Rabies surveillance in the United States during 2017

Xiaoyue Ma MPH
Ben P. Monroe MPH
Julie M. Cleaton MPH
Lillian A. Orciari MS
Yu Li PhD
Jordona D. Kirby MS
Richard B. Chipman MS
Brett W. Petersen MD
Ryan M. Wallace DVM
Jesse D. Blanton DrPh

From the Poxvirus and Rabies Branch, Division of High-Consequence Pathogens and Pathology, National Center for Emerging and Zoonotic Infectious Disease, CDC, 1600 Clifton Rd NE, Atlanta, GA 30333 (Ma, Monroe, Cleaton, Orciari, Li, Petersen, Wallace, Blanton); and Wildlife Services, APHIS, USDA, 59 Chenell Dr, Ste 7, Concord, NH 03301 (Kirby, Chipman).

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

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OBJECTIVE
To describe rabies and rabies-related events occurring during 2017 in the United States.

DESIGN
Cross-sectional analysis of passive surveillance data.

ANIMALS
All animals submitted for laboratory diagnosis of rabies in the United States during 2017.

PROCEDURES
State and territorial public health departments provided data on animals submitted for rabies testing in 2017. Data were analyzed temporally and geographically to assess trends in domestic and sylvatic animal rabies cases.

RESULTS
During 2017, 52 jurisdictions reported 4,454 rabid animals to the CDC, representing a 9.3% decrease from the 4,910 rabid animals reported in 2016. Of the 4,454 cases of animal rabies, 4,055 (91.0%) involved wildlife species. Relative contributions by the major animal groups were as follows: 1,433 (32.2%) bats, 1,275 (28.6%) raccoons, 939 (21.1%) skunks, 314 (7.0%) foxes, 276 (6.2%) cats, 62 (1.4%) dogs, and 36 (0.8%) cattle. There was a 0.4% increase in the number of samples submitted for testing in 2017, compared with the number submitted in 2016. Two human rabies deaths were reported in 2017, compared with none in 2016.

CONCLUSIONS AND CLINICAL RELEVANCE
The overall number of reported cases of animal rabies has decreased over time. 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 postexposure prophylaxis recommendations. (*J Am Vet Med Assoc* 2018;253:1555–1568)

This report provides information on the epidemiology of rabies and rabies-associated events in the United States during 2017. Rabies updates for Canada and Mexico in 2017 are also summarized.

Rabies is a zoonotic disease caused by RNA viruses in the genus *Lyssavirus*.[1] All mammals are susceptible to rabies virus infection. Rabies virus is commonly transmitted via a bite from an infected animal but can also be transmitted when fresh saliva from an infected animal comes into contact with wounds or mucous membranes of another mammal. Rabies is almost invariably fatal once clinical signs develop. However, rabies can be prevented in people if appropriate PEP is administered prior to symptom onset.

ABBREVIATIONS

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

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.[2,3] For persons with immunosuppression, rabies PEP is the same, with the exception that a 5-dose vaccination regimen (ie, on days 0, 3, 7, 14, and 28) is recommended. Recommended PEP for exposed persons who have been previously vaccinated consists of 2 booster doses of rabies vaccine on days 0 and 3.[2]

Globally, an estimated 59,000 people die of rabies every year,[4] with > 99% of these deaths a result of infection with the RVV that circulates in dogs.[5] In the United States, canine rabies was successfully controlled during the late 1970s, and wildlife has accounted for > 90% of all rabid animals reported in the United States since the 1980s. 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 (Texas and Arizona gray fox RVVs), arctic foxes (arctic fox RVV), and mongooses (dog-mongoose RVV in Puerto Rico). With the exception of bat RVVs, circulation of distinct RVVs associated with the primary reservoir species occurs in geographically definable regions, where transmission is primarily between members of the same species. 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.[6–8]

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 wildlife, timely administration of PEP, and education of health-care professionals and the public. Despite these advances, human rabies cases continue to occur and are primarily associated with bat exposures in the United States and exposure to rabid dogs in countries where canine RVVs are endemic.[9,10] 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.[3,11] In the case of exposures involving other species, including wildlife, animals should be submitted for rabies testing when available to rule out the risk of rabies transmission.[2,12]

Prevention of rabies exposure in domestic pets through vaccination remains an important barrier to reduce the likelihood of rabies exposure in humans. Rabies control efforts in wildlife represent a large-scale effort led by the Wildlife Services division of the USDA APHIS. A national wildlife vaccination program was started in 1995 and currently consists of distributing ORVs by fixed-wing aircraft in rural areas and by 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. Since the wildlife vaccination program was begun, it has helped contribute to the elimination of the dog-coyote RVV and the control of the gray fox RVV in Texas and has helped prevent 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 secondary intervention methods such as health education, exposure prevention, and PEP.

Reporting and Analysis

Human and animal rabies have been nationally notifiable conditions in the United States since 1944.[15] Animal rabies surveillance is primarily a passive,

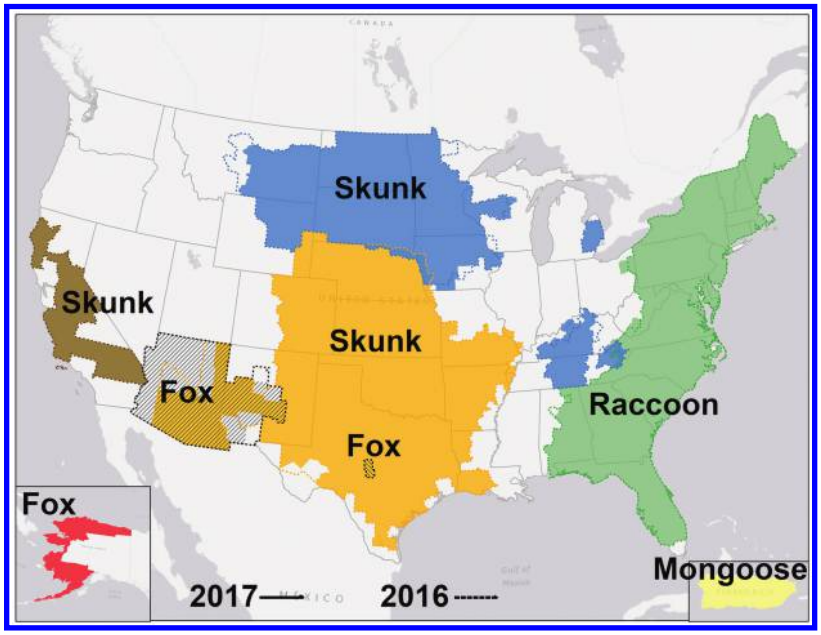

Figure 1—Distribution of major RVVs among mesocarnivores in the United States and Puerto Rico. Black diagonal lines represent distribution of fox RVVs (Arizona gray fox and Texas gray fox RVVs). Solid borders represent RVV distributions from 2013 through 2017; dashed borders represent the previous 5-year distributions from 2012 through 2016.

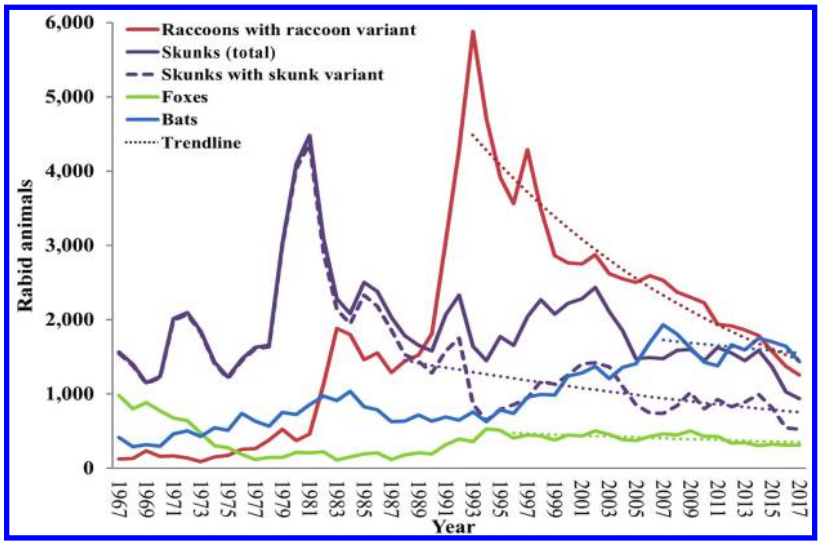

Figure 2—Cases of rabies among wildlife in the United States, by year and species, for 1966 through 2017.

