Rabies surveillance in the United States during 2016

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OBJECTIVE
To describe rabies and rabies-related events occurring during 2016 in the United States.

DESIGN
Observational study based on passive surveillance data.

ANIMALS
All animals submitted for rabies testing in the United States during 2016.

PROCEDURES
State and territorial public health programs provided data on animals submitted for rabies testing in 2016. Data were analyzed temporally and geographically to assess trends in domestic and sylvatic animal rabies cases.

RESULTS
During 2016, 50 states and Puerto Rico reported 4,910 rabid animals to the CDC, representing a 10.9% decrease from the 5,508 rabid animals reported in 2015. Of the 4,910 cases of animal rabies, 4,487 (91.4%) involved wildlife. Relative contributions by the major animal groups were as follows: 1,646 (33.5%) bats, 1,403 (28.6%) raccoons, 1,031 (21.0%) skunks, 313 (6.4%) foxes, 257 (5.2%) cats, 70 (1.4%) cattle, and 58 (1.2%) dogs. There was a 4.6% decrease in the number of samples submitted for testing in 2016, compared with the number submitted in 2015. No human rabies deaths were reported in 2016.

CONCLUSIONS AND CLINICAL RELEVANCE
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;252:945–957)

The present report presents an overview of rabies epidemiology and rabies-associated events that occurred in the United States during 2016. Rabies updates for Canada and Mexico in 2016 are also summarized.

Rabies is a zoonotic disease caused by RNA viruses in the genus *Lyssavirus*.[1] All species of mammals are susceptible to rabies virus infection. The primary route of rabies virus transmission is through the bite of an infected animal, but rabies virus may also be transmitted if fresh saliva from a rabid animal comes into contact with wounds or mucous membranes of another mammal. Rabies is almost invariably fatal in humans once symptoms develop. Despite its high fatality rate, rabies is entirely preventable if appropriate PEP is administered after a suspected rabies virus exposure. For healthy exposed persons who have never received a rabies vaccine, 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 should include a 5-dose vaccination regimen (ie, on days 0, 3, 7, 14, and 28), although the immune response still might be inadequate in this population.[3] 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 dogs causing > 99% of these human rabies deaths.[5] Canine rabies was successfully controlled in the United States during the late 1970s, and wildlife has accounted for > 90% of all rabid animals reported in the United States since 1980. The primary reservoir species responsible for maintaining terrestrial RVVs in the United States are raccoons (raccoon RVV), skunks (south central, north central, and California skunk RVVs), gray foxes (Texas and Arizona gray fox RVVs), arctic foxes (arctic fox RVV),

ABBREVIATIONS

CI	Confidence interval
PEP	Postexposure prophylaxis
RVV	Rabies virus variant

and mongooses (dog-mongoose RVV in Puerto Rico). Circulation of distinct RVVs associated with the major terrestrial animal reservoirs occurs in geographically definable regions, where transmission is primarily between members of the same species **(Figure 1)**. In addition to the terrestrial RVVs, there are multiple RVVs associated with bats.[6–8]

Rabies control in wildlife is a large-scale effort led by the Wildlife Services division of the USDA's APHIS. Efforts are primarily focused on the annual delivery of oral rabies vaccine–laden baits targeted at raccoons along the East Coast of the United States. Oral vaccination of wildlife has greatly reduced the spread of rabies in numerous countries in North America and Europe.[9,10] Vaccination of bats, however, 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.

In the United States, the burden of rabies in humans has been dramatically reduced because of the 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 or exposure to rabid dogs in countries where canine RVVs are still endemic.[11,12] 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.[3,13] For potential bat-associated rabies virus exposures, the Advisory Committee on Immunization Practices recommends evaluation of persons bitten by or in direct contact with bats and of persons who may have had unrecognized contact with a bat (eg, a deeply sleeping person, unattended child, mentally disabled person, or intoxicated person). In these instances, testing of bats to exclude infection remains the most definitive way to rule out the risk of rabies transmission.[2,14]

