of a potential rabies virus exposure involving a cat, dog, or ferret, a 10-day animal observation period is routinely recommended.[9,10] In the instance of exposures involving other species, including wildlife, animals should be submitted for rabies testing when available to rule out the risk of rabies transmission.[11,12]

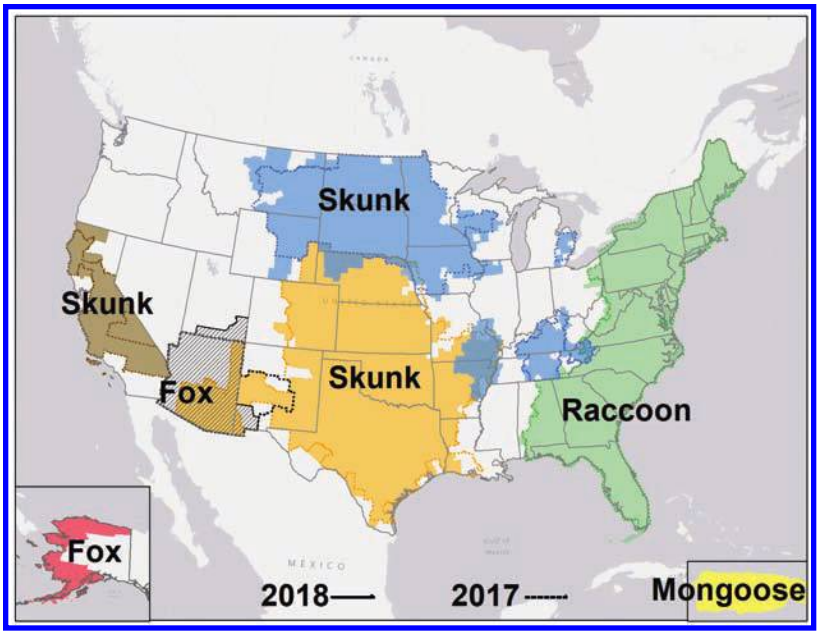

Figure 1—Distribution of major RVVs among mesocarnivores in the United States and Puerto Rico. The areas indicated by black diagonal stripes represents the distribution of Arizona gray fox RVV. The solid-colored areas represent RVV distributions for 2014 through 2018; dashed borders represent the previous 5-year distributions for 2013 through 2017.

Prevention of rabies in domestic pets through vaccination remains an important barrier to reduce the likelihood of human exposure to rabies. The primary rabies control effort involving wildlife is a large-scale program led by the Wildlife Services division of the USDA APHIS. The USDA APHIS manages a national wildlife vaccination program, started in 1995, that distributes ORVs by means of fixed-wing aircraft in rural areas and ground vehicles, helicopters, and bait stations in urban and suburban areas.[13] Currently, 2 ORVs are used in the United States: a licensed vaccinia-rabies glycoprotein recombinant vaccine and an experimental adenovirus-rabies glycoprotein recombinant vaccine. Ever since the cooperative program was begun, it has shown success in contributing to the elimination of the dog-coyote and gray fox RVVs from Texas and in preventing the westward expansion of the raccoon RVV from the eastern United States.[13,14] However, vaccination of bats is currently not feasible. Thus, preventing human infections with bat-associated RVVs relies on intervention methods such as health education, exposure prevention, and PEP.

Rabies virus is most commonly transmitted via a bite from a rabid animal but can also be transmitted when fresh saliva from an infected mammal comes into contact with wounds or mucous membranes of another mammal. Rabies is almost inevitably fatal once clinical signs develop. However, rabies can be prevented in people if PEP is appropriately administered prior to symptom onset. For healthy exposed persons who have never been vaccinated against rabies, PEP consists of immediate wound washing, infiltration of the wound with human rabies immune globulin, and IM administration of 4 doses of cell culture–derived vaccine on days 0, 3, 7, and 14.[9,11] For persons with immunosuppression, a fifth dose of vaccine is recommended on day 28. Recommended PEP for exposed persons who have been previously vaccinated consists of 2 booster doses of rabies vaccine on days 0 and 3.[11]

Reporting and Analysis

Human and animal rabies were designated as nationally notifiable conditions in the United States in 1944.[15] In the United States, the national rabies surveillance system is a laboratory-based system that consists of 125 state public health, agriculture, and university laboratories performing the standard direct fluorescent antibody test.[16] These state laboratories test animals collected through passive surveillance, and their work represents 95% of annual animal rabies surveillance activities. In addition, USDA APHIS

Wildlife Services conducts active surveillance in selected areas and tests animals with the direct rapid immunohistochemical test.[17] Confirmatory testing by means of direct fluorescent antibody testing and variant typing are performed on a case-by-case basis at the national rabies reference laboratory in Atlanta and at several regional reference laboratories.

The CDC national rabies surveillance system collects detailed information on all animals submitted for rabies testing, including animal species, location information (county and state), date of testing or specimen collection (or both), test used (direct fluorescent antibody test or direct rapid immunohistochemical test), and test result. In addition, information on vaccination status, whether there were any human or animal exposures, and results of RVV typing are obtained when available.[18] The Council for State and Territorial Epidemiologists advises that a diagnosis of rabies in any animal with a history of international travel in the past 60 days or in any human should be reported to the CDC within 24 hours. A diagnosis of rabies in an animal without a history of international travel should be reported to the CDC's National Rabies Surveillance System under standard notification timelines.[19]

For the present report, animal rabies cases in 2018 were summarized by reporting jurisdiction and reservoir, and results for 2018 were compared with historical trends. Percentages of rabid animals were calculated with only those animals with a positive or negative test result included in the denominator. Animals considered to be in an unsatisfactory condition for testing or with an indeterminate test result were excluded from these calculations. Rabies testing is primarily conducted as part of passive public health investigations of human or domestic animal exposures. Thus, the percentages of rabid animals reported here are not reflective of the true incidence of rabies in the general population. The spatial distribution of rabies cases was analyzed for major wildlife reservoirs (bats, raccoons, skunks, and foxes) and domestic animals (dogs and cats).

The geographic distribution of RVVs in terrestrial reservoirs in the United States was determined by aggregating counts of rabid animals from 2013 through 2018 by county and species (Figure 1). Rabies was considered enzootic in the local terrestrial reservoir species for counties that reported ≥ 1 rabid terrestrial animal during that 5-year period, unless additional testing confirmed that rabies was due to infection with a bat RVV or an epidemiological investigation found that the case was a result of translocation and no additional cases were reported during the following 12 months. Counties within a region in which terrestrial rabies was enzootic were considered to be free from terrestrial rabies if the county had not reported any rabies cases involving terrestrial animals during the preceding 5 years and the following conditions were met: the county had tested ≥ 15 terrestrial reservoir animals or ≥ 30 domestic vector species (dogs, cats, or cattle) during the past 5 years and all results were negative, and all bordering counties had reported no rabies cases in terrestrial animals in the past 5 years.

Numbers of rabies cases involving the major wildlife reservoir species (bats, raccoons, skunks, and foxes) for 1966 through 2018 were analyzed to determine temporal trends **(Figure 2)**. Skunks infected with the raccoon RVV were analyzed separately from those infected with a skunk RVV. For purposes of this trend analysis, all terrestrial animals with rabies were presumed to have been infected with the RVV endemic to the county of diagnosis.[3]

Summaries of 2018 rabies surveillance data for Canada and Mexico were provided by the Canadian Food Inspection Agency Centre of Expertise for Rabies[20] and the Centro Nacional de Programas Preventivos y Control de Enfermedades of the Secretaria de Salud (Ministry of Health), respectively.

Samples Tested for Rabies

During 2018, a total of 100,267 animal samples were submitted for laboratory testing for rabies in the United States and territories (29.9 animals tested/100,000 US human population), of which 97,735 (97.5%) were considered suitable for testing (this number included samples with positive, negative, and indeterminate test results). This represented a 4.4% increase in the number of animals tested, compared

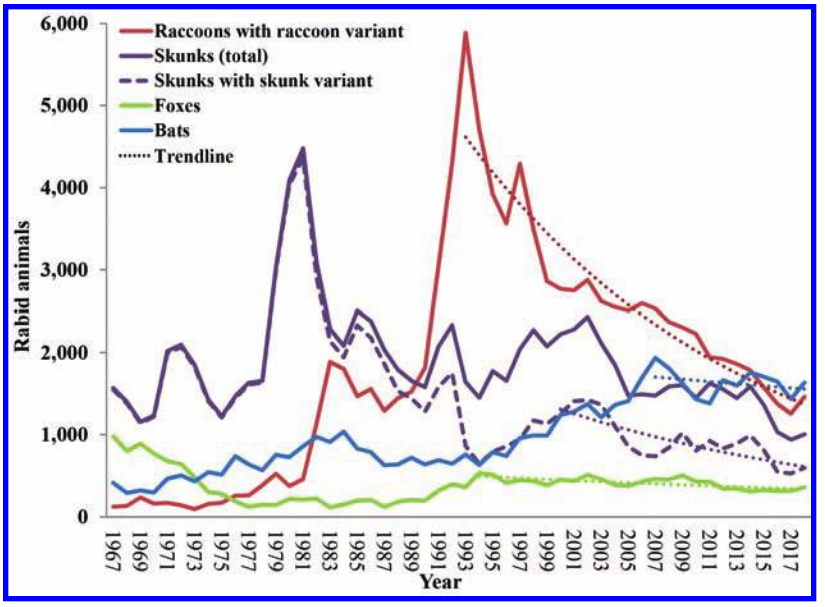

Figure 2—Cases of rabies among wildlife in the United States, by year and species, for 1966 through 2018.

with the number tested during 2017 (n = 93,651). During 2018, USDA Wildlife Services tested 6,602 animals with the direct rapid immunohistochemical test, accounting for 6.8% of all animals tested in 2018. A total of 4,951 animal rabies cases were reported in 2018, an 11.2% increase from the number reported in 2017 (n = 4,454).