Table 1—Cases of rabies in the United States, by location, during 2017.

					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 2017	2016 cases	Change (%)
AK	Arctic Fox	12	3	9	0	0	3	0	0	0	0	0	0	9	0	0	0	7.3	21	−42.9
AL	Raccoon	52	2	50	2	0	0	0	0	0	10	31	0	9	0	0	0	2.4	77	−32.5
AR	Skunk	43	2	41	1	0	1	0	0	0	22	0	19	0	0	0	0	4.9	23	87.0
AZ	Skunk	152	0	152	0	0	0	0	0	0	80	0	34	30	8[b]	0	0	18.0	153	−0.7
CA	Skunk	231	4	227	1	0	3	0	0	0	198	0	28	1	0	0	0	4.5	226	2.2
CO	Skunk	165	2	163	0	0	2	0	0	0	63	1	93	5	1[c]	0	0	10.3	88	87.5
CT	Raccoon	41	4	37	2	1	1	0	0	0	15	13	5	3	1[d]	0	0	3.6	91	−54.9
DC	Raccoon	23	0	23	0	0	0	0	0	0	3	20	0	0	0	0	0	13.1	24	−4.2
DE	Raccoon	16	7	9	6	0	1	0	0	0	2	6	0	1	0	0	0	10.5	5	220.0
FL	Raccoon	79	13	66	11	0	2	0	0	0	19	37	2	8	0	0	1	3.8	59	33.9
GA	Raccoon	253	16	237	10	0	6	0	0	0	11	126	53	42	5[e]	0	0	14.1	232	9.1
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	2	8	2	0	0	0	0	0	6	0	2	0	0	0	0	0.8	19	−47.4
ID	Bat	15	0	15	0	0	0	0	0	0	15	0	0	0	0	0	0	5.4	20	−25.0
IL	Bat	58	0	58	0	0	0	0	0	0	58	0	0	0	0	0	0	1.6	63	−7.9
IN	Bat	14	0	14	0	0	0	0	0	0	14	0	0	0	0	0	0	1.2	17	−17.6
KS	Skunk	40	10	30	3	3	1	3	0	0	4	0	26	0	0	0	0	3.9	54	−25.9
KY	Skunk	11	4	7	0	2	2	0	0	0	3	0	4	0	0	0	0	1.4	22	−50.0
LA	Skunk	15	0	15	0	0	0	0	0	0	2	0	13	0	0	0	0	2.6	4	275.0
MA	Raccoon	98	1	97	1	0	0	0	0	0	20	35	21	11	2[f]	8[s]	0	3.8	146	−32.9
MD	Raccoon	242	34	208	33	1	0	0	0	0	40	139	9	10	2[g]	8[t]	0	7.2	336	−28.0
ME	Raccoon	71	0	71	0	0	0	0	0	0	8	34	21	8	0	0	0	7.3	76	−6.6
MI	Skunk	38	1	37	1	0	0	0	0	0	35	0	2	0	0	0	0	1.1	41	−7.3
MN	Skunk	35	3	32	1	1	0	1	0	0	20	1	10	1	0	0	0	1.9	55	−36.4
MO	Skunk	20	2	18	0	0	2	0	0	0	17	0	1	0	0	0	0	1.1	25	−20.0
MS	Bat	1	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0.2	3	−66.7
MT	Skunk	13	0	13	0	0	0	0	0	0	13	0	0	0	0	0	0	2.7	10	30.0
NC	Raccoon	273	25	248	17	1	3	3	1	0	18	129	52	44	4[h]	1[u]	0	7.5	257	6.2
ND	Skunk	14	3	11	2	0	0	0	1	0	0	0	11	0	0	0	0	2.8	16	−12.5
NE	Skunk	19	2	17	2	0	0	0	0	0	10	0	7	0	0	0	0	1.7	19	0.0
NH	Raccoon	28	1	27	1	0	0	0	0	0	6	7	9	3	1[i]	1[v]	0	6.1	23	21.7
NJ	Raccoon	207	20	187	18	1	0	0	1	0	31	112	30	8	4[j]	2[w]	0	8.3	263	−21.3
NM	Skunk	13	0	13	0	0	0	0	0	0	5	0	2	2	4[k]	0	0	2.8	4	225.0
NV	Bat	10	0	10	0	0	0	0	0	0	10	0	0	0	0	0	0	2.9	14	−28.6
NY	Raccoon	276	33	243	28	1	1	1	2	0	73	104	35	23	4[l]	4[x]	0	4.7	393	−29.8
NYC	Raccoon	18	2	16	2	0	0	0	0	0	0	12	4	0	0	0	0	6.1	5	260.0
OH	Bat	21	1	20	1	0	0	0	0	0	13	7	0	0	0	0	0	0.4	41	−48.8
OK	Skunk	42	15	27	7	5	2	0	1	0	3	0	24	0	0	0	0	4.8	47	−10.6
OR	Bat	17	1	16	1	0	0	0	0	0	13	0	1	1	1[m]	0	0	4.6	15	13.3
PA	Raccoon	381	68	313	60	3	2	3	0	0	41	200	41	25	1[n]	5[y]	0	5.2	414	−8.0
PR	Mongoose	31	14	17	2	0	11	0	1	0	0	0	0	0	17[o]	0	0	36.1	20	55.0
RI	Raccoon	17	2	15	2	0	0	0	0	0	4	10	0	1	0	0	0	3.1	26	−34.6
SC	Raccoon	63	8	55	6	0	1	0	1	0	4	29	12	7	2[p]	1[z]	0	4.5	94	−33.0
SD	Skunk	22	10	12	2	4	3	0	1	0	3	1	8	0	0	0	0	3.9	27	−18.5
TN	Skunk	35	2	33	1	0	1	0	0	0	10	5	16	2	0	0	0	2.0	46	−23.9
TX	Skunk	679	42	637	20	8	12	2	0	0	396	17	210	12	2[q]	0	0	5.9	751	−9.6
UT	Bat	23	0	23	0	0	0	0	0	0	23	0	0	0	0	0	0	7.5	20	15.0
VA	Raccoon	355	34	321	25	4	2	0	2	1[a]	20	157	100	40	2[r]	2[aa]	1	9.8	362	−1.9
VT	Raccoon	41	0	41	0	0	0	0	0	0	8	21	5	6	0	1[ab]	0	4.0	48	−14.6
WA	Bat	22	0	22	0	0	0	0	0	0	22	0	0	0	0	0	0	4.8	20	10.0
WI	Skunk	29	1	28	1	0	0	0	0	0	28	0	0	0	0	0	0	1.5	29	0.0
WV	Raccoon	38	5	33	4	1	0	0	0	0	1	21	9	2	0	0	0	3.9	33	15.2
WY	Skunk	32	0	32	0	0	0	0	0	0	12	0	20	0	0	0	0	5.6	33	−3.0
Total	—	**4,454**	**399**	**4,055**	**276**	**36**	**62**	**13**	**11**	**1**	**1,433**	**1,275**	**939**	**314**	**61**	**33**	**2**	**4.8**	**4,910**	**−9.3**
	% 2017	100.0	9.0	91.0	6.2	0.8	1.4	0.3	0.2	0.0	32.2	28.6	21.1	7.0	1.4	0.7				
	% Pos 2017	4.8	0.9	8.5	1.3	3.4	0.3	1.9	1.8	0.6	5.9	9.7	22.6	17.5	2.7	1.6				
	Total **2016**	**4,910**	**423**	**4,487**	**257**	**70**	**58**	**23**	**13**	**2**	**1,646**	**1,403**	**1,031**	**313**	**45**	**49**				
	Change (%)	−9.3	−5.7	−9.6	7.4	−48.6	6.9	−43.5	−15.4	−50.0	−12.9	−9.1	−8.9	0.3	35.6	−32.7				