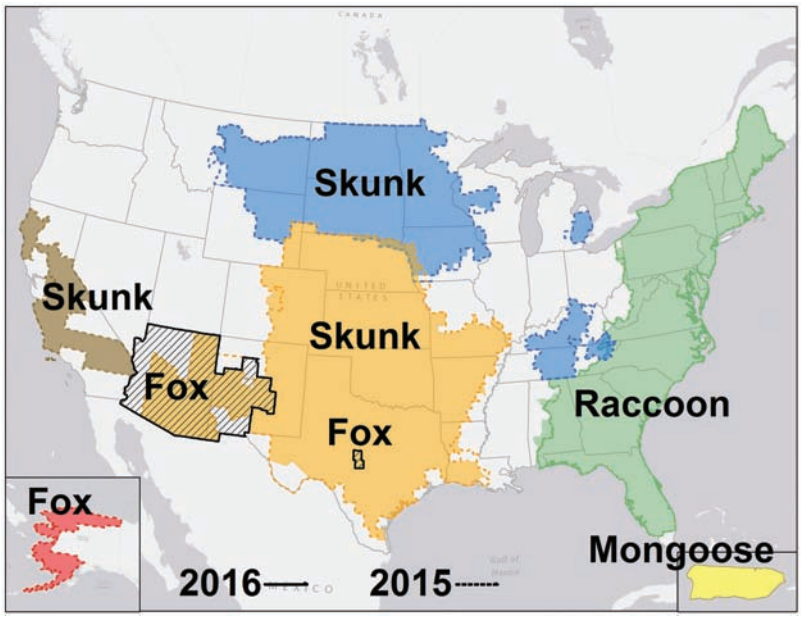

Figure 1—Distribution of major RVVs among mesocarnivores in the United States and Puerto Rico for 2011 through 2016. Black diagonal lines represent distribution of fox (Arizona gray fox and Texas gray fox) RVVs. Solid borders represent RVV distribution for 2012 through 2016; dashed borders represent the previous 5-year distribution for 2011 through 2015.

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, laboratory-based system that comprises > 130 state health, agriculture, and university pathology laboratories. These laboratories perform the standard direct fluorescent antibody test.[16] In addition, as a component of a large-scale oral rabies vaccination program, the USDA 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 spreadsheet software files. States provide information pertaining to 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 (when performed) 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 positive or negative test results included in the denominator. Thus, percentages reported here should not be interpreted as the incidence of rabies in these animal populations because most public health programs only test animals involved in potential exposure of humans or domestic animals to rabies. Therefore, the cases reported here may not represent the true number of animal rabies cases within these populations.

Annual trends in wildlife rabies cases were analyzed by species for 1966 through 2016. Owing to frequent spillover of the raccoon RVV into skunks, trends in the number of skunks with

the skunk RVV and in the number of skunks with the raccoon RVV were analyzed separately. Data were analyzed by means of standard software[a] to identify significant temporal trends. Trends are reported as the annual percentage change in the reported number of cases over the period of interest, with 95% CIs **(Figure 2)**.

Summary data for rabies in Canada during 2016 were provided by the Canadian Food Inspection Agency Centre of Expertise for Rabies, Ottawa, ON.[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 2016, a total of 95,424 animal samples were submitted for laboratory testing in the United States and territories, of which 93,535 (98.0%) were considered suitable for testing (this number includes samples with positive, negative, and indeterminate test results). This represented a 4.4% decrease in the number of animals tested, compared with the number tested during 2015 (n = 97,866). The USDA Wildlife Services tested 6,829 animals with the direct rapid immunohistochemical test, accounting for 7.3% of all animals submitted in 2016. The number of animals submitted for rabies testing during 2016 (n = 95,424) was significantly lower than the mean number tested during the previous 5 years (101,699; 95% CI, 98,954 to 104,443).

Rabies in Wildlife

Wildlife accounted for 91.4% (4,487/4,910) of rabies cases reported in 2016, representing an 11.8% decrease from 2015 **(Table 1)**. In 2016, bats were the most frequently reported rabid animals in the United States, representing 33.5% (n = 1,646) of all animal rabies cases detected, followed by raccoons (28.6% [1,403]), skunks (21.0% [1,031]), foxes (6.4% [313]), rodents and lagomorphs (1.0% [49]), and other wild animals (0.9% [45]).

Bats

There were 23,979 bats submitted for testing in 2016, of which 1,646 (6.9%) were positive. This represented a minor (3.4%) decrease in the number of rabid bats, compared with the number reported in 2015 (n = 1,704; Table 1). The percentage of rabid bats among the total submitted for testing (6.9%) was significantly higher than the mean percentage during the previous 5 years (6.2%; 95% CI, 5.9% to 6.5%; **Table 2**). Forty-six of the 48 contiguous states reported detecting rabid bats **(Figure 3)**. No rabid bats were reported in North Dakota, New Mexico, Alaska, Hawaii, or Puerto Rico. In 9 states (Idaho, Indiana, Mississippi, Montana, Nevada, Oregon, Utah, Washington, and Wisconsin), bats were the only rabid animals detected in 2016. Twelve states reported a ≥ 50% increase in the number of rabid bats detected: Idaho (100% increase), Kentucky (128.6% increase), Louisiana (50% increase), Minnesota (131.3% increase), Nevada (75% increase), Ohio (80% increase), Oklahoma (66.7% increase), South Dakota (60% increase), Tennessee (80% increase), Vermont (50% increase), Washington (122.2% increase), and West Virginia (500% increase). The RVV was reported for 488 of the 1,646 (29.6%) bats positive for rabies **(Table 3)**. Of the 23,979 bats tested for rabies, 11,952 (49.8%) were described beyond the taxonomic level of order **(Table 4)**.