Rabies in Wildlife

Wildlife accounted for 92.7% (4,589/4,951) of animal rabies cases reported in 2018, representing a 13.2% increase from the 4,055 rabid wildlife reported in 2017 **(Table 1)**. In 2018, bats were the most frequently reported rabid animals in the United States, representing 33.0% (n = 1,635) of all animal rabies cases, followed by raccoons (30.3% [1,499]), skunks (20.3% [1,004]), and foxes (7.2% [357]).

Bats

During 2018, 27,483 bats were tested, of which 1,635 (5.9%) were confirmed positive for rabies. This represented a 14.1% increase from the number of rabid bats reported in 2017 (n = 1,433; Table 1). The percentage of rabid bats among the total tested (5.9%) was similar to the mean percentage during the previous 5 years (6.3%; 95% CI, 5.9% to 6.7%; **Table 2**). Forty-seven jurisdictions reported rabid bats during 2018 **(Figure 3)**. No rabid bats were reported in Alaska, the District of

Table 1—Number of cases of rabies in the United States, by location, during 2018.

					Domestic animals						Wildlife									
Location	Primary reservoir	Total animal cases	Domestic animals	Wildlife	Cats	Cattle	Dogs	Horses and donkeys	Sheep and goats	Other domestic*	Bats	Raccoons	Skunks	Foxes	Other wildlife†	Rodents and lagomorphs‡	Humans	% Pos 2018	2017 cases	Change (%)
AK	Arctic fox	9	2	7	0	0	2	0	0	0	0	0	0	5	2[c]	0	0	23.1%	12	−25.0%
AL	Raccoon	57	0	57	0	0	0	0	0	0	9	33	2	13	0	0	0	2.9%	52	9.6%
AR	Skunk	31	2	29	0	1	1	0	0	0	12	0	17	0	0	0	0	3.7%	43	−27.9%
AZ	Skunk	163	1	162	0	1	0	0	0	0	54	2	36	59	11[d]	0	0	15.8%	152	7.2%
CA	Skunk	226	0	226	0	0	0	0	0	0	194	1	28	3	0	0	0	4.4%	231	−2.2%
CO	Skunk	328	11	317	6	0	4	0	0	1[a]	80	3	233	0	1[e]	0	0	16.0%	165	98.8%
CT	Raccoon	40	5	35	5	0	0	0	0	0	14	15	2	3	0	1[t]	0	3.3%	41	−2.4%
DC	Raccoon	22	1	21	1	0	0	0	0	0	0	21	0	0	0	0	0	9.1%	23	−4.3%
DE	Raccoon	21	8	13	5	0	1	2	0	0	0	8	0	5	0	0	1	13.1%	16	31.3%
FL	Raccoon	110	17	93	16	0	1	0	0	0	20	61	1	10	1[f]	0	1	4.2%	79	39.2%
GA	Raccoon	261	25	236	16	0	7	0	2	0	18	146	42	24	5[g]	1[u]	0	13.4%	253	3.2%
HI	None	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0%	0	0.0%
IA	Skunk	10	1	9	0	1	0	0	0	0	9	0	0	0	0	0	0	0.7%	10	0.0%
ID	Bat	12	0	12	0	0	0	0	0	0	12	0	0	0	0	0	0	3.5%	15	−20.0%
IL	Bat	85	0	85	0	0	0	0	0	0	85	0	0	0	0	0	0	2.2%	58	46.6%
IN	Bat	13	0	13	0	0	0	0	0	0	13	0	0	0	0	0	0	1.0%	14	−7.1%
KS	Skunk	30	3	27	0	2	0	1	0	0	3	1	22	1	0	0	0	2.8%	40	−25.0%
KY	Skunk	18	0	18	0	0	0	0	0	0	13	0	4	1	0	0	0	2.2%	11	63.6%
LA	Skunk	11	1	10	1	0	0	0	0	0	9	0	1	0	0	0	0	1.9%	15	−26.7%
MA	Raccoon	100	6	94	6	0	0	0	0	0	26	41	16	8	1[h]	2[v]	0	3.8%	98	2.0%
MD	Raccoon	268	28	240	24	2	2	0	0	0	26	168	15	23	4[i]	4[w]	0	7.8%	242	10.7%
ME	Raccoon	109	1	108	1	0	0	0	0	0	12	55	28	9	1[j]	3[x]	0	10.0%	71	53.5%
MI	Skunk	79	0	79	0	0	0	0	0	0	77	0	2	0	0	0	0	2.2%	38	107.9%
MN	Skunk	32	2	30	1	0	1	0	0	0	27	0	3	0	0	0	0	1.6%	35	−8.6%
MO	Skunk	20	2	18	1	0	1	0	0	0	14	0	4	0	0	0	0	1.0%	20	0.0%
MS	Bat	5	0	5	0	0	0	0	0	0	5	0	0	0	0	0	0	1.2%	1	400.0%
MT	Skunk	17	1	16	1	0	0	0	0	0	15	0	1	0	0	0	0	3.6%	13	30.8%
NC	Raccoon	332	19	313	13	2	3	1	0	0	24	169	58	55	7[k]	0	0	7.7%	273	21.6%
ND	Skunk	12	5	7	1	3	1	0	0	0	3	0	4	0	0	0	0	2.5%	14	−14.3%
NE	Skunk	22	3	19	1	1	0	1	0	0	17	0	2	0	0	0	0	1.6%	19	15.8%
NH	Raccoon	33	2	31	1	0	0	0	1	0	4	12	6	7	0	2[y]	0	6.1%	28	17.9%
NJ	Raccoon	201	16	185	16	0	0	0	0	0	36	112	29	6	0	2[z]	0	7.3%	207	−2.9%
NM	Skunk	15	1	14	1	0	0	0	0	0	6	0	7	1	0	0	0	3.0%	13	15.4%
NV	Bat	14	0	14	0	0	0	0	0	0	14	0	0	0	0	0	0	3.8%	10	40.0%
NY	Raccoon	320	24	296	19	1	1	1	2	0	106	125	25	29	8[l]	3[aa]	0	5.4%	276	15.9%
NYC	Raccoon	14	1	13	1	0	0	0	0	0	0	10	2	0	1[m]	0	0	2.3%	18	−22.2%
OH	Bat	54	0	54	0	0	0	0	0	0	42	11	0	1	0	0	0	1.2%	21	157.1%
OK	Skunk	30	3	27	1	2	0	0	0	0	1	0	25	1	0	0	0	4.0%	42	−28.6%
OR	Bat	15	0	15	0	0	0	0	0	0	15	0	0	0	0	0	0	4.3%	17	−11.8%
PA	Raccoon	356	45	311	35	3	5	1	1	0	48	193	36	28	1[n]	5[ab]	0	5.5%	381	−6.6%
PR	Mongoose	31	17	14	3	0	13	1	0	0	0	0	0	0	14[o]	0	0	38.3%	31	0.0%
RI	Raccoon	21	1	20	1	0	0	0	0	0	9	9	1	1	0	0	0	3.3%	17	23.5%
SC	Raccoon	100	19	81	15	2	1	0	1	0	13	42	16	9	1[p]	0	0	6.6%	63	58.7%
SD	Skunk	15	1	14	0	1	0	0	0	0	6	0	8	0	0	0	0	2.8%	22	−31.8%
TN	Skunk	29	1	28	0	0	1	0	0	0	6	3	19	0	0	0	0	1.5%	35	−17.1%
TX	Skunk	695	36	659	14	2	15	3	2	0	422	30	188	15	4[q]	0	0	5.7%	679	2.4%
UT	Bat	14	0	14	0	0	0	0	0	0	14	0	0	0	0	0	1	4.7%	23	−39.1%
VA	Raccoon	382	42	340	29	8	3	1	0	1[b]	21	192	85	35	4[r]	3[ac]	0	10.8%	355	7.6%
VT	Raccoon	24	1	23	1	0	0	0	0	0	5	11	3	2	1[s]	1[ad]	0	2.1%	41	−41.5%
WA	Bat	40	0	40	0	0	0	0	0	0	40	0	0	0	0	0	0	6.6%	22	81.8%
WI	Skunk	25	0	25	0	0	0	0	0	0	25	0	0	0	0	0	0	1.3%	29	−13.8%
WV	Raccoon	40	6	34	5	0	0	0	1	0	2	25	4	3	0	0	0	3.7%	38	5.3%
WY	Skunk	40	2	38	0	1	0	1	0	0	9	0	29	0	0	0	0	4.6%	32	25.0%
Total	—	**4,951**	**362**	**4,589**	**241**	**33**	**63**	**13**	**10**	**2**	**1,635**	**1,499**	**1,004**	**357**	**67**	**27**	**3**	5.1%	**4,454**	11.2%
	% 2018	100.0	7.3%	92.7%	4.9%	0.7%	1.3%	0.3%	0.2%	0.0%	33.0%	30.3%	20.3%	7.2%	1.4%	0.5%				
	% Pos 2018	5.1%	0.8%	9.1%	1.1%	3.2%	0.3%	1.6%	1.6%	1.1%	5.9%	11.7%	25.5%	19.6%	3.0%	1.3%				
	Total 2017	**4,454**	**399**	**4,055**	**276**	**36**	**62**	**13**	**11**	**1**	**1,433**	**1,275**	**939**	**314**	**61**	**33**				
	Change (%)	11.2%	−9.3%	13.2%	−12.7%	−8.3%	1.6%	0.0%	−9.1%	100.0%	14.1%	17.6%	6.9%	13.7%	9.8%	−18.2%				