*Other domestic includes [a]1 swine. †Other wildlife includes [b]6 bobcats, 1 coyote, and 1 javelina; [c]1 coyote; [d]1 bobcat; [e]4 bobcats and 1 coyote; [f]1 bobcat and 1 coyote; [g]2 opossums; [h]2 bobcats, 1 coyote, and 1 deer; [i]1 bobcat; [j]2 bobcats, 1 coyote, and 1 deer; [k]2 bobcats, 1 coyote, and 1 ringtail; [l]1 coyote, 1 deer, 1 opossum, and 1 otter; [m]1 coyote; [n]1 coyote; [o]17 mongooses; [p]2 coyotes; [q]1 bobcat and 1 coyote; and [r]2 bobcats. ‡Rodents and lagomorphs include [s]8 groundhogs; [t]8 groundhogs; [u]1 groundhog; [v]1 groundhog; [w]2 groundhogs; [x]4 groundhogs; [y]5 groundhogs; [z]1 groundhog; [aa]2 groundhogs; and [ab]1 groundhog. Pos = Positive.

laboratory-based system that comprises > 130 state health, agriculture, and university laboratories. These laboratories perform the standard direct fluorescent antibody test.[16] In addition, USDA APHIS Wildlife Services tests animals collected through active surveillance in selected geographic regions with the direct rapid immunohistochemical test.[10,17]

The CDC rabies program requests information on animals submitted for rabies testing from reporting jurisdictions. Annual data are compiled at the end of the calendar year, and a comprehensive national data set is typically available by the third quarter of the following year.[18] Data submission primarily occurs through emailed spreadsheets. States provide information that consists of species, county, date of testing or specimen collection, and test results for all animals submitted for rabies testing. Information on vaccination status of domestic animals and results of RVV typing are provided when available.

For the present report, percentages of rabid animals were calculated on the basis of total numbers of animals tested, with only those animals with a positive or negative test result included in the denominator (ie, animals with indeterminate test results were not included). Because most public health programs only test animals suspected to have rabies following a human or domestic animal exposure, percentages reported here may not represent the true incidence of animal rabies within these populations.

Geographic ranges of nonbat RVVs in the United States were produced by aggregating counts of rabid animals from 2012 through 2017 by county and species **(Figure 1)**. Counties were considered to have only bat RVVs if they had reported no cases in a terrestrial reservoir species for the past 5 years and met one or both of the following conditions: all bordering counties had reported no cases in a terrestrial reservoir species for the past 5 years, and the county had tested ≥ 15 animals representing terrestrial reservoir species or ≥ 30 domestic animals representing vector species (eg, cats, dogs, or livestock) and results were negative for all tested animals.

Annual trends in wildlife rabies cases were analyzed by species for 1966 through 2017. Owing to frequent spillover of the raccoon RVV into skunks, trends in the numbers of skunks infected with a skunk RVV and skunks infected with the raccoon RVV were analyzed separately. Data were analyzed with standard software[a] to identify significant temporal trends. Trends are reported as the annual percentage change in reported cases over the time period with 95% CIs **(Figure 2)**.

Summary data for rabies in Canada during 2017 were provided by the Canadian Food Inspection Agency Centre of Expertise for Rabies.[19] Data for Mexico were provided by the Centro Nacional de Programas Preventivos y Control de Enfermedades of the Secretaria de Salud (Ministry of Health).

Samples

During 2017, a total of 95,853 animal samples were submitted for laboratory testing for rabies in the United States and territories, of which 93,651 (97.7%) were considered suitable for testing (this number included samples with positive, negative, and indeterminate test results). This represented a 0.1% increase in the number of animals tested, compared with the number tested during 2016 (n = 93,535). During 2017, USDA Wildlife Services tested 8,006 animals with the direct rapid immunohistochemical test, accounting for 8.5% of all animals submitted for testing in 2017.

Rabies in Wildlife

Wildlife accounted for 91.0% (4,055/4,454) of rabies cases reported in 2017, representing a 9.6% decrease from the 4,487 rabid wildlife reported in 2016 **(Table 1)**. In 2017, bats were the most frequently

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 2012 through 2017.

	2017		2012–2016			
			No. of rabid animals		Percentage of samples with positive results	
Animals	No. of rabid animals	Percentage of samples with positive results	Mean	95% CI	Mean	95% CI
Domestic animals						
Cats	276*	1.3*	255	246–265	1.1	1.1–1.2
Cattle	36*	3.4*	87	72–102	6.8	5.7–7.8
Dogs	62	0.3	71	59–84	0.3	0.3–0.4
Horses and donkeys	13*	1.9*	28	17–39	3.5	2.5–4.4
Sheep and goats	11	1.8	10	8–13	1.9	1.4–2.4
Wildlife						
Raccoons	1,275*	9.7*	1,739	1,540–1,938	13.8	12.3–15.4
Bats	1,433*	5.9*	1,677	1,625–1,729	6.4	6.0–6.7
Skunks	939*	22.6*	1,394	1,201–1,587	29.5	26.3–32.6
Foxes	314	17.5*	327	313–340	18.8	17.6–19.9
All rabid animals	4,454*	4.8*	5,696	5,255–6,137	5.8	5.5–6.1
Rabid domestic animals	399*	0.9*	455	419–490	0.9	0.9–1.0
Rabid wildlife	4,055*	8.5*	5,241	4,825–5,656	10.6	10.0–11.2

*Significantly ($P < 0.05$) different from mean value for 2012 through 2016.

reported rabid animals in the United States, representing 32.2% (n = 1,433) of all animal rabies cases, followed by raccoons (28.6% [1,275]), skunks (21.1% [939]), and foxes (7.0% [314]).

Bats

During 2017, 24,458 bats were tested, of which 1,433 (5.9%) were confirmed positive for rabies. This represented a 12.9% decrease from the number of rabid bats reported in 2016 (n = 1,646; Table 1). The percentage of rabid bats among the total submitted for testing (5.9%) was significantly lower than the mean percentage during the previous 5 years (6.4%; 95% CI, 6.0% to 6.7%; **Table 2**). Forty-seven jurisdictions reported rabid bats during 2017 **(Figure 3)**. No rabid bats were reported in North Dakota, New York City, Alaska, Hawaii, or Puerto Rico. In 8 states (Idaho, Illinois, Indiana, Mississippi, Montana, Nevada, Utah, and Washington), bats were the only rabid animals detected in 2017. Four states and the District of Columbia reported a ≥ 50% increase in the number of rabid bats detected: Arkansas (214% increase), Delaware (100% increase), District of Columbia (50% increase), New Hampshire (50% increase), and New Mexico (increased from 0 to 5 cases). Among the bats tested for rabies, 11,623 (47.5%) were described beyond the taxonomic level of order; variant typing results were reported for 581 (40.5%) of the reported rabid bats **(Tables 3 and 4)**.

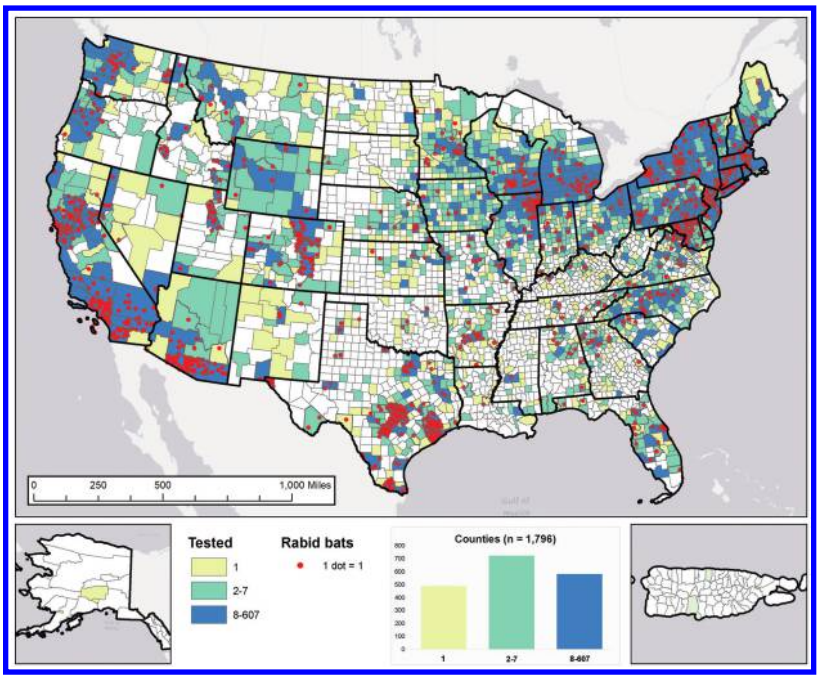

Figure 3—Distribution, by county, of bats tested for rabies during 2017. Histogram represents number of counties in each category for total number of bats submitted for rabies testing. Point locations for rabid bats were randomly selected within each reporting jurisdiction.