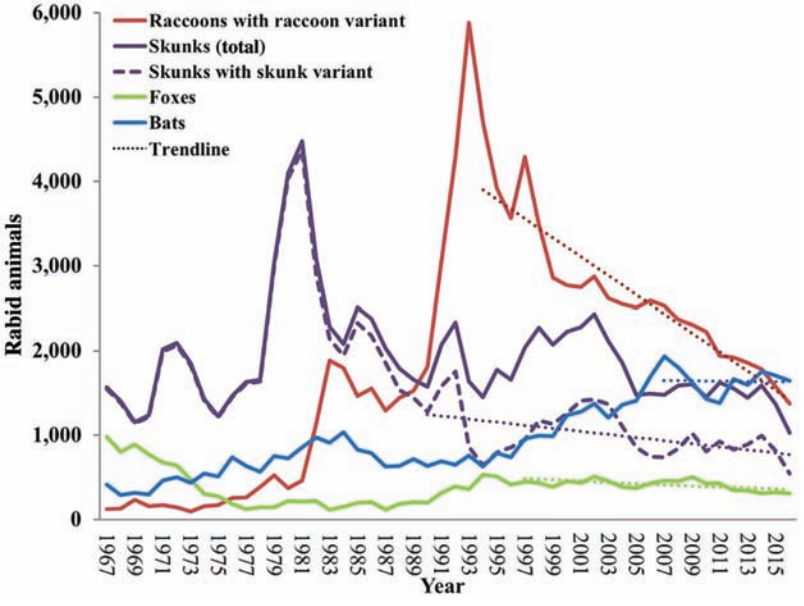

Figure 2—Cases of rabies among wildlife in the United States, by year and species, for 1966 through 2016.

Raccoons

There were 11,998 raccoons submitted for rabies testing in 2016, of which 1,403 (11.7%) were confirmed positive. This represented a 13.3% decrease, compared with the 1,619 rabid raccoons detected in 2015 (Table 1). The percentage of raccoons submitted for testing that were found to be rabid (11.7%) was significantly lower than the mean of the previous 5 years (14.4%; 95% CI, 13.3% to 15.5%; Table 2). States in which raccoon rabies was considered enzootic accounted for 98.1% of all rabid raccoons reported in 2016 (n = 1,376; **Figure 4**). Variant typing was conducted on 347 of these 1,376 raccoons, all of which were determined to be infected with the raccoon RVV. The remaining 27 (1.9%) rabid raccoons were detected in states where the raccoon RVV is not enzootic: Colorado (n = 2), Ohio (5), Tennes-

Table 1—Cases of rabies in the United States, by location, during 2016.