*Other domestic includes [a]1 alpaca and [b]1 yak. †Other wildlife includes [c]2 coyotes; [d]2 bobcats, 1 coati, 7 coyotes, and 1 javelina; [e]1 coyote; [f]1 otter; [g]1 armadillo, 3 bobcats, and 1 coyote; [h]1 bear; [i]1 bobcat, 2 opossums, and 1 otter; [j]1 otter; [k]1 bear, 2 bobcats, 3 coyotes, and 1 deer; [l]2 bobcats, 2 coyotes, and 4 deer; [m]1 opossum; [n]1 coyote; [o]14 mongooses; [p]1 coyote; [q]1 bobcat, 1 coyote, and 2 opossums; [r]3 bobcats and 1 coyote; and [s]1 bobcat. ‡Rodents and lagomorphs include [t]1 groundhog; [u]1 beaver; [v]2 groundhogs; [w]4 groundhogs; [x]3 groundhogs; [y]2 groundhogs; [z]2 groundhogs; [aa]1 beaver and 2 groundhogs; [ab]2 beavers and 3 groundhogs; [ac]3 groundhogs; and [ad]1 groundhog.

— = Not applicable. NYC = New York City. Pos = Positive.

Primary reservoir refers to the most common RVV in the locality.

Table 2—Number of animals reported to be rabid in the United States and percentages of samples tested for rabies that yielded positive results for 2013 through 2018.

Animals	2018		2013–2017			
			No. of rabid animals		Percentage of samples with positive results	
	No. of rabid animals	Percentage of samples with positive results	Mean	95% CI	Mean	95% CI
Domestic animals						
Cats	241*	1.1	259	247–272	1.2	1.1–1.2
Cattle	33*	3.2*	71	53–89	5.7	4.5–6.9
Dogs	63	0.3	67	56–78	0.3	0.3–0.4
Horses and donkeys	13*	1.6*	21	15–28	2.8	2.1–3.6
Sheep and goats	10	1.6	10	8–12	1.7	1.4–2.1
Wildlife						
Bats	1,635	5.9	1,627	1,519–1,736	6.3	5.9–6.7
Raccoons	1,499	11.7	1,603	1,370–1,837	13.1	10.9–15.4
Skunks	1,004*	25.5	1,274	1,031–1,517	27.8	23.8–31.8
Foxes	357*	19.6	321	303–334	18.6	17.3–19.8
All rabid animals	4,951	5.1	5,354	4,774–5,934	5.5	5.1–5.9
Rabid domestic animals	362*	0.8*	431	408–454	0.9	0.9–0.9
Rabid wildlife	4,589	9.1	4,923	4,362–5,484	10.1	9.1–11.0

*Significantly ($P < 0.05$) different from mean value for 2013 through 2017.

Columbia, Delaware, Hawaii, New York City, or Puerto Rico. In 9 states (Idaho, Illinois, Indiana, Mississippi, Nevada, Oregon, Utah, Washington, and Wisconsin), bats were the only rabid animals detected in 2018. Fourteen states reported a ≥ 50% increase in the number of rabid bats detected: Georgia (64% increase), Iowa (50% increase), Kentucky (333% increase), Louisiana (350% increase), Maine (50% increase), Michigan (120% increase), Mississippi (400% increase), Nebraska (70% increase), Ohio (223% increase), Rhode Island (125% increase), South Carolina (225% increase), South Dakota (100% increase), Washington (82% increase), and West Virginia (100% increase). Among the bats tested for rabies, 13,117 (47.7%) were described beyond the taxonomic level of order **(Table 3)**; big brown bats (*E fuscus*) were the most commonly tested (n = 9,064), followed by Mexican free-tailed bats (*T brasiliensis*; 1,748) and evening bats (*N humeralis*; 461). Variant typing results were reported for 605 (37.0%) of the reported rabid bats **(Table 4)**.

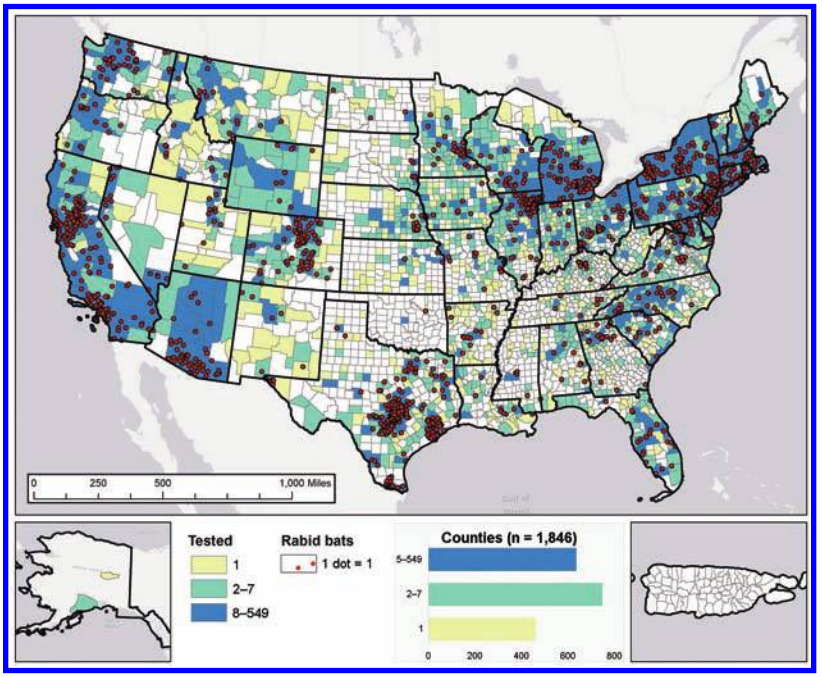

Figure 3—Reported cases of rabies involving bats, by county, during 2018. Histogram represents number of counties in each category for total number of bats submitted for rabies testing. Point locations for rabid bats were randomly selected within each reporting jurisdiction.

Raccoons

There were 12,818 raccoons tested for rabies in 2018, of which 1,499 (11.7%) were confirmed positive. This represented a 17.6% increase, compared with the 1,275 rabid raccoons reported in 2017 (Table 1). The percentage of rabid raccoons among the total tested (11.7%) was similar to the mean percentage during the previous 5 years (13.1%; 95% CI, 10.9% to 15.4%; Table 2). Eighteen states, the District of Columbia, and New York City remained enzootic for the raccoon RVV. These reporting jurisdictions accounted for 96.6% of all rabid raccoons reported in 2018 (n = 1,448; **Figure 4**). Variant typing was conducted on 293 of the rabid raccoons from states where the raccoon RVV was enzootic, and all 293 were confirmed to be infected with the raccoon RVV.

The remaining 51 (3.4%) rabid raccoons were reported from states where the raccoon RVV was not enzootic: Arizona (n = 2), California (1), Colorado (3), Kansas (1), Ohio (11), Tennessee (3), and Texas (30). Variant typing results were reported for 48 of

Table 3—Species of bats submitted for rabies testing in the United States during 2018.