Raccoons

There were 13,142 raccoons tested for rabies in 2017, of which 1,275 (9.7%) were confirmed positive. This represented a 9.1% decrease, compared with the 1,403 rabid raccoons reported in 2016 (Table 1). The percentage of rabid raccoons among the total submitted for testing (9.7%) was significantly lower than the mean percentage during the previous 5 years (13.8%; 95% CI, 12.3% to 15.4%; Table 2). States in which the raccoon RVV was considered enzootic accounted for 97.5% of all rabid raccoons reported in 2017 (n = 1,243; **Figure 4**). Variant typing was conducted on 247 of these rabid raccoons, all of which were confirmed to be infected with the raccoon RVV. The remaining 32 (2.5%) rabid raccoons were reported from states where the raccoon RVV is not enzootic: Colorado (n = 1), Minnesota (1), Ohio (7), South Dakota (1), Tennessee (5), and Texas (17). Samples from 30 of the 32 (94%) rabid raccoons from states where the racoon RVV was not enzootic were submitted for variant typing. Seventeen were infected with the south central skunk RVV (Texas), 1 was infected with the north central skunk RVV (Minnesota), and 12 were infected with the raccoon RVV (Ohio and Tennessee).

Table 3—Rabies virus variants identified in domestic and wild animals in 2017.

	Domestic animals						Wildlife						
Variant	**Cats**	**Cattle**	**Dogs**	**Horses and donkeys**	**Sheep and goats**	**Other domestic***	**Raccoons**	**Bats**	**Skunks**	**Foxes**	**Other wild†**	**Rodents and lagomorphs‡**	**Total**
Raccoon	52	5	12	4	2	1	259	0	153	101	8	11	**608**
South central skunk	23	11	15	5	0	0	17	0	257	17	3	0	**348**
North central skunk	4	1	3	1	0	0	1	0	30	1	0	0	**41**
California skunk	1	0	2	0	0	0	0	0	11	0	0	0	**14**
Arctic fox	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Arizona gray fox	0	0	0	0	0	0	0	0	0	27	10	0	**37**
Dog (Egypt)	0	0	1	0	0	0	0	0	0	0	0	0	**1**
Bat	3	0	0	0	0	0	0	581	5	4	2	0	**595**
No variant reported	193	19	29	3	9	0	998	852	483	164	38	22	**2,810**
Total infected	**276**	**36**	**62**	**13**	**11**	**1**	**1,275**	**1,433**	**939**	**314**	**61**	**33**	**4,454**
Variant typed (%)	30.1	47.2	53.2	76.9	18.2	100.0	21.7	40.5	48.6	47.8	37.7	33.3	36.9
Variant typed (%), 2014–2016													
Mean (%)	26.2	48.5	54.2	37.8	33.4	88.9	20.7	25.7	45.1	31.2	19.4	16.4	29.9
95% CI	23.1–29.3	42.0–55.0	44.2–64.2	18.3–57.3	10.1–56.7	67.1–100	15.1–26.3	20.8–30.7	43.2–47.0	15.3–47.0	5.5–33.4	8.9–24.0	26.2–33.6

*Other domestic includes 1 swine with the raccoon RVV. †Other wild includes 4 bobcats, 2 coyotes, 1 deer, and 1 opossum with the raccoon RVV; 1 bobcat and 2 coyotes with the south central skunk RVV; 8 bobcats, 1 coyote, and 1 javelina with the Arizona gray fox RVV; 1 coyote with the *Eptesicus fuscus* (big brown bat) RVV; and 1 ringtail with the *Tadarida brasiliensis* (Mexican free-tailed bat) RVV. ‡Rodents and lagomorphs include 11 groundhogs with the raccoon RVV.

Table 4—Species of bats submitted for rabies testing in the United States during 2017.

Species (common name)	No. tested	No. positive	Percentage positive
Order Chiroptera (unspecified)	12,835	500	3.9
E fuscus (big brown bat)	8,516	301	3.5
T brasiliensis (Mexican free-tailed bat)	1,396	440	31.5
Myotis lucifugus (little brown bat)	330	5	1.5
Nycticeius humeralis (evening bat)	283	13	4.6
Lasiurus borealis (red bat)	237	26	11.0
Myotis californicus (California myotis)	139	4	2.9
Lasionycteris noctivagans (silver-haired bat)	89	9	10.1
Myotis velifer (cave myotis)	85	2	2.4
Parastrellus hesperus (canyon bat)	70	48	68.6
Myotis spp (not further differentiated)	59	4	6.8
Myotis volans (long-legged myotis)	57	5	8.8
Lasiurus cinereus (hoary bat)	47	30	63.8
Myotis evotis (long-eared myotis)	46	1	2.2
Myotis yumanensis (Yuma myotis)	36	12	33.3
Lasiurus intermedius (northern yellow bat)	34	7	20.6
Perimyotis subflavus (tricolored bat)	31	1	3.4
Lasiurus seminolus (Seminole bat)	30	5	16.7
Antrozous pallidus (desert pallid bat)	18	5	27.8
Lasiurus xanthinus (western yellow bat)	17	5	29.4
Lasiurus ega (southern yellow bat)	15	6	40.0
Myotis austroriparius (southeastern myotis)	12	1	8.3
Myotis thysanodes (fringed myotis)	12	0	0.0
Leptonycteris yerbabuenae (lesser long-nosed bat)	11	0	0.0
Myotis ciliolabrum (western small-footed myotis)	10	1	10.0
Myotis keenii (Keen myotis)	9	0	0.0
Lasiurus spp (not further differentiated)	9	0	0.0
Myotis septentrionalis (northern long-eared bat)	7	0	0.0
Nyctinomops macrotis (big free-tailed bat)	5	1	20.0
Corynorhinus rafinesquii (Rafinesque big-eared bat)	3	0	0.0
Desmodus rotundus (common vampire bat)*	3	0	0.0
Myotis leibii (eastern small-footed myotis)	2	0	0.0
Corynorhinus townsendii (Townsend big-eared bat)	1	1	100
Artibeus jamaicensis (Jamaican fruit bat)*	1	0	0.0
Myotis occultus (Arizona myotis)	1	0	0.0
Eumops perotis (western mastiff bat)	1	0	0.0
Phyllostomus hastatus (greater spear-nosed bat)*	1	0	0.0
Total	**24,458**	**1,433**	**5.9**

*Nonnative bat species submitted from captive collections.

Eighteen states, the District of Colombia, and New York City remained enzootic for the raccoon RVV. Eleven of these jurisdictions reported a decrease in the number of raccoon rabies cases detected, compared with the number detected in 2016: Alabama (54.8% decrease), Colorado (50.0% decrease), Connecticut (238.5% decrease), Massachusetts (71.4% decrease), Maryland (10.8% decrease), Maine (20.6% decrease), New Jersey (22.3% decrease), New York (50% decrease), South Carolina (51.7% decrease), Texas (5.6% decrease), and Virginia (5.1% decrease). Fourteen jurisdictions reported an increase in the number of raccoon rabies cases detected, compared with the number detected in 2016 (District of Columbia [17.6% increase], Delaware [200.0% increase], Florida [19.4% increase], Georgia [11.5% increase], Minnesota [100.0% increase], North Carolina [5.7% increase], New Hampshire [16.7% increase], New York City [200.0% increase], Ohio [40.0% increase], Pennsylvania [7.0% increase], Rhode Island [11.1% increase], South Dakota [100.0% increase], Tennessee