					Domestic animals						Wildlife									
Location	Primary reservoir	Total animal cases	Domestic animals	Wildlife	Cats	Cattle	Dogs	Horses and donkeys	Sheep and goats	Other domestic*	Raccoons	Bats	Skunks	Foxes	Other wildlife†	Rodents and lagomorphs‡	Humans	% Pos 2016	2015 cases	Change (%)
AK	Arctic fox	21	0	21	0	0	0	0	0	0	0	0	0	19	2[b]	0	0	6.54	7	200.0
AL	Raccoon	77	1	76	0	0	1	0	0	0	48	15	0	12	1[c]	0	0	4.14	87	−11.5
AR	Skunk	23	1	22	0	0	0	1	0	0	0	7	15	0	0	0	0	2.84	73	−68.5
AZ	Skunk	153	2	151	1	0	0	1	0	0	0	72	71	5	3[d]	0	0	15.24	120	27.5
CA	Skunk	226	6	220	3	0	3	0	0	0	0	176	32	12	0	0	0	4.22	230	−1.7
CO	Skunk	88	3	85	3	0	0	0	0	0	2	57	26	0	0	0	0	6.11	119	−26.1
CT	Raccoon	91	7	84	7	0	0	0	0	0	44	16	15	5	0	4[q]	0	6.71	170	−46.5
DC	Raccoon	24	0	24	0	0	0	0	0	0	17	2	0	5	0	0	0	13.87	10	140.0
DE	Raccoon	5	2	3	1	0	0	1	0	0	2	1	0	0	0	0	0	3.97	11	−54.5
FL	Raccoon	59	6	53	4	0	0	2	0	0	31	13	0	6	3[e]	0	0	3.13	85	−30.6
GA	Raccoon	232	24	208	13	2	8	0	1	0	113	18	49	25	3[f]	0	0	12.89	266	−12.8
HI	None	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00	0	0.0
IA	Skunk	19	6	13	1	1	3	1	0	0	0	12	1	0	0	0	0	1.49	12	58.3
ID	Bat only	20	0	20	0	0	0	0	0	0	0	20	0	0	0	0	0	5.68	10	100.0
IL	Bat only	63	1	62	1	0	0	0	0	0	0	62	0	0	0	0	0	1.78	97	−35.1
IN	Bat only	17	0	17	0	0	0	0	0	0	0	17	0	0	0	0	0	1.54	13	30.8
KS	Skunk	54	12	42	5	4	1	1	1	0	0	6	35	1	0	0	0	5.21	100	−46.0
KY	Skunk	22	2	20	1	1	0	0	0	0	0	16	3	1	0	0	0	3.02	11	100.0
LA	Skunk	4	0	4	0	0	0	0	0	0	0	3	1	0	0	0	0	0.81	5	−20.0
MA	Raccoon	146	5	141	5	0	0	0	0	0	60	21	44	11	0	5[r]	0	5.68	145	0.7
MD	Raccoon	336	29	307	27	2	0	0	0	0	154	104	26	17	0	6[s]	0	9.48	342	−1.8
ME	Raccoon	76	3	73	2	1	0	0	0	0	41	8	20	3	0	1[t]	0	7.15	34	123.5
MI	Skunk	41	0	41	0	0	0	0	0	0	0	37	4	0	0	0	0	1.32	38	7.9
MN	Skunk	55	7	48	2	4	0	1	0	0	0	37	10	1	0	0	0	2.81	28	96.4
MO	Skunk	25	3	22	1	1	1	0	0	0	0	17	5	0	0	0	0	1.41	31	−19.4
MS	Bat only	3	0	3	0	0	0	0	0	0	0	3	0	0	0	0	0	0.94	4	−25.0
MT	Skunk	10	0	10	0	0	0	0	0	0	0	10	0	0	0	0	0	2.08	22	−54.5
MC	Raccoon	257	16	241	10	4	2	0	0	0	122	26	38	52	1[g]	2[u]	0	7.01	342	−24.9
ND	Skunk	16	9	7	1	5	1	1	1	0	0	0	7	0	0	0	0	3.07	6	166.7
NE	Skunk	19	1	18	0	1	0	0	0	0	0	14	4	0	0	0	0	1.69	28	−32.1
NH	Raccoon	23	0	23	0	0	0	0	0	0	6	4	6	5	1[h]	1[v]	0	5.03	24	−4.2
NJ	Raccoon	263	26	237	25	0	1	0	0	0	137	59	24	9	1[i]	7[w]	0	9.76	308	−14.6
NM	Skunk	4	0	4	0	0	0	0	0	0	0	0	4	0	0	0	0	0.82	13	−69.2
NV	Bat only	14	0	14	0	0	0	0	0	0	0	14	0	0	0	0	0	4.20	8	75.0
NY	Raccoon	393	37	356	26	6	0	2	3	0	156	81	79	23	9[j]	8[x]	0	6.84	372	5.6
NYC	Raccoon	5	0	5	0	0	0	0	0	0	4	1	0	0	0	0	0	1.55	6	−16.7
OH	Bat only	41	0	41	0	0	0	0	0	0	5	36	0	0	0	0	0	0.97	26	57.7
OK	Skunk	47	9	38	2	3	2	2	0	0	0	5	33	0	0	0	0	5.33	86	−45.3
OR	Bat only	15	0	15	0	0	0	0	0	0	0	15	0	0	0	0	0	4.32	20	−25.0
PA	Raccoon	414	69	345	51	8	3	4	3	0	187	64	49	32	3[k]	10[y]	0	5.80	345	20.0
PR	Mongoose	20	9	11	0	0	8	1	0	0	0	0	0	0	11[l]	0	0	25.64	17	17.6
RI	Raccoon	26	0	26	0	0	0	0	0	0	9	9	2	3	1[m]	2[z]	0	4.74	17	52.9
SC	Raccoon	94	11	83	6	0	4	1	0	0	44	10	17	11	1[n]	0	0	6.22	130	−27.7
SD	Skunk	27	6	21	3	2	1	0	0	0	0	8	13	0	0	0	0	4.05	29	−6.9
TN	Skunk	46	7	39	1	0	5	1	0	0	2	9	27	1	0	0	0	2.41	37	24.3
TX	Skunk	751	46	705	24	9	10	2	1	0	18	430	237	18	2[o]	0	0	6.16	952	−21.1
UT	Bat only	20	0	20	0	0	0	0	0	0	0	20	0	0	0	0	0	6.85	22	−9.1
VA	Raccoon	362	48	314	27	12	4	1	2	2[a]	165	16	100	28	3[p]	2[aa]	0	11.62	528	−31.4
VT	Raccoon	48	3	45	1	1	0	0	1	0	21	9	10	5	0	0	0	4.97	25	92.0
WA	Bat only	20	0	20	0	0	0	0	0	0	0	20	0	0	0	0	0	4.71	10	100.0
WI	Skunk	29	0	29	0	0	0	0	0	0	0	29	0	0	0	0	0	1.45	22	31.8
WV	Raccoon	33	3	30	2	1	0	0	0	0	15	6	5	3	0	1[ab]	0	2.83	50	−34.0
WY	Skunk	33	3	30	1	2	0	0	0	0	0	11	19	0	0	0	0	5.06	15	120.0
Total	—	**4,910**	**423**	**4,487**	**257**	**70**	**58**	**23**	**13**	**2**	**1,403**	**1,646**	**1,031**	**313**	**45**	**49**	**0**	**—**	**5,508**	**−10.9**
	% 2016	100.0	8.6	91.4	5.2	1.4	1.2	0.5	0.3	0.0	28.6	33.5	21.0	6.4	0.9	1.0	0.0			
	% Pos 2016	5.3	0.9	9.6	1.2	5.6	0.3	3.1	2.3	1.1	11.7	6.9	23.8	17.2	1.9	2.3	**0.0**			
	Total 2015	**5,508**	**420**	**5,088**	**244**	**85**	**67**	**14**	**7**	**3**	**1,619**	**1,704**	**1,365**	**325**	**41**	**34**	**3**			
	Change (%)	−10.9	0.7	−11.8	5.3	−17.6	−13.4	64.3	85.7	−33.3	−13.3	−3.4	−24.5	−3.7	9.8	44.1	−100.0			