Species (common name)	No. tested	No. positive	Percentage positive
Order Chiroptera (unspecified)	14,366	571	4.0
Eptesicus fuscus (big brown bat)	9,064	377	4.2
Tadarida brasiliensis (Mexican free-tailed bat)	1,748	442	25.3
Nycticeius humeralis (evening bat)	461	15	3.3
Myotis lucifugus (little brown bat)	330	17	5.2
Lasiurus borealis (red bat)	302	30	9.9
Myotis californicus (California myotis)	237	16	6.8
Lasionycteris noctivagans (silver-haired bat)	197	17	8.6
Myotis velifer (cave myotis)	110	3	2.7
Lasiurus cinereus (hoary bat)	79	39	49.4
Myotis evotis (long-eared myotis)	69	3	4.3
Parastrellus hesperus (canyon bat)	68	41	60.3
Lasiurus seminolus (Seminole bat)	60	4	6.7
Myotis yumanensis (Yuma myotis)	57	16	28.1
Myotis spp (not further differentiated)	55	5	9.1
Myotis volans (long-legged myotis)	43	3	7.0
Myotis thysanodes (fringed myotis)	35	3	8.6
Perimyotis subflavus (tricolored bat)	35	0	0.0
Lasiurus intermedius (northern yellow bat)	30	5	16.7
Family Molossidae (unspecified)	19	7	36.8
Myotis austroriparius (southeastern myotis)	18	0	0.0
Antrozous pallidus (desert pallid bat)	17	9	52.9
Myotis ciliolabrum (western small-footed myotis)	17	0	0.0
Desmodus rotundus (common vampire bat)*	11	6	54.5
Leptonycteris yerbabuenae (lesser long-nosed bat)	11	0	0.0
Lasiurus ega (southern yellow bat)	9	3	33.3
Lasiurus xanthinus (western yellow bat)	7	1	14.3
Myotis leibii (eastern small-footed myotis)	5	0	0.0
Plecotus townsendii (Townsend big-eared bat)	4	1	25.0
Myotis septentrionalis (northern long-eared bat)	4	0	0.0
Nyctinomops macrotis (big free-tailed bat)	4	0	0.0
Lasiurus blossevillii (desert red bat)	3	1	33.3
Myotis keenii (Keen myotis)	3	0	0.0
Rousettus aegyptiacus (Egyptian rousette)	3	0	0.0
Eumops perotis (western mastiff bat)	1	0	0.0
Plecotus rafinesquii (Rafinesque big-eared bat)	1	0	0.0
Total	**27,483**	**1,635**	**5.9**

*Non-native bat species submitted from a wildlife research center in Wisconsin.

Table 4— Number of rabies virus variants identified in domestic and wild animals in 2018.

	Domestic						Wildlife						
Variant	Cats	Cattle	Dogs	Monkeys and donkeys	Sheep and goats	Other domestic*	Raccoons	Bats	Skunks	Foxes	Other wild†	Rodents and lagomorphs‡	Total
Raccoon	64	10	14	2	0	1	307	0	137	104	13	7	**659**
South central skunk	15	4	17	6	2	0	31	0	240	16	4	0	**335**
North central skunk	2	3	2	0	0	0	0	0	29	1	0	0	**37**
California skunk	0	0	0	0	0	0	1	0	15	1	0	0	**17**
Arctic fox	0	0	2	0	0	0	0	0	0	5	1	0	**8**
Arizona gray fox	0	1	0	0	0	0	1	0	4	49	9	0	**64**
Canine	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Mongoose (Puerto Rico)	0	0	1	0	0	0	0	0	0	0	0	0	**1**
Bat	2	0	1	0	0	0	1	605	5	3	0	0	**617**
No variant reported	158	15	26	5	8	1	1,158	1,030	574	178	40	20	**3,213**
Total infected	**241**	**33**	**63**	**13**	**10**	**2**	**1,499**	**1,635**	**1,004**	**357**	**67**	**27**	**4,951**
Variant typed (%)	34.4	54.5	58.7	61.5	20.0	50.0	22.7	37.0	42.8	50.1	40.3	25.9	35.1
Variant typed (%), 2014–2017													
Mean	27.2	48.2	54.0	47.6	29.6	91.7	21.0	29.4	46.0	35.3	24.0	20.7	31.6
95% CI	24.2–30.7	43.5–53.5	46.9–62.1	24.0–74.9	11.5–50.5	75.4–110.5	17.0–25.6	21.4–38.7	43.8–48.5	21.5–51.3	10.7–39.4	10.8–32.0	27.3–36.6

*Other domestic includes 1 yak with the raccoon RVV. †Other wild includes 1 armadillo, 2 bears, 5 bobcats, 4 coyotes, and 1 deer with the raccoon RVV; 1 bobcat, 1 coyote, and 2 opossums with the south central skunk RVV; 1 coyote with the arctic fox RVV; and 2 bobcats, 1 coati, 5 coyotes, and 1 javelina with the Arizona gray fox RVV. ‡Rodents and lagomorphs include 2 beavers and 5 groundhogs with the raccoon RVV.

the 51 (94.1%) rabid raccoons from states where the racoon RVV was not enzootic (Table 4). Thirty-one were infected with the south central skunk RVV (Texas and Kansas), 1 was infected with the California skunk RVV (California), 1 was infected with the Arizona gray fox RVV (Arizona), 1 was infected with a bat RVV (Arizona), and 14 were infected with the raccoon RVV (Ohio and Tennessee).

Eighteen jurisdictions reported an increase in the number of raccoon rabies cases detected, compared

with the number detected in 2017: Alabama (6.5% increase), Colorado (200.0% increase), Connecticut (15.4% increase), District of Columbia (5.0% increase), Delaware (33.3% increase), Florida (64.9% increase), Georgia (15.9% increase), Massachusetts (17.1% increase), Maryland (20.9% increase), Maine (61.8% increase), North Carolina (31.0% increase), New Hampshire (71.4% increase), New York (20.2% increase), Ohio (57.1% increase), South Carolina (44.8% increase), Texas (76.5% increase), Virginia (22.3% increase), and West Virginia (19.0% increase). Seven jurisdictions reported a decrease in the number of raccoon rabies cases detected, compared with the number detected in 2017: Minnesota (100.0% decrease), New York City (16.7% decrease), Pennsylvania (3.5% decrease), Rhode Island (10.0% decrease), South Dakota (100.0% decrease), Tennessee (40.0% decrease), and Vermont (47.6% decrease). Of the 3,316 nonbat animal rabies cases detected in 2018, 72.9% were reported from states where the raccoon RVV was enzootic. The number of raccoon rabies cases peaked in 1993, at 5,912.[21]

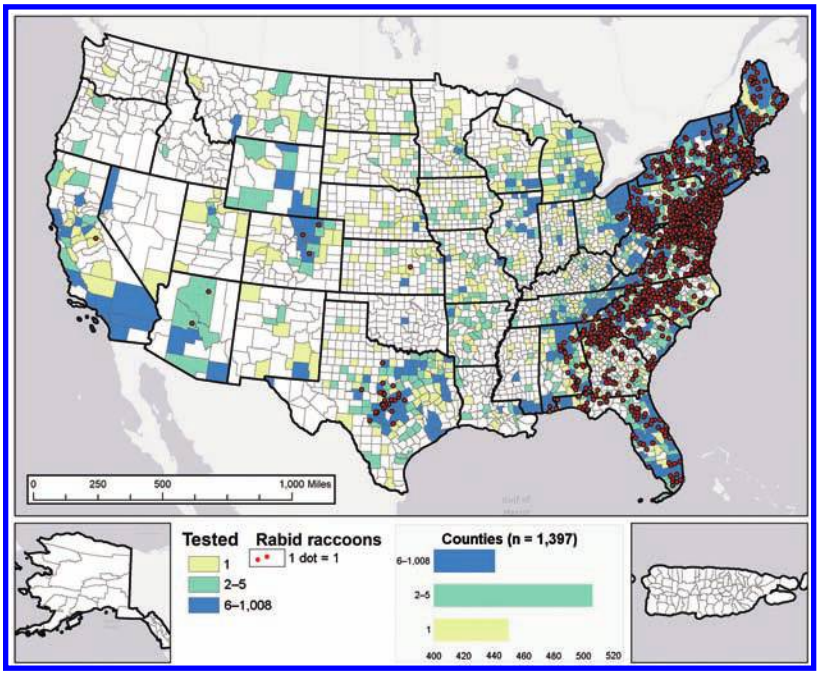

Figure 4—Reported cases of rabies involving raccoons, by county, during 2018. Histogram represents number of counties in each category for total number of raccoons submitted for rabies testing. Point locations for rabid raccoons were randomly selected within each reporting jurisdiction.

Skunks

A total of 3,938 skunks were tested for rabies in 2018, of which 1,004 (25.5%) were positive **(Figure 5)**. This represented a 6.9% increase from the number of rabid skunks reported during 2017 (n = 939; Table 1). The percentage of rabid skunks among the total tested (25.5%) during 2018 was similar to the mean percentage during the previous 5 years (27.8%; 95% CI, 23.8% to 31.8%; Table 2). Eight of the 21 states where skunk RVVs were considered enzootic reported a decrease in the number of rabid skunks during 2018, compared with the number detected in 2017: Arkansas (10.5% decrease), Iowa (100.0% decrease), Kansas (15.4% decrease), Louisiana (92.3% decrease), Minnesota (70.0% decrease), North Dakota (63.6% decrease), Nebraska (71.4% decrease), and Texas (10.5% decrease). Eight of the 21 states where skunk RVVs were considered enzootic reported an increase in the number of rabid skunks: Arizona (5.9% increase), Colorado (150.5% increase), Missouri (300.0% increase), Montana (100.0% increase), New Mexico (250.0% increase), Oklahoma (4.2% increase), Tennessee (18.8% increase), and Wyoming (45.0% increase).