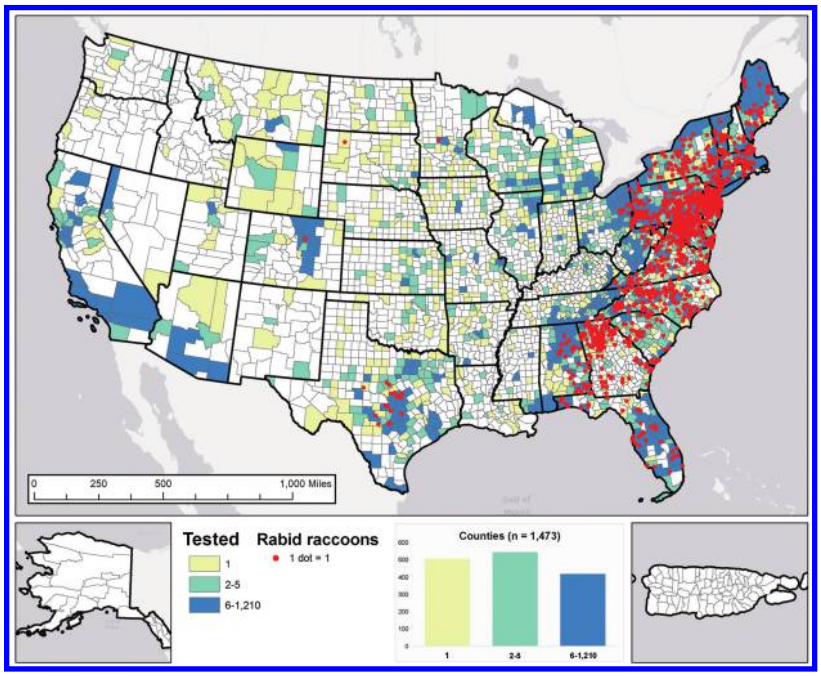

Figure 4—Distribution, by county, of raccoons tested for rabies during 2017. Histogram represents number of counties in each category for total number of raccoons submitted for rabies testing. Point locations for rabid raccoons were randomly selected within each reporting jurisdiction.

[150.0% increase], and West Virginia [40.0% increase]). Of the 3,021 rabies cases detected in 2017 that did not involve bats, 74.2% were reported from states where the raccoon RVV was enzootic. The number of raccoon rabies cases peaked in 1993, at 5,912.[20]

Skunks

A total of 4,148 skunks were tested for rabies in 2017, of which 939 (22.6%) were positive **(Figure 5)**. This represented an 8.9% decrease from the number of rabid skunks reported during 2016 (n = 1,031; Table 1). The percentage of rabid skunks among the total submitted for testing (22.6%) during 2017 was significantly lower than the mean percentage during the previous 5 years (29.5%; 95% CI, 26.3% to 32.6%; Table 2).

Ten of the 21 states where skunk RVVs were considered enzootic reported a decrease in the number of rabid skunks during 2017, compared with the number detected in 2016: Arizona (52.1% decrease), California (12.5% decrease), Kansas (25.7% decrease), Michigan (50.0% decrease), Missouri (80.0% decrease), New Mexico (50.0% decrease), Oklahoma (27.3% decrease), South Dakota (38.5% decrease), Tennessee (40.7% decrease), and Texas (11.4% decrease). Eight of the 21 states where skunk RVVs were considered enzootic reported an increase in the number of rabid skunks (Arkansas, Colorado, Iowa, Kentucky, Louisiana, North Dakota, Nebraska, and Wyoming).

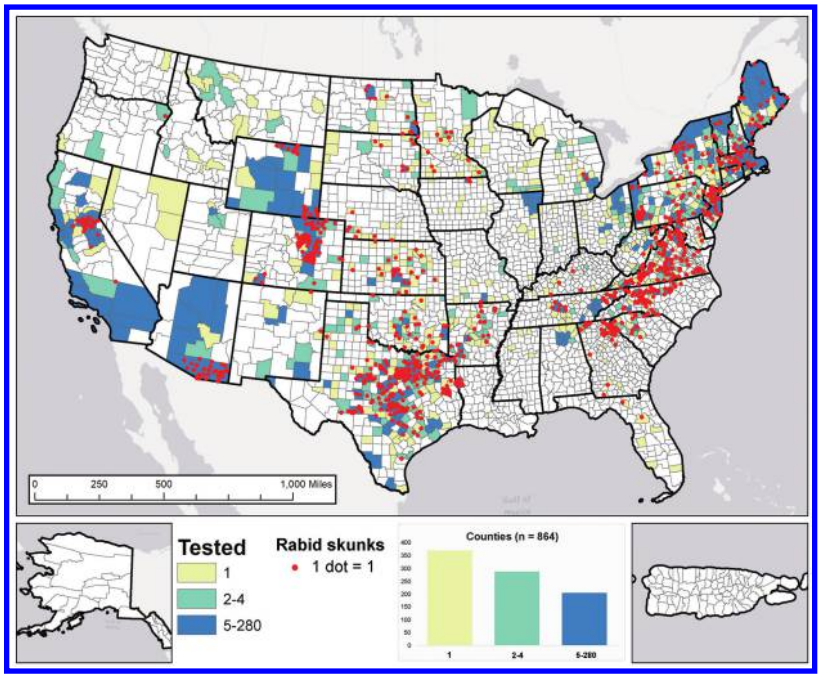

Figure 5—Distribution, by county, of skunks tested for rabies during 2017. Histogram represents number of counties in each category for total number of skunks submitted for rabies testing. Point locations for rabid skunks were randomly selected within each reporting jurisdiction.

Foxes

There were 1,799 foxes submitted for rabies testing in 2017, of which 314 (17.5%) were rabid **(Figure 6)**. This represented a 0.3% increase, compared with the 313 reported in 2016 (Table 1). The percentage of rabid foxes among the total submitted for testing (17.5%) was significantly lower than the mean percentage for the previous 5 years (18.8%; 95% CI, 17.6% to 19.9%; Table 2). No animals were reported infected with the Texas gray fox RVV in 2017; the last animal reported with this RVV was a cow in 2013.[21]

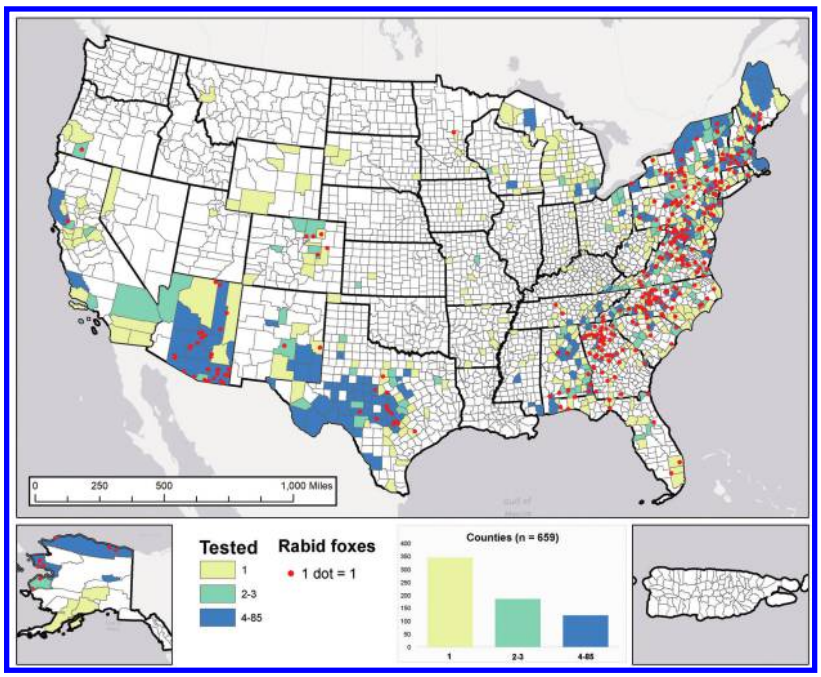

Figure 6—Distribution, by county, of foxes tested for rabies during 2017. Histogram represents number of counties in each category for total number of foxes submitted for rabies testing. Point locations for rabid foxes were randomly selected within each reporting jurisdiction.

Other wild animals

During 2017, Puerto Rico reported 17 rabid mongooses of 18 tested, a 55% increase from the 11 rabid mongooses reported in 2016. Other reported rabid wildlife included 22 bobcats (*Lynx rufus*), 13 coyotes (*Canis latrans*), 3 deer (presumably *Odocoileus virginianus*), 3 opossums (family Didelphidae), 1 javelina (*Tayassu tajacu*), 1 ringtail (*Bassariscus astutus*), and 1 otter (*Lontra canadensis*; Table 1). Rabid rodents and lagomorphs reported in 2017 included 33 groundhogs (*Marmota monax*). Variant typing was performed on 23 of the 61 (37.7%) other wild animals and 11 of the 33 (33.3%) rodents and lagomorphs reported to be rabid (Table 3).