*Other domestic includes [a]2 alpacas. †Other wildlife includes [b]2 wolves; [c]1 bobcat; [d]1 coyote and 2 bobcats; [e]1 bobcat, 1 deer, and 1 otter; [f]2 bobcats and 1 coyote; [g]1 deer; [h]1 coyote; [i]1 antelope; [j]2 bobcats, 2 coyotes, 2 deer, and 3 fishers; [k]1 coyote and 2 deer; [l]11 mongooses; [m]1 coyote; [n]1 deer; [o]1 bobcat and 1 antelope; and [p]1 bobcat and 2 coyotes. ‡Rodents and lagomorphs include [q]3 groundhogs and 1 beaver; [r]5 groundhogs; [s]5 groundhogs and 1 beaver; [t]1 groundhog; [u]2 beavers; [v]1 groundhog; [w]6 groundhogs and 1 beaver; [x]8 groundhogs; [y]10 groundhogs; [z]2 groundhogs; [aa]2 groundhogs; and [ab]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 2011 through 2016.

	2016		2011–2015			
			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	257	1.2	265	243–286	1.1	1.1–1.2
Cattle	70	5.6*	86	70–102	6.9	5.9–7.8
Dogs	58*	0.3	74	63–85	0.3	0.3–0.4
Horses and donkeys	23	3.1	32	20–44	3.9	2.7–5.1
Sheep and goats	13*	2.3	10	8–12	2.0	1.4–2.6
Wildlife						
Raccoons	1,403*	11.7*	1,855	1,727–1,982	14.4	13.3–15.5
Bats	1,646	6.9*	1,624	1,494–1,753	6.2	5.9–6.5
Skunks	1,031*	23.8*	1,513	1,420–1,607	30.6	28.9–32.3
Foxes	313	17.2*	349	310–389	19.2	18.3–20.0
All rabid animals	4,910*	5.3*	5,920	5,698–6,142	5.9	5.7–6.2
Rabid domestic animals	423*	0.9	469	435–504	1.0	0.9–1.0
Rabid wildlife	4,487*	9.6*	5,450	5,256–5,645	10.9	10.6–11.2

*Significantly ($P < 0.05$) different from mean value for 2011 through 2015.

see (2), and Texas (18). Twenty-two of these nonenzootic samples were variant typed; the 17 from Texas were infected with the south central skunk RVV, and the 5 from Ohio and Tennessee were infected with the raccoon RVV.