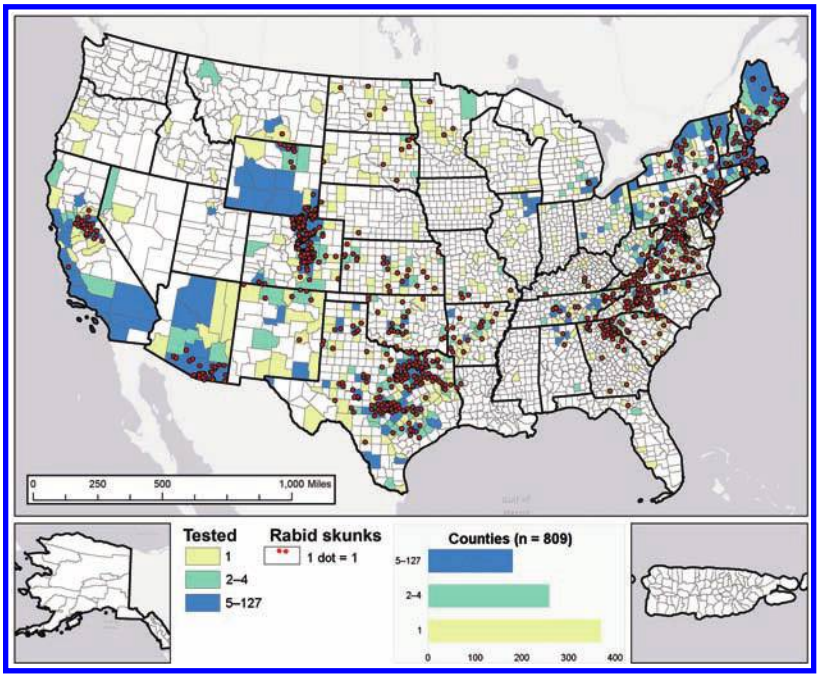

Figure 5—Reported cases of rabies involving skunks, by county, during 2018. Histogram represents number of counties in each category for total number of skunks submitted for rabies testing. Point locations for rabid skunks were randomly selected within each reporting jurisdiction.

Foxes

There were 1,818 foxes tested for rabies in 2018, of which 357 (19.6%) were rabid **(Figure 6)**. This represented a 13.7% increase, compared with the 314 reported in 2017 (Table 1). The percentage of rabid

foxes among the total submitted for testing (19.6%) was similar to the mean percentage during the previous 5 years (18.6%; 95% CI, 17.3% to 19.8%; Table 2). No animals were reported infected with the Texas gray fox RVV in 2018; the last animal reported with this RVV was a cow in 2013.[22]

Other wild animals

During 2018, Puerto Rico reported 14 rabid mongooses of 15 tested, a 17.6% decrease from the 17 rabid mongooses reported in 2017. Other reported rabid wildlife included 15 bobcats (*Lynx rufus*), 20 coyotes (*Canis latrans*), 5 deer (presumably *Odocoileus virginianus*), 5 opossums (*Didelphis virginiana*), 1 armadillo (*Dasypus novemcinctus*), 2 bears (*Ursus* spp), 1 coati (*Nasua nasua*), 1 javelina (*Tayassu tajacu*), and 3 otters (*Lontra canadensis*; Table 1). Rabid rodents and lagomorphs reported in 2018 included 23 groundhogs (*Marmota monax*) and 4 beavers (*Castor canadensis*). Variant typing was performed on 27 of the 67 (40.3%) other wild animals and 7 of the 27 (25.9%) rodents and lagomorphs reported to be rabid (Table 4).

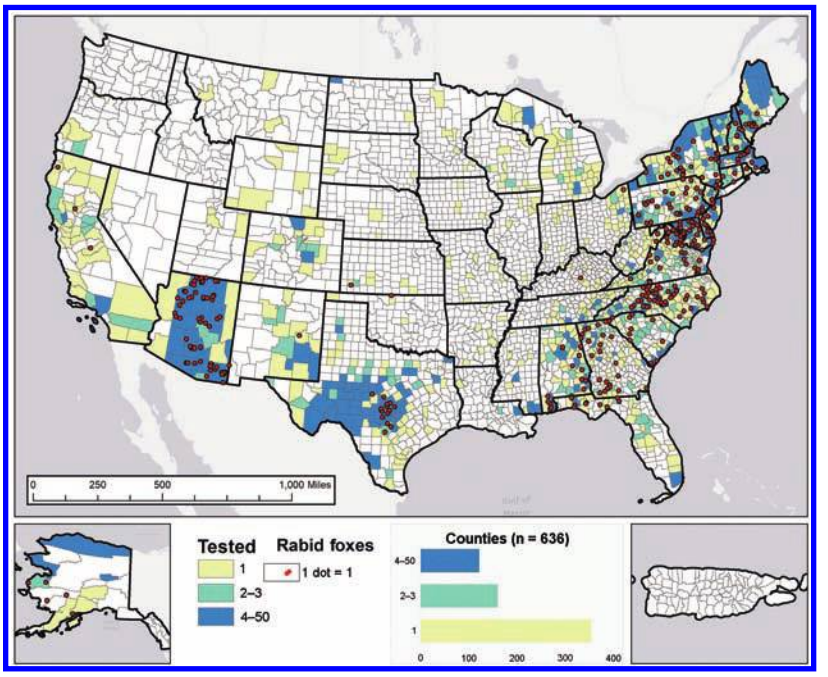

Figure 6—Reported cases of rabies involving foxes, by county, during 2018. Histogram represents number of counties in each category for total number of foxes submitted for rabies testing. Point locations for rabid foxes were randomly selected within each reporting jurisdiction.

Rabies in Domestic Animals

During 2018, domestic animals accounted for 47.2% of all animals submitted for rabies testing and 9.0% (362/4,951) of all animal rabies cases reported. The 362 rabid domestic animals reported in 2018 represented a 9.3% decrease, compared with the 399 reported in 2017 (Table 1). More than half of the 362 rabid domestic animals detected in 2018 were reported from 6 states: Pennsylvania (n = 45), Texas (36), Virginia (42), Maryland (28), Georgia (25), and New York (24).

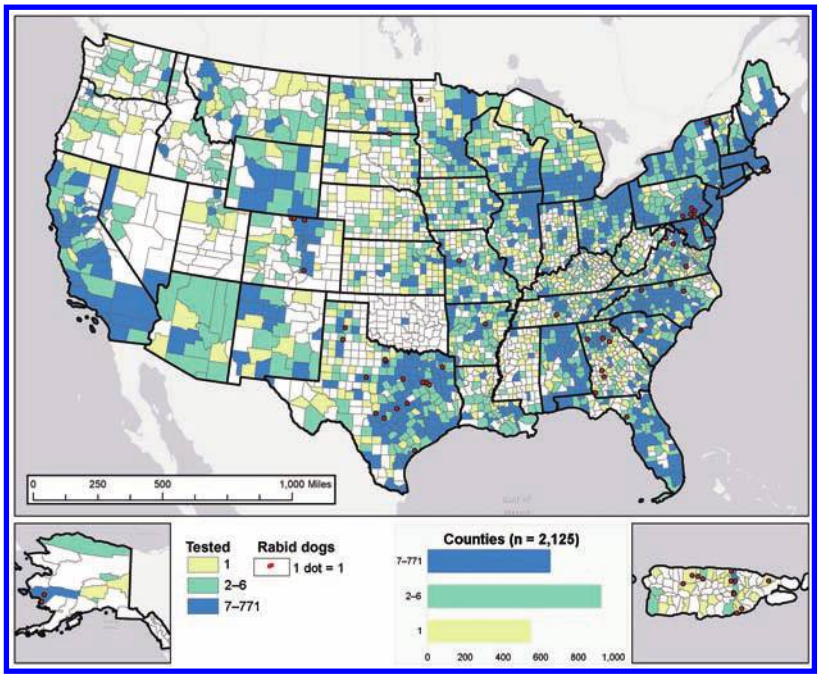

Figure 7—Reported cases of rabies involving dogs, by county, during 2018. Histogram represents number of counties in each category for total number of dogs submitted for rabies testing. Point locations for rabid dogs were randomly selected within each reporting jurisdiction.

Dogs

In 2018, 22,418 dogs were tested for rabies, and 63 (0.3%) were confirmed rabid. This represented a 1.6% increase from the 62 rabid dogs reported in 2017. Most rabid dogs were reported from 7 jurisdictions: Texas (n = 15 [23.8%]), Puerto Rico (13 [20.6%]), Georgia (7 [11.1%]), Pennsylvania (5 [7.9%]), Colorado (4 [6.3%]), North Carolina (3 [4.8%]), and Virginia (3 [4.8%]; **Figure 7**). The percentage of dogs tested for rabies that were confirmed to be rabid in 2018 (0.3%) was unchanged from the mean percentage for the previous 5 years (0.3%; 95% CI, 0.3% to 0.4%; Table 2). Among the rabid dogs for which vaccination status was reported (n = 7 [11.1%]), 2 had a history of expired rabies vacci-

nation, and the others were not vaccinated. The RVV was provided for 37 (58.7%) of the reported rabid dogs, among which 14 were infected with the raccoon RVV, 17 were infected with the south central skunk RVV, 2 were infected with north central skunk RVV, 2 were infected with the arctic fox RVV, 1 was infected with a bat RVV, and 1 was infected with a Puerto Rico mongoose RVV (Table 4).