Rabies in Domestic Animals

During 2017, domestic animals accounted for 48.6% of all animals submitted for rabies testing and 9.0% (399/4,454) of all animal rabies cases reported. The 399 rabid domestic animals reported in 2017 represented a 5.7% decrease, compared with the 423 reported in 2016 (Table 1). More than half of the 399 rabid domestic animals detected in 2017 were reported from 5 states: Pennsylvania (n = 68), Texas (42), Virginia (34), Maryland (34), and New York (33).

Dogs

In 2017, 21,683 dogs were tested for rabies, and 62 (0.3%) were confirmed rabid. This represented a 6.9% increase from the 58 rabid dogs reported in 2016. Most of the rabid dogs were reported from 7 jurisdictions: Texas (n = 12 [19.4%]), Puerto Rico (11 [17.7%]), Georgia (6 [9.7%]), Alaska (3 [4.8%]), California (3 [4.8%]), North Carolina (3 [4.8%]), and South Dakota (3 [4.8%]; **Figure 7**). The percentage of dogs submitted for testing that were confirmed to be rabid in 2017 (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 = 12 [19.4%]), 2 had a history of vaccination. The RVV was provided for 33 (53.2%) of the reported rabid dogs, among which 12 were infected with the raccoon RVV, 15 were infected with the south central skunk RVV, 3 were infected with the north central skunk RVV, 2 were infected with the California skunk RVV, and 1 was infected with a canine RVV (representing a dog imported from Egypt; Table 3).

Cats

There were 21,187 cats submitted for rabies testing in 2017, of which 276 (1.3%) were confirmed rabid. This represented a 7.4% increase in the number of rabid cats, compared with the 257 reported in 2016 (Table 1). The percentage of cats submitted for testing that were confirmed to be rabid (1.3%) was significantly higher than the mean percentage for the previous 5 years (1.1%; 95% CI, 1.1% to 1.2%; Table 2). Rabies vaccination status was reported for 12 (4.3%) rabid cats. Nine of the rabid cats had no history of vaccination, and 3 were reported to have been vaccinated. Most of the rabid cats were reported from states where the raccoon RVV was considered enzootic: Pennsylvania (n = 60 [21.7%]), Maryland (33 [12.0%]), New York (28 [10.1%]), and Virginia (25 [9.1%]; **Figure 8**). The RVV was provided for 83 (30.1%) of the reported rabid cats (Table 3). Most (n = 52 [62.7%]) were infected with the raccoon RVV, with the remainder infected with the south central skunk RVV (23 [27.7%]),

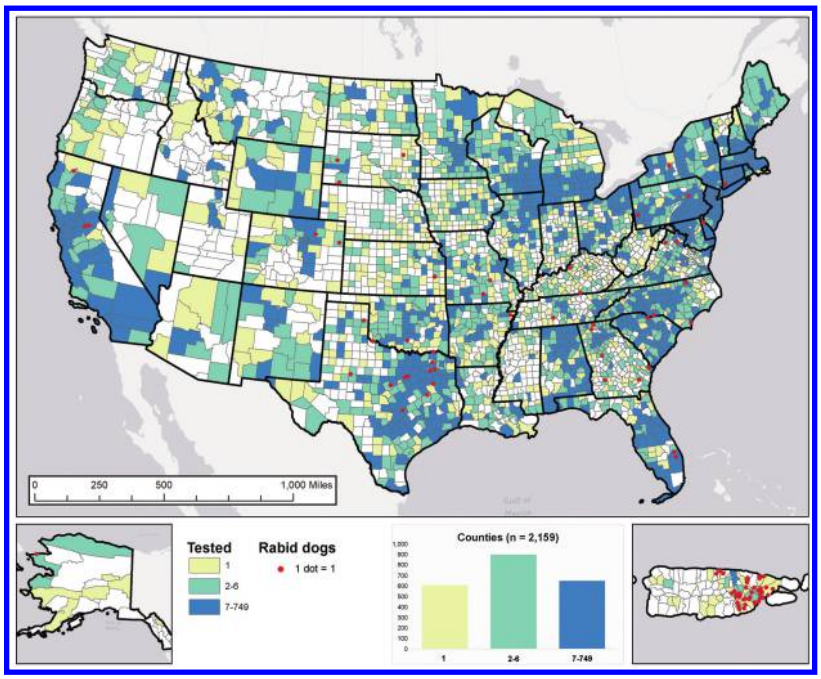

Figure 7—Distribution, by county, of dogs tested for rabies during 2017. Histogram represents number of counties in each category for total number of dogs submitted for rabies testing. Point locations for rabid dogs were randomly selected within each reporting jurisdiction.

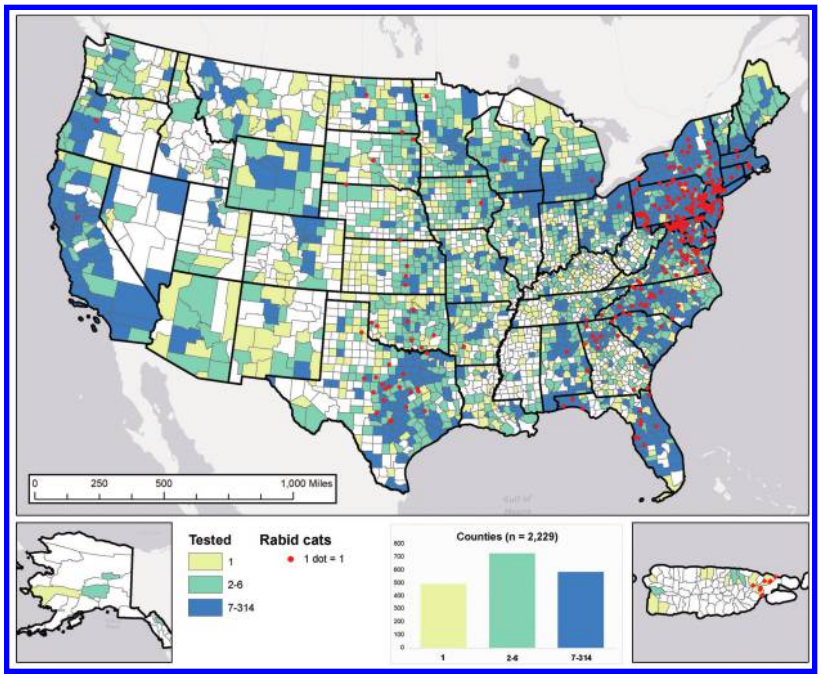

Figure 8—Distribution, by county, of cats tested for rabies during 2017. Histogram represents number of counties in each category for total number of cats submitted for rabies testing. Point locations for rabid cats were randomly selected within each reporting jurisdiction.

the north central skunk RVV (4 [4.8%]), the California skunk RVV (1 [1.2%]), or a bat RVV (3 [3.6%]).

Other domestic animals

A total of 1,045 cattle were tested for rabies during 2017, of which 36 (3.4%) were confirmed rabid. This represented a 48.6% decrease in the number of rabid cattle, compared with the number reported in 2016 (n = 70; Table 1). The percentage of cattle submitted for testing that were confirmed to be rabid (3.4%) was significantly lower than the mean percentage for the previous 5 years (6.8%; 95% CI, 5.7% to 7.8%; Table 2). Texas reported the highest number of rabid cattle (n = 8 [22.2%]), followed by Oklahoma (5 [13.9%]), South Dakota (4 [11.1%]), and Virginia (4 [11.1%]). Thirteen rabid horses and donkeys were reported in 2017, a 43.5% decrease from the 23 reported in 2016. The percentage of horses and donkeys submitted for testing that were confirmed to be rabid (1.9%) was significantly lower than the mean percentage for the previous 5 years (3.5%; 95% CI, 2.5% to 4.4%).

Rabies in Humans

During 2017, antemortem and postmortem samples from 21 human patients in 14 states suspected to have rabies were submitted to the CDC for diagnostic testing, of which 2 (9.5%) were confirmed to be positive **(Table 5)**. The first case involved a 65-year-old

Table 5—Cases of rabies in humans in the United States and Puerto Rico, January 2003 through October 2018, by circumstances of exposure and RVV.