Eighteen states, the District of Columbia, and New York City remained enzootic for the raccoon RVV. Eleven of these 20 (55%) states and jurisdictions reported a decrease in the number of raccoon rabies cases detected, compared with the number detected in 2015 (Alabama [14.3% decrease], Connecticut [48.2% decrease], Florida [34% decrease], Georgia [16.3% decrease], Maryland [7.8% decrease], North Carolina [28.2% decrease], New Hampshire [14.3% decrease], New Jersey [12.7% decrease], South Carolina [27.9% decrease], Virginia [36.5% decrease], and West Virginia [40% decrease]). Seven states or jurisdictions reported increases in the number of raccoon rabies cases (District of Columbia, Massachusetts, Maine, New York, Pennsylvania, Rhode Island, and Vermont). The number of raccoon rabies cases peaked in 1993, at 5,912.[20]

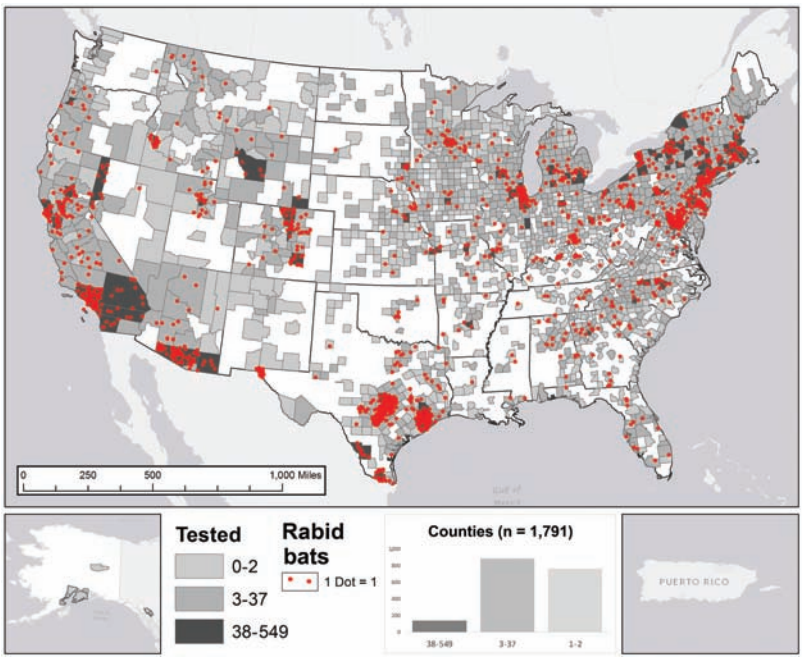

Figure 3—Reported cases of rabies involving bats, by county, during 2016. Histogram represents number of counties in each category for total number of bats submitted for rabies testing. Point locations for rabid bats were randomly selected within each reporting jurisdiction.

Skunks

A total of 4,339 skunks were submitted for testing in 2016, of which 1,031 (23.8%) were positive **(Figure 5)**. This represented a 24.5% decrease from the number of rabid skunks reported during 2015 (n = 1,365; Table 1). The percentage of skunks tested during 2016 that were found to be rabid (23.8%) was significantly lower than the previous 5-year mean (30.6%; 95% CI, 28.9% to 32.3%; Table 2).

Ten of the 21 states (47.6%) where skunk RVVs were considered enzootic reported a decrease in the number of rabid skunks during 2016, compared with 2015 (Arkansas [71.7% decrease], Colorado

Table 3—Rabies virus variants identified in domestic and wild animals in 2016.