Cats

There were 21,764 cats tested for rabies in 2018, of which 241 (1.1%) were confirmed rabid. This represented a 12.7% decrease in the number of rabid cats, compared with the 276 reported in 2017 (Table 1). The percentage of cats tested for rabies that were confirmed to be rabid (1.1%) was similar to the mean percentage during the previous 5 years (1.2%; 95% CI, 1.1% to 1.2%; Table 2). Rabies vaccination status was reported for 6 (2.5%) rabid cats. Four of the rabid cats had no history of vaccination, and 2 were reported to have been vaccinated. Most of the rabid cats were reported from states where the raccoon RVV was considered enzootic: Pennsylvania (n = 35 [14.5%]), Maryland (24 [10.0%]), New York (19 [7.9%]), Virginia (29 [12.0%]), Florida (16 [6.6%]), Georgia (16 [6.6%]), New Jersey (16 [6.6%]), South Carolina (15 [6.2%]), and North Carolina (13 [5.4%]; **Figure 8**). The RVV was provided for 83 (34.4%) of the reported rabid cats (Table 4). Most (n = 64 [77.1%]) were infected with the raccoon RVV, with the remainder infected with the south central skunk RVV (15 [18.1%]), north central skunk RVV (2 [2.4%]), or a bat RVV (2 [2.4%]).

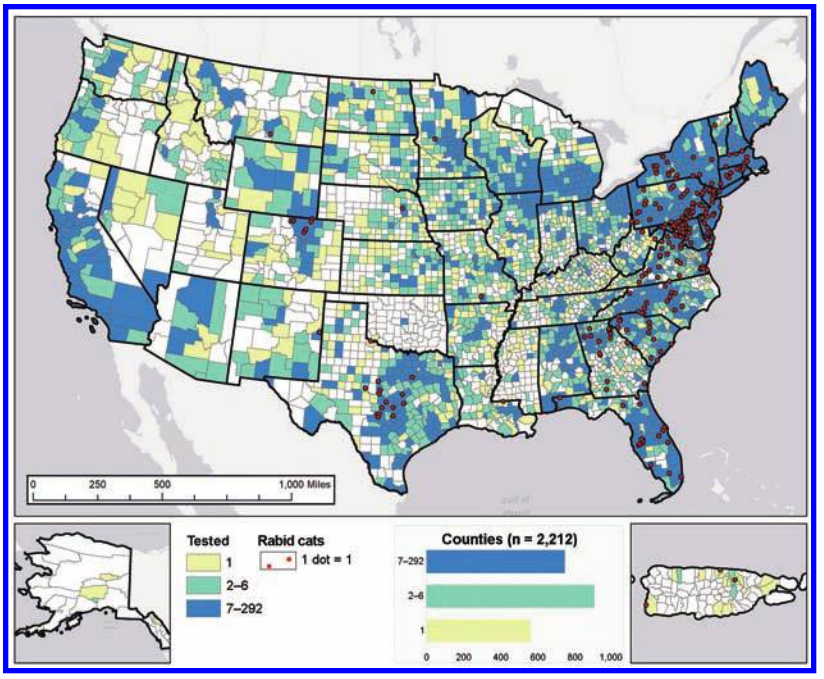

Figure 8—Reported cases of rabies involving cats, by county, during 2018. Histogram represents number of counties in each category for total number of cats submitted for rabies testing. Point locations for rabid cats were randomly selected within each reporting jurisdiction.

Other domestic animals

A total of 1,044 cattle were tested for rabies during 2018, of which 33 (3.2%) were confirmed rabid. This represented an 8.3% decrease in the number of rabid cattle, compared with the number reported in 2017 (n = 36; Table 1). The percentage of cattle tested for rabies that were confirmed to be rabid (3.2%) was significantly lower than the mean percentage for the previous 5 years (5.7%; 95% CI, 4.5% to 6.9%; Table 2). Virginia reported the highest number of rabid cattle (n = 8 [24.2%]), followed by Pennsylvania (3 [9.1%]), and North Dakota (3 [9.1%]). Thirteen rabid horses and donkeys were reported in 2018, which represented no change from the 13 reported in 2017. The percentage of horses and donkeys tested for rabies that were confirmed to be rabid (1.6%) was significantly lower than the mean percentage for the previous 5 years (2.8%; 95% CI, 2.1% to 3.6%; Table 2).

Rabies in Humans

During 2018, antemortem samples from 23 human patients in 17 states and US territories suspected to have rabies were submitted to the CDC for laboratory diagnostic testing, of which 3 (13.0%) were confirmed to be positive **(Table 5)**. The first case involved a 6-year-old boy from Florida who died of rabies in January 2018. He had been bitten by a bat approximately 2 weeks prior to symptom onset, and laboratory diagnostic testing by the CDC confirmed infection with an RVV associated with *T brasiliensis* bats. The second case involved a 69-year-old female resident of Delaware who died of rabies after being treated in Pennsylvania in August 2018. Laboratory diagnostic testing by the CDC detected the raccoon RVV, but no specific animal exposures were identified. The third case involved a 55-year-old man in Utah who developed symptoms of neck pain on October 16, 2018. The symptoms were initially attributed to a work accident but progressed to include nuchal muscle spasms and decreased sensation in his right arm. Following hospitalization on October 20, 2018, the patient received supportive care but continued to decompensate and died on November 4, 2018. Laboratory diagnostic testing of antemortem and postmortem samples by the CDC confirmed infection with an RVV associated with *T brasiliensis* bats. Family members reported that he had removed several bats from his home without wearing gloves, but no specific bites were reported, and he never received rabies PEP for these exposures.

Table 5—Cases of rabies in humans in the United States and Puerto Rico, January 2009 through October 2019, by circumstances of exposure and RVV.

Date of onset	Date of death	Reporting state	Age (y)	Sex	Exposure*	RVV†
25 Feb 09	Survived	TX	17	F	Contact	Bat, unknown
5 Oct 09	20 Oct 09	IN	43	M	Unknown	Bat, Ps
20 Oct 09	11 Nov 09	MI	55	M	Contact	Bat, Ln
23 Oct 09	20 Nov 09	VA	42	M	Contact, India	Dog, India
2 Aug 10	21 Aug 10	LA	19	M	Bite, Mexico	Bat, Dr
24 Dec 10	10 Jan 11	WI	70	M	Unknown	Bat, Ps
30 Apr 11	Survived	CA	8	F	Unknown	Unknown
30 Jun 11	20 Jul 11	NJ	73	F	Bite, Haiti	Dog, Haiti
14 Aug 11	31 Aug 11	NY	25	M	Contact, Afghanistan	Dog, Afghanistan
21 Aug 11	1 Sep 11	NC	20	M	Unknown (organ donor)‡	Raccoon, eastern United States
1 Sep 11	14 Oct 11	MA	40	M	Contact, Brazil	Dog, Brazil
3 Dec 11	19 Dec 11	SC	46	F	Unknown	Bat, Tb
22 Dec 11	23 Jan 12	MA	63	M	Contact	Bat, My sp
6 Jul 12	31 Jul 12	CA	34	M	Bite	Bat, Tb
31 Jan 13	27 Feb 13	MD	49	M	Kidney transplant	Raccoon, eastern United States
16 May 13	11 Jun 13	TX	28	M	Unknown, Guatemala	Dog, Guatemala
12 Sep 14	26 Sep 14	MO	52	M	Unknown	Bat, Ps
30 Jul 15	24 Aug 15	MA	65	M	Bite, Philippines	Dog, Philippines
17 Sep 15	3 Oct 15	WY	77	F	Contact	Bat, Ln
25 Nov 15	1 Dec 15	PR	54	M	Bite	Dog-mongoose, Puerto Rico
5 May 17	21 May 17	VA	65	F	Bite	Dog, India
6 Oct 17	21 Oct 17	FL	56	F	Bite	Bat, Tb
28 Dec 17	14 Jan 18	FL	6	M	Bite	Bat, Tb
15 Jul 18	23 Aug 18	DE	69	F	Unknown	Raccoon, eastern United States
16 Oct 18	4 Nov 18	UT	55	M	Contact	Bat, Tb

*Data for exposure history are reported when plausible information was reported directly by the patient (if lucid or credible) or when a reliable account of an incident consistent with rabies virus exposure (eg, dog bite) was reported by an independent witness (usually a family member). Exposure histories are categorized as bite, contact (eg, waking to find bat on exposed skin) but no known bite was acknowledged, or unknown (ie, no known contact with an animal was elicited during case investigation). †Variants of the rabies virus associated with terrestrial animals in the United States and Puerto Rico are identified with the names of the reservoir animal (eg, dog or raccoon), followed by the name of the most definitive geographic entity (usually the country) from which the variant has been identified. Variants of the rabies virus associated with bats are identified with the names of the species of bats in which they have been found to be circulating. Because information regarding the location of the exposure and the identity of the exposing animal is almost always retrospective and much information is frequently unavailable, the location of the exposure and the identity of the animal responsible for the infection are often limited to deduction. ‡Infection was not identified until 2013, when an organ recipient developed rabies.