Date of onset	Date of death	Reporting state	Age (y)	Sex	Exposure*	RVV†
10 Feb 03	10 Mar 03	VA	25	M	Unknown	Raccoon, eastern United States
28 May 03	5 Jun 03	PR	64	M	Bite, Puerto Rico	Dog-mongoose, Puerto Rico
23 Aug 03	14 Sep 03	CA	66	M	Bite	Bat, Ln
9 Feb 04	15 Feb 04	FL	41	M	Bite, Haiti	Dog, Haiti
27 Apr 04	3 May 04	AR	20	M	Bite (organ donor)	Bat, Tb
25 May 04	31 May 04	OK	53	M	Liver transplant	Bat, Tb
27 May 04	21 Jun 04	TX	18	M	Kidney transplant	Bat, Tb
29 May 04	9 Jun 04	TX	50	F	Kidney transplant	Bat, Tb
2 Jun 04	10 Jun 04	TX	55	F	Arterial transplant	Bat, Tb
12 Oct 04	Survived	WI	15	F	Bite	Bat, unknown
19 Oct 04	26 Oct 04	CA	22	M	Unknown, El Salvador	Dog, El Salvador
27 Sep 05	27 Sep 05	MS	10	M	Contact	Bat, unknown
4 May 06	12 May 06	TX	16	M	Contact	Bat, Tb
30 Sep 06	2 Nov 06	IN	10	F	Bite	Bat, Ln
15 Nov 06	14 Dec 06	CA	11	M	Bite, Philippines	Dog, Philippines
19 Sep 07	20 Oct 07	MN	46	M	Bite	Bat, unknown
16 Mar 08	18 Mar 08	CA	16	M	Bite, Mexico	Fox, Tb related
19 Nov 08	30 Nov 08	MO	55	M	Bite	Bat, Ln
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

*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 = *D rotundus*. Ln = *L noctivagans*. My sp = *Myotis* species. Ps = *P subflavus*. Tb = *T brasiliensis*.

woman who died of rabies in Virginia after being bitten by a dog while traveling in India. The second case involved a 56-year-old woman in Florida who died of rabies after being bitten by a bat.[22]

National Rabies Control Efforts

Primary rabies control efforts in the United States are led by municipal, county, and state health departments. 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 diagnosis 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 a large-scale program for oral rabies vaccination of targeted wildlife populations with the objective of controlling and ultimately eliminating RVVs associated with specific wildlife reservoirs.

During 2017, the national rabies management program maintained an ORV zone focused on preventing the spread of the raccoon RVV. The zone stretched 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-Tennessee border. In this area, a total of 8,772,616 baits (vaccinia-rabies glycoprotein recombinant vaccine baits, 66.9%; adenovirus-rabies glycoprotein recombinant vaccine baits, 33.1%) were distributed across more than 108,000 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 dog-coyote RVV, and 30,000 vaccinia-rabies glycoprotein recombinant vaccine baits were distributed across 256 km^2 in central Texas to evaluate the effectiveness of oral rabies vaccination in striped skunks.[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 reportedly extremely low, state health departments in collaboration with the CDC and USDA maintained surveillance for such events. In 2017, a total of 242 bait contacts were reported from 11 of 15 reporting states (Alabama, Georgia, Kentucky, Massachusetts, Maryland, Maine, New Jersey, New York, Ohio, Pennsylvania, Tennessee, Texas, Virginia, Vermont, and West Virginia). Four states (Georgia, Kentucky, Texas, and Virginia) did not report any bait contacts **(Table 6)**. Additional calls from the public may have been received that did not involve direct contact with a vaccine bait. No adverse reactions in humans from vaccine exposure were reported in 2017. Since the start of the ORV program in the United States, 2 cases of severe adverse reactions in humans have been reported following direct exposure to the vaccine (both following contact with the vaccinia-rabies glycoprotein recombinant vaccine). Both patients were treated without sequelae.[24,25] This represented a cumulative incidence of < 1 adverse event/87.5 million baits distributed.

Rabies in Canada and Mexico

Canada

In 2017, the Canadian Food Inspection Agency tested 2,775 samples for rabies, of which 239 (8.6%) were positive.[19] This represented a small decrease (9.2%) in the number of samples tested, compared with the 3,055 tested in 2016. Most (66.8%) of the samples tested during 2017 came from animals that

Table 6—Reported human and animal contact with baits containing an ORV, 2017.

	ORV in bait			
Variable	**V-RG**	**A-RG**	**Unknown**	**Total**
No. of baits reportedly found	164	66	12	**242**
Human contact				
No. who had contact with bait	141	32	4	**177**
No. who had contact with vaccine	32	6	1	**39**
No. of adverse events reported	0	0	0	**0**
Animal contact				
No. that consumed bait or had contact with vaccine	51	17	3	**71**
No. of adverse events reported*	12	5	0	**17**
No. of baits distributed	6,931,047	2,906,269	NA	**9,837,316**

Information on contact with baits containing an ORV was reported by 15 states (Alabama, Georgia, Kentucky, Massachusetts, Maryland, Maine, New Jersey, New York, Ohio, Pennsylvania, Tennessee, Texas, Virginia, Vermont, and West Virginia). Four of these states (Georgia, Kentucky, Texas, and Virginia) did not report any bait contacts.

*Adverse events consisted of mild gastrointestinal illness with the exception of 1 animal that was reported to have stopped eating for 5 days before vomiting up the bait.

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

potentially exposed a person to rabies; all other tested samples came from animals that had contact with a domestic animal (19.7%) or did not have any documented contact with humans or domestic animals (13.5%). Although most rabies cases involved wildlife species (222/239 [92.9%]), domestic species accounted for 44.5% (1,235/2,775) of the samples submitted for testing. Of the positive test results, 132 (55%) were confirmatory tests on wildlife surveillance samples that had initially been analyzed in provincial laboratories with the direct rapid immunohistochemical test[26] or by means of conventional immunohistochemical staining on formalin-fixed, paraffin-embedded tissues. An additional 6 cases involving wildlife were reported to the Canadian Food Inspection Agency but were not submitted for confirmatory testing. This included 4 bats from Saskatchewan and 2 red foxes from the Northwest Territories; none of these 6 animals had any reported exposure to humans or domestic animals. Outbreaks with the raccoon RVV that were originally detected in 2014 and 2015 in New Brunswick and Ontario, respectively, continued in 2017. With similar levels of surveillance between years, the number of New Brunswick cases remained constant (3 in 2016; 4 in 2017), whereas the number of cases substantially decreased in Ontario (258 in 2016; 119 in 2017). This decrease in the number of cases in Ontario likely explained the decrease in the percentage of samples submitted for testing that had positive results in 2017 (8.6%), compared with 2016 (12.8%). However, given these outbreaks, raccoons not surprisingly again accounted for the highest percentage of cases in 2017 (36%), followed by skunks (26%), bats (23%), and foxes (6.7%). As in 2016, Ontario submitted the highest number of samples for testing (1,619) and had the highest number of cases (149). Similar to previous years, only bat rabies cases were detected in British Columbia (n = 11) and Alberta (7). The prairie provinces of Saskatchewan and Manitoba recorded cases in skunks (n = 22), domestic animals (7), and bats (3), whereas Quebec recorded cases in bats (8), arctic foxes (3), a dog, and a cat, and New Brunswick reported cases in bats (7), skunks (3), and a raccoon. Northwest Territories recorded cases only in wildlife in 2017 (1 arctic fox and 1 red fox), whereas Nunavut recorded 10 cases involving arctic foxes and 3 involving dogs. No cases were detected in Nova Scotia, Prince Edward Island, Newfoundland and Labrador, or Yukon, although the number of samples tested from each of these jurisdictions was low (range, 1 to 17). Among domestic animals, rabies was detected in 7 dogs, 7 bovids, and 4 cats; these cases were the result of spillover of skunk RVV in the prairie provinces (3 bovids, 2 cats, and 2 dogs), infection with a fox RVV (4 bovids) or raccoon RVV (1 cat) in southwestern Ontario, or infection with a fox RVV in the northern regions (5 dogs). For 1 case involving a cat, the RVV could not be typed because the sample consisted of formalin-fixed, paraffin-embedded tissue. No spillover cases associated with bat RVVs were detected in nonbat species in 2017.