	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	49	18	15	2	2	2	352	0	153	110	8	5	**716**
South central skunk	24	9	11	2	1	0	17	0	275	17	2	0	**358**
North central skunk	2	5	9	1	0	0	0	0	34	1	0	0	**52**
California skunk	0	0	0	0	0	0	0	0	0	0	0	0	0
Arctic fox	0	0	0	0	0	0	0	0	0	8	2	0	**10**
Arizona gray fox	0	0	0	0	0	0	0	0	0	4	3	0	**7**
Texas gray fox	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Bat	0	0	0	0	0	0	0	488	1	4	0	0	**493**
No variant reported	182	38	23	18	10	0	1,034	1,158	568	169	30	44	**3,274**
Total infected	**257**	**70**	**58**	**23**	**13**	**2**	**1,403**	**1,646**	**1,031**	**313**	**45**	**49**	**4,910**
Variant typed (%)	29.2	45.7	60.3	21.7	23.1	100.0	26.3	29.6	44.9	46.0	33.3	10.2	**33.3**
Variant typed (%), 2013–2015													
Mean	27.6	43.3	46.8	45.6	40.5	68.9	18.6	25.4	43.8	23.7	14.0	16.4	**28.4**
95% CI	22.8–32.5	31.8–54.9	37.3–56.3	36.2–55.0	23.1–57.9	41.1–96.7	17.2–20.0	21.8–29.0	41.0–46.5	18.5–28.8	10.5–17.4	10.1–22.6	27.1–29.7

*Other domestic includes 2 alpacas with the raccoon RVV. †Other wild includes 2 antelopes with the raccoon and south central skunk RVVs, 2 bobcats with the Arizona gray fox RVV, 1 bobcat with the raccoon RVV, 1 bobcat with the south central skunk RVV, 1 coyote with the Arizona gray fox RVV, 4 coyotes with the raccoon RVV, 2 deer with the raccoon RVV, and 2 wolves with the arctic fox RVV. ‡Rodents and lagomorphs include 2 beavers with the raccoon RVV and 3 groundhogs with the raccoon RVV.

Table 4—Species of bats submitted for rabies testing in the United States during 2016.

Species (common name)	**No. tested**	**No. positive**	**Percentage positive**
Order Chiroptera (not specified)	12,027	775	6.4
Eptesicus fuscus (big brown bat)	8,469	394	4.7
Myotis lucifugus (little brown bat)	363	7	1.9
Tadarida brasiliensis (Mexican free-tailed bat)	1,666	350	21.0
Lasionycteris noctivagans (silver-haired bat)	221	17	7.7
Nycticeius humeralis (evening bat)	319	11	3.4
Lasiurus borealis (red bat)	277	29	10.5
Myotis spp (not further differentiated)	54	1	1.9
Myotis californicus (California myotis)	88	4	4.5
Lasiurus cinereus (hoary bat)	43	21	48.8
Myotis yumanesis (Yuma myotis)	43	0	0.0
Myotis evotis (long-eared myotis)	55	4	7.3
Nyctinomops macrotis (big free-tailed bat)	2	1	50.0
Myotis volans (long-legged myotis)	51	7	13.7
Myotis keenii (Keen myotis)	2	0	0.0
Perimyotis subflavus (tricolored bat)	33	2	6.1
Lasiurus intermedius (northern yellow bat)	37	6	16.2
Myotis thysanodes (fringed myotis)	6	0	0
Antrozous pallidus (desert pallid bat)	23	5	21.7
Myotis austroriparius (southeastern myotis)	1	0	0.0
Myotis ciliolabrum (western small-footed myotis)	17	1	5.9
Lasiurus ega (southern yellow bat)	17	2	11.8
Leptonycteris yerbabuenae (lesser long-nosed bat)	18	0	0.0
Lasiurus seminolus (Seminole bat)	43	6	14.0
Parastrellus hesperus (canyon bat)	2	0	0.0
Plecotus townsendii (Townsend big-eared bat)	1	0	0.0
Desmodus rotundus (common vampire bat)	1	0	0.0
Myotis septentrionalis (northern long-eared bat)	10	0	0.0
Lasiurus xanthinus (western yellow bat)	2	0	0.0
Myotis auriculus (southwestern myotis)	9	0	0.0
Myotis leibii (eastern small-footed myotis)	2	0	0.0
Myotis velifer (cave myotis)	69	3	4.3
Rousettus aegyptiacus (Egytian fruit bat)	4	0	0.0
Myotis grisecens (gray bat)	1	0	0.0
Euderma maculatum (spotted bat)	1	0	0.0
Family Molossidae (unspecified free-tailed bats)	2	0	0.0
Total	**23,979**	**1,646**	**6.9**

[42.2% decrease], Kansas [47.8% decrease], Louisiana [66.7% decrease], Missouri [16.7% decrease], Montana [100.0% decrease], Nebraska [50% decrease], Oklahoma [46.8% decrease], South Dakota [13.3% decrease], and Texas [45% decrease]). Eight of the states where skunk RVVs were considered enzootic reported increases in the number of rabid skunk cases (Arizona, California, Kentucky, Michigan, Minnesota, North Dakota, New Mexico, and Wyoming).