Dr = *Desmodus rotundus*. Ln = *Lasionycteris noctivagans*. My sp = *Myotis* species. Ps = *Perimyotis subflavus*. Tb = *Tadarida brasiliensis*.

National Rabies Control Efforts

Primary rabies control efforts in the United States are led by municipal, county, and state health departments. These jurisdictions focus on preventative measures such as encouraging vaccination of pets (to prevent secondary rabies exposure from wildlife reservoirs); providing animal control services and shelters to respond to sick, nuisance, and unwanted animals; providing risk assessments and laboratory testing of animals for residents suspected to have been exposed to rabies; and assisting with access to rabies PEP for persons confirmed or suspected to have been exposed to rabies. In addition, USDA Wildlife Services, state agencies, and the CDC have cooperated on large-scale ORV programs targeting wild carnivore populations with the objective of controlling and ultimately eliminating RVVs associated with specific terrestrial wildlife reservoirs.

During 2018, the national rabies management program maintained an ORV zone to prevent the spread of the raccoon RVV. The zone was located along the US-Canada border in parts of Maine to New York and then from Lake Erie at the New York-Ohio-Pennsylvania border south through the Appalachia region to the Alabama-Georgia-North Carolina-Tennessee border. In this area, a total of 8,820,715 baits (vaccinia-rabies glycoprotein recombinant vaccine baits, 65.6%; adenovirus-rabies glycoprotein recombinant vaccine baits, 34.4%) were distributed across more than 118,000 km^2. In addition, a total of 1,034,700 baits (all vaccinia-rabies glycoprotein recombinant vaccine) were distributed across more than 42,000 km^2 along the US-Mexico border in Texas to prevent the reintroduction of the canine-coyote RVV.[23]

Although human and domestic animal contact with ORV baits is reportedly rare and the incidence of adverse events resulting from contact with baits is extremely low, state health departments in collaboration with the CDC and USDA maintained surveillance for such events. In 2018, a total of 246 bait contacts were reported from 15 of 17 reporting states (Alabama, Georgia, Kentucky, Massachusetts, Maryland, Maine, New Hampshire, New Jersey, New York, North Carolina, Ohio, Pennsylvania, Tennessee, Texas, Virginia, Vermont, and West Virginia). Two states (Kentucky and New Hampshire) did not report any bait contacts **(Table 6)**. Only 1 adverse event (a mild skin reaction) associated with human exposure to baits containing ORV was reported in 2018. Since the start of the ORV program in the United States, only 2 cases of severe adverse reactions in humans have been reported following direct exposures to vaccine-containing baits (both following contact with vaccinia-rabies glycoprotein recombinant vaccine baits). Both of these individuals had immunocompromise, and both patients

were treated and recovered without sequelae.[24,25] This represented a cumulative incidence of < 1 adverse event/98.4 million baits distributed.

Rabies in Canada and Mexico

Canada

In 2018, the Canadian Food Inspection Agency tested 2,842 samples for rabies, of which 183 (6.4%) were positive (7.7 animals tested/100,000 Canadian human population). This represented a nominal increase (2.4%) in the number of samples tested, compared with the 2,775 tested in 2017. Most (69.3%) of the samples tested during 2018 came from animals that had potentially exposed a person to rabies; all other tested samples came from animals that had had contact with a domestic animal (19.1%) or did not have any documented contact with humans or domestic animals (11.6%). Although most rabies cases involved wildlife species (169/183 [92.3%]), domestic species accounted for 43.7% (1,241/2,842) of the samples submitted for testing. Of the positive test results, 75 (41%) were confirmatory tests on wildlife surveillance samples that had initially been analyzed in provincial laboratories with the direct rapid immunohistochemical test or by means of conventional immunohistochemical staining on formalin-fixed, paraffin-embedded tissues. Six cases of rabies involving big brown bats (*E fuscus*) originating from the province of Saskatchewan were reported to the Canadian Food Inspection Agency, but these bats were not submitted for confirmatory testing. None of the wildlife surveillance cases had any reported exposure to humans or domestic animals. For the first time since 2014, no rabies cases due to the raccoon RVV were detected in the province of New Brunswick, although 4 rabid big brown bats were detected. In Ontario, the number of rabies cases attributed to the raccoon RVV continued to decrease following the beginning of an outbreak in 2015,[26] with only 65 cases reported in 2018, compared with 119 cases reported in 2017 and 258 cases reported in 2016. Fifty rabies cases attributed to the raccoon RVV involved raccoons, and 15 involved skunks. This decrease in the number of rabies cases associated with the raccoon RVV in Ontario meant that bats represented the highest percentage of rabies cases in Canada in 2018 (n = 61 [33.9%]), followed by raccoons (50 [27.3%]), skunks (37 [20.2%]), and foxes (20 [10.9%]), a change from 2017, when the numbers of rabid raccoons and skunks surpassed the number of rabid bats. As in 2017, Ontario submitted the highest number of samples for testing (n = 1,570) and had the highest number of rabies cases (104). In addition to those caused by the raccoon RVV, Ontario recorded 31 cases involving bats, in addition to 6 cases involving skunks and 1 case involving a bovid that were attributed to the fox RVV. One additional case of rabies in a skunk was due to an RVV associated with big brown bats. Similar to previous years, only rabies cases due to bat RVVs were detected in British Columbia (10 bats) and Alberta (9 bats and 1 cat). Saskatchewan recorded cases involving skunks (n = 7), dogs (3), and bats (5), and Manitoba recorded cases involving arctic and red foxes (1 each), a bovid, a goat, 2 dogs, and 8 skunks. Quebec recorded cases involving foxes (2 red and 3 arctic) and 3 dogs from northern Quebec (Nunavik), all infected with the arctic fox RVV, as well as 3 cases involving big brown bats. The territory of Nunavut recorded cases due to the arctic fox RVV involving 11 arctic foxes, 1 red fox, and 2 dogs. Newfoundland and Labrador recorded a single case due to the arctic fox RVV involving a red fox, whereas the Northwest Territories, Nova Scotia, Prince Edward Island, and Yukon recorded no rabies cases in 2018, although the number of samples tested from each of these jurisdictions was low (range, 2 to 13). Seven human suspect cases were investigated; all had negative results for a reverse transcriptase PCR assay performed on various specimens.

Mexico

During 2018, Mexico reported 2 human rabies cases associated with wildlife. The first was transmit-

Table 6—Reported human and animal contact with baits containing an ORV during 2018.

Variable	ORV in bait			Total
	V-RG	A-RG	Unknown	
No. of baits reportedly found	175	49	22	**246**
Human contact				
No. who had contact with bait	151	32	8	**191**
No. who had contact with vaccine	17	5	2	**24**
No. of adverse events reported	1	0	0	**1**
Animal contact				
No. that consumed bait or had contact with vaccine	36	20	3	**59**
No. of adverse events reported*	8	1	1	**10**
No. of baits distributed	6,824,193	3,031,222	NA	**9,855,415**

Information on contact with baits containing an ORV was reported by 17 states (Alabama, Georgia, Kentucky, Massachusetts, Maryland, Maine, New Hampshire, New Jersey, New York, North Carolina, Ohio, Pennsylvania, Tennessee, Texas, Virginia, Vermont, and West Virginia). Two of these states (Kentucky and New Hampshire) did not report any bait contacts.

A-RG = Adenovirus-rabies glycoprotein recombinant vaccine. NA = Not applicable. V-RG = Vaccinia-rabies glycoprotein recombinant vaccine.

ted by a fox in Durango in which the virus was genetically characterized as the Mexico gray fox RVV (V-7); the second was transmitted by a hematophagous bat in Guerrero State infected with the vampire bat RVV (V-8).

Since 2006, there have been no cases of human rabies transmitted by dogs in Mexico; the last deaths occurred in 2005 in the central states of the country. The absence of dog-mediated human rabies deaths in Mexico was achieved by 2 strategies: an annual 2-week, intensive campaign to vaccinate dogs and cats against rabies during each of the previous 10 years (distributing, on average, 18 million doses annually to dogs and cats at no cost to their owners); and prompt anti-rabies medical care for exposed individuals with human anti-rabies cell culture vaccine. In 2019, the World Health Organization officially recognized Mexico as being free from dog-mediated human rabies deaths.

In 2018, rabies virus surveillance in Mexico was maintained by sending samples to the various state public health laboratories or the Instituto de Diagnóstico y Referencia Epidemiológicos. Of the 24,872 samples processed in 2018, only 117 (0.5%) yielded positive results. Most of the samples that were tested (n = 23,197 [93.3%]) were from dogs. The remaining samples were mainly from cats, cattle, bats, and skunks.

Of the 117 positive samples, 89 were from cattle, 16 were from bats, 2 were from cats, 2 were from skunks, 7 were from various species of livestock (pig, horse, and goat), and 1 was from a Mexican wild cat. The 2 domestic cats were both unvaccinated and had been abandoned in Yucatan and Baja California Sur. In both cases, results of genetic characterization suggested transmission of rabies virus by wildlife (V-10).