Mexico

During 2017, 3 cases of rabies were reported in unvaccinated dogs in Mexico; these dogs were in Chiapas, Sinaloa, and Yucatan. Results of antigenic characterization corresponded to a skunk RVV.

The successful control of canine rabies and dog-mediated human rabies in Mexico has been due to the implementation of 2 main strategies: national campaigns of canine and feline vaccination against rabies, and timely medical care, including PEP, of persons bitten by rabid animals. The national rabies vaccination campaigns in Mexico consist of intensive efforts over the past 10 years that have reached an average of 18 million dogs and cats each year. The program is free to owners.

Rabies surveillance is conducted by state public health laboratories. In 2017, 27,912 samples were tested, of which 150 (0.5%) were positive for rabies. Dogs (n = 25,870) accounted for 92.7% of the total samples submitted for rabies testing. Confirmed rabid animals included bovids (n = 119 [79.3%]), bats (12 [8%]), skunks (9 [6%]), cats (4 [2.7%]), dogs (3 [2%]), and other animals (3 [2%]).

No cases of dog- or wildlife-mediated human rabies were detected in Mexico in 2017. The last case of dog-mediated human rabies detected in Mexico was in 2005.

Discussion

The CDC has requested information on rabies-positive animals for more than 70 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 number of rabid raccoons and the percentage of tested raccoons determined to be rabid both continued to decrease in 2017, following a general trend observed for this species since the mid-1990s. In contrast, the number of reported cases of rabies involving bats has increased over this same period, and bats were once again the most frequently reported rabid animal in the United States. Factors accounting for these observed trends may include the ORV program for raccoons, population fluctuations in reservoir species, and alterations in public perceptions of the risk of rabies.

The rabies virus is one of the most successful zoonotic disease agents globally, with more than 30 reported animal reservoir species and near-global distribution. In the United States, the diversity of the more than 16 RVVs that have been documented is due to sustained host shifts from canine RVVs as well as extant chiropteran variants.[6] Four decades ago, the epidemiology of rabies in the United States was very different, with canine, coyote, and gray fox RVVs present in the southern United States; raccoon

RVVs sequestered to the Southeastern and Mid-Atlantic regions; a red fox RVV in the northeastern United States; and the role of bats in the circulation of RVVs barely recognized. Virus variant characterization is a critical component for monitoring host-shift events, and early identification of novel RVVs can help with instituting control measures and developing appropriate public health messages. In 2017, typing of specimens from bats, skunks, foxes, and other wildlife species increased. However, infecting RVVs for > 45% of rabid dogs and 70% of rabid cats were not further characterized. Guidance for focusing laboratory efforts to type samples most relevant to monitoring the evolution of new RVVs and responding to the movement of RVVs has been developed and should help increase and improve the efficient use of RVV typing.

Cats were the most frequently reported rabid domestic animal in the United States during 2017 and have been so since 1992. The percentage of tested cats found to be rabid in 2017 was the highest (1.3%) it has been since 2008. Most of the rabid cats were reported from states where the raccoon RVV was considered enzootic. The interaction between cats and raccoons puts cats at risk of exposure to the raccoon RVV. Currently, some states do not have laws requiring rabies vaccination of cats.[18] Monitoring cat rabies and increasing RVV typing in rabid cats are important strategies for protecting humans from cat-associated rabies infection.

For the fourth time since the United States declared freedom from the canine RVV (in 2007), a rabid dog was imported in 2017 from a country in which the canine RVV was endemic. Since 2007, canine RVV–infected dogs have been imported from India (2007), Iraq (2008), and Egypt (2015 and 2017). All 4 of these dogs were imported by animal rescue organizations; the 2 most recent importation events were due to proven (2015) or suspected (2017) falsification of rabies vaccination certificates.[28] The 2017 case resulted in 2 human exposures, which necessitated PEP.[29] No other animals were exposed, and no secondary cases arose from these importation events. The World Organisation for Animal Health (OIE) recommends serologic confirmation of adequate antirabies antibody titers prior to movement of dogs from endemic countries to those that are free from canine RVV. However, in the United States, only verification of vaccination by health certificate is required. Immediate notification of the CDC of any confirmed rabid animals entering the United States is required. Detection, diagnosis, and notification were highly effective at preventing onward transmission of rabies associated with imported canine rabies cases.

The lack of real-time electronic surveillance for animal rabies often results in a delay in multistate analyses that can range from a minimum of 9 months to as high as 18 months. This frequently impedes the CDC's ability to monitor regional and national trends. To address this delay in data review, the CDC, in collaboration with the Association of Public Health Laboratories, has developed a standard HL7 message guide for animal rabies reporting to facilitate electronic laboratory reporting of rabies diagnostic activity in state public health, agriculture, and university laboratories. This system will allow for real-time reporting of diagnostic assay results from laboratory information management systems, thereby decreasing the lag time in standard reporting, improving data quality, and reducing the need for duplicate data entry from states. In 2017, 17 states submitted rabies surveillance data in near real-time through the use of an automated messaging system (4 used the standard HL7 rabies message guide). Four additional states began implementing processes to send standard electronic data messages. Ultimately, this system is expected to provide a portal to improve regional access to surveillance data by public health jurisdictions and for the national ORV program.

2018 Rabies Update

Two human rabies cases have been reported in the United States from January through October 2018. The first case involved a 6-year-old boy who developed numbness in his right hand on December 28, 2017, at the site of a bat bite he had received approximately 2 weeks before the onset of symptoms. His illness progressed rapidly to include muscle spasms and ataxia before requiring hospital admission and intubation. Samples tested by the CDC confirmed infection with an RVV associated with *Tadarida brasiliensis* bats. He died on January 14, 2018, despite aggressive experimental therapy including heavy sedation in the intensive care unit. The second case involved a 69-year-old female resident of Delaware who presented for medical care on July 20, 2018, with a 5-day history of nausea, vomiting, and diarrhea. Her condition deteriorated rapidly to include altered mental status requiring intubation, and she was transferred to a tertiary care hospital in Pennsylvania for further treatment. She received empirical treatment with plasma exchange therapy before samples submitted to the CDC confirmed a diagnosis of rabies. She died on August 23, 2018, and CDC testing of postmortem samples identified an RVV associated with raccoons in the eastern United States. No specific animal exposures were identified, but the patient lived in a rural area of Delaware where feral cats and raccoons were found living around her property.

Starting in 2017, the World Health Organization began the process of reviewing and updating global recommendations on human rabies prevention. The Strategic Advisory Group of Experts committee approved several changes to pre-exposure prophylaxis and PEP schedules, including reductions in the number of doses of vaccine administered and the length of time over which vaccine doses were administered. New recommendations also included changes to rec-

ommendations for rabies immunoglobulin administration, focusing on the dosage necessary to ensure infiltration of wounds.[30] An Advisory Committee on Immunization Practices working group has been formed to update human rabies prevention recommendations in the United States. The new World Health Organization guidelines are being evaluated by this working group as part of standard practices to review existing evidence for recommendation changes.

During 2018, the World Organisation for Animal Health updated the *Manual of Diagnostic Tests and Vaccines for Terrestrial Animals* to recognize the direct rapid immunohistochemical test and pan-lyssavirus reverse transcriptase PCR assay as reference standards for rabies diagnostic testing, expanding the available diagnostic tools for rabies.[31] Real-time reverse transcriptase PCR assays can be used to reduce the number of inconclusive results of rabies testing.[32] A recently developed pan-lyssavirus reverse transcriptase PCR assay (LN34) is the only published TaqMan probe–based PCR assay that meets the pan-lyssavirus PCR assay standard with the ability to detect all the known lyssaviruses with high sensitivity and specificity. The LN34 PCR assay has been evaluated in multiple domestic and international laboratory validation processes. Currently, the CDC and the Association of Public Health Laboratories are working to develop guidance for diagnostic testing based on multiple rabies assays and to support adoption of the LN34 PCR assay as a primary or confirmatory rabies diagnostic test.

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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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Footnotes

a. Joinpoint trend analysis software, Division of Cancer Control and Population Sciences, National Cancer Institute, Bethesda, Md. Available at: surveillance.cancer.gov/joinpoint. Accessed Sep 12, 2018.

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