Discussion

The CDC has collected information on rabies-positive animals for more than 75 years. Laboratory testing of animals suspected to be rabid remains a critical public health function and continues to be a cost-effective method to directly influence human rabies PEP recommendations.[27] The United States and its territories have some of the world's most diverse rabies epidemiology, with at least 30 bat and 8 terrestrial rabies reservoir species with distinct geographic distributions. The near-universal presence of rabies reservoir species throughout the United States means that humans and domestic animals have a potential for exposure. Approximately 60,000 people are treated for suspected rabies exposures annually, and several hundred domestic animals die of rabies virus infection. Yet human deaths are relatively rare, in part because of ready access to PEP.

Routine collection, analysis, and dissemination of the types of data provided in the present report are the foundations of rabies surveillance. The present report marks the 75th national rabies surveillance report. Over this time, the epidemiology of rabies has changed substantially, with the elimination of RVVs associated with dogs, red foxes, Texas gray foxes, and coyotes. In addition, over the past 75 years, the national rabies surveillance system has documented important changes in the distribution of rabies in skunk populations in the Midwest and a drastic expansion of the raccoon RVV reservoir territory. These epidemiological trends were recognized and characterized through the development of one of the world's most robust national rabies surveillance programs, which tests nearly 30 suspected rabid animals/100,000 citizens annually. Continued data collection, analysis, and dissemination are used to identify rabies risk areas and inform rabies management strategies. This process is possible only because of the extensive activities routinely conducted by the state and local programs that contributed to the present report.

Although the overall number of animal rabies cases was higher in 2018 than in 2017, it was still in line with numbers reported over the past 5 years, representing a relatively consistent case-detection rate since 2011. Overall trends by species indicate that the numbers of cases involving raccoons and skunks have been decreasing but that the numbers involving bats and foxes have been relatively stable. Although this may reflect the impact of wildlife control efforts focused on raccoons, natural enzootic cycles cannot be discounted. Recent analyses of national rabies surveillance program data have shown that the numbers of terrestrial rabies cases involving raccoons and skunks are significantly lower in areas where USDA Wildlife Services is conducting oral vaccination programs.[28]

The year 2018 marks the fourth year during which bats were the most frequently reported rabid animal in the United States, surpassing raccoons in 2015. The number of rabid bats increased in 2018, compared with the number reported in 2017, but the percentage of rabid bats among the total tested was unchanged. National surveillance data continue to indicate that a wide range of bat species are affected by rabies, with rabies reported in bats representing 25 species from 47 jurisdictions. However, 52% of bats submitted for testing in 2018 were not identified to the genus level, and only 37.0% of rabid bats underwent variant typing, indicating that there could be even more diversity in affected bat species and more transmission cycles than are currently recognized. Bats are the only rabies reservoir species found throughout North and South America, and any interaction with a bat should be immediately reported to a health authority for a risk assessment.[29]

Cats and dogs accounted for 84.0% (304/362) of rabid domestic animals reported in 2018. The number of rabid cats was almost 4 times the number of rabid dogs, and the rate of positive rabies tests was also higher for cats than for dogs. Most (183/241 [75.9%]) rabid cats were reported from states where the raccoon RVV was enzootic. Rabies vaccination of dogs and cats is the most important strategy to reduce the

risk of rabies in dogs and cats and the possibility of transmission to humans. However, the vaccination status of rabid cats and dogs was rarely reported to the National Rabies Surveillance Program. Vaccination status is not a required reporting element but may be available from reporting jurisdictions that conducted rabies investigations. Further examination of the causes of persistent domestic animal rabies cases may provide insight into how to prevent these events from occurring. Improved national reporting of vaccination status may improve our understanding of trends and the role lack of vaccination plays in domestic animal rabies epidemiology.

Rabies virus variant typing is a critical component for monitoring changes in rabies reservoirs and identifying host-shift events and the emergence of novel RVVs. In 2018, samples from 37 of the 63 (58.7%) rabid dogs underwent RVV typing. However, for the remaining 26 dogs, the RVV was not reported. As is the case for vaccination status, variant typing results are not part of the routine reporting requirements; however, variant typing is highly encouraged for certain high-risk species and high-risk situations. The United States eliminated the canine RVV in the mid-1970s and again eliminated rabies circulation in dogs in 2007 after a reincursion in the 1980s. The National Rabies Management Program has supported canine RVV elimination efforts for > 80 years. Ensuring that the United States remains free of rabies virus circulation in dogs requires enhanced monitoring of canine rabies cases, including investigating the travel history of affected dogs, determining their vaccination history, and performing variant typing. Cases of rabies involving dogs with a history of international travel should be reported to the National Rabies Surveillance Program within 24 hours after the diagnosis is made. In 2018, 2 dogs were brought into the continental United States and later developed rabies due to nonendemic variants. One dog had been imported into New York from Canada and was later found to be infected with the arctic fox RVV. The other dog had been brought to Maryland from Puerto Rico by a rescue organization and was found to be infected with the mongoose RVV. Two additional importation events occurred in 2019. A dog imported from Egypt was found to be infected with the canine RVV, and another dog imported from Puerto Rico to Virginia was found to be infected with the mongoose RVV. Human-mediated translocation of domestic animals will continue to pose a risk to the unintentional spread of rabies viruses, and vigilance by rescue agencies, veterinarians, and public health officials is critical to ensure these events are recognized and addressed in a timely manner. Of the 4 importation events that occurred in 2018 and 2019, none resulted in successful transmission events. Continued efforts to improve RVV typing in dogs are necessary to ensure the United States remains canine rabies free.

Over the past 5 years, results of RVV typing were reported to the National Rabies Surveillance Program for only 31.6% of confirmed rabid animals. Although variant typing of reservoir species found within the traditional reservoir territory is not routinely advised because > 99% of these animals will have the expected variant result, periodic representative sampling is recommended. In 2018, a rabid skunk in Missouri was found to be infected with the north central skunk RVV, even though the state was considered to have only the south central skunk RVV. Recently, the National Rabies Surveillance Program coordinated retrospective reviews of variant typing results with state health departments in Missouri, Arkansas, and Kentucky and with the Kansas State University Rabies Laboratory. Results from this review identified 32 instances of rabid animals with the north central skunk RVV in counties that had previously been recognized to have only the south central skunk RVV. These variant results had not been documented in the National Rabies Surveillance System, highlighting the importance of systematic and routine variant typing and reporting of variant results to the National Rabies Surveillance Program. The recognition of this cryptic enzootic cycle of the north central skunk RVV is not expected to change public health recommendations or the public's risk of rabies virus exposure because the enzootic zone appears to overlap with the south central skunk RVV zone. Nevertheless, jurisdictions near the newly recognized north central skunk RVV territory in Missouri and Arkansas should consider variant typing terrestrial mammals so that the extent of this territory is fully understood.

The ability to detect rabies in animals is dependent on the 125 public health laboratories and veterinary diagnostic laboratories in the United States that perform rabies testing. Well-trained, technically competent laboratorians are essential to rabies diagnosis. The CDC and Association of Public Health Laboratories cosponsored a course—Laboratory Methods for Detecting Rabies Virus—in 2018 that was attended by laboratorians from 24 states and the District of Columbia. This was an intensive 5-day course consisting of lectures and hands-on training related to collection of samples, rabies diagnostic methods (direct fluorescent antibody test, direct rapid immunohistochemical test, and LN 34 real-time reverse transcriptase PCR assay), and variant determination by antigenic typing and sequence analysis methods.

In 2018 and 2019, US laboratories were faced with dilemmas as a result of periodic shortages experienced by 1 manufacturer of an anti-rabies fluorescein isothiocyanate conjugate used in the direct fluorescent antibody test. The national standard protocol for the direct fluorescent antibody test requires the use of 2 different anti-rabies conjugates for each test, but the only other conjugates licensed for use in the United States cannot be used in the same test because they contain the same antibodies. Therefore, all laboratories in the United States must use the conjugate that was in short supply in each test. Through sharing between laboratories, testing continued until the shortage was eventually corrected. Despite the shortage, the anti-rabies conjugates performed as ex-

pected against all RVVs in the United States during 2018 and 2019.

2019 Rabies Update

No human rabies cases were reported in the United States from January through September 2019. Two new human rabies immunoglobulin products for the prevention of human rabies virus infection have become available in recent years. KEDRAB, manufactured by Kamada Ltd, was licensed by the FDA for use in PEP protocols in August 2017. HYPERRAB, manufactured by Grifols Therapeutics LLC, was licensed by the FDA in February 2018. HYPERRAB is distinguished from the previously licensed HYPERRAB S/D in that it is twice as potent (ie, 300 U/mL vs 150 U/mL). Consequently, a smaller volume of HYPERRAB is required to achieve the 20-U/kg (9.1-U/lb) dose recommended for all human rabies immunoglobulin products. Health-care providers should verify that the correct dose of human rabies immunoglobulin is calculated before administration to ensure that PEP is given according to recommendations.

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Use of trade names and commercial sources is for identification only and does not imply endorsement by the US Department of Health and Human Services. The findings and conclusions in this report are those of the authors and do not necessarily represent the views of the CDC.

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