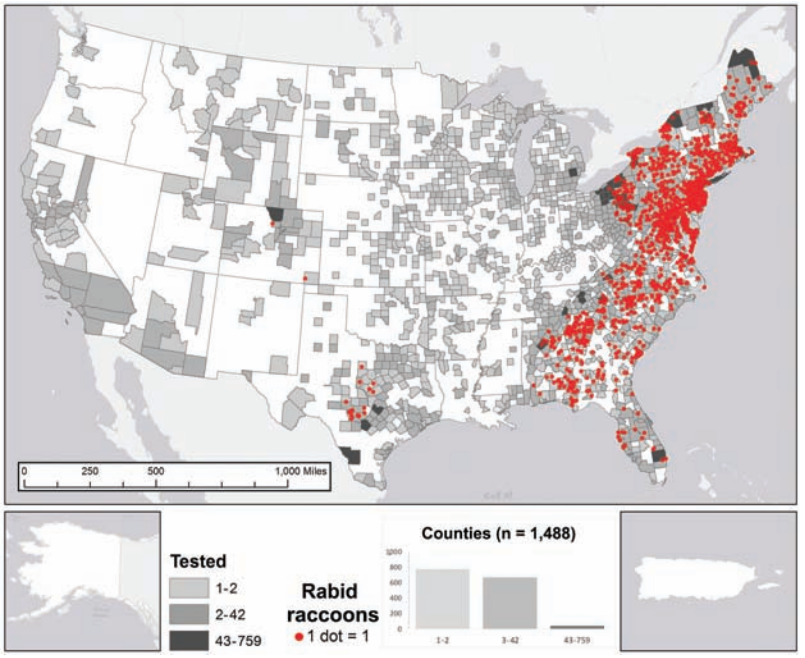

Figure 4—Reported cases of rabies involving raccoons, by county, during 2016. Histogram represents number of counties in each category for total number of raccoons submitted for rabies testing. Point locations for rabid raccoons were randomly selected within each reporting jurisdiction.

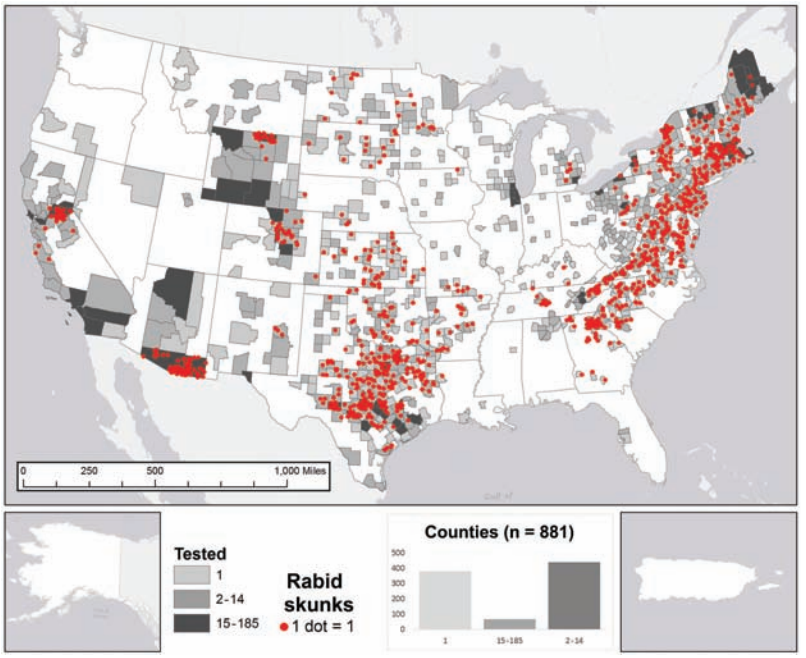

Figure 5—Reported cases of rabies involving skunks, by county, during 2016. Histogram represents number of counties in each category for total number of skunks submitted for rabies testing. Point locations for rabid skunks were randomly selected within each reporting jurisdiction.

Foxes

There were 1,818 foxes submitted for rabies testing in 2016, of which 313 (17.2%) were positive **(Figure 6)**. This represented a 3.7% decrease, compared with the 325 reported in 2015 (Table 1). The percentage of foxes submitted for testing that were found to be rabid (17.2%) was significantly lower than the mean for the previous 5 years (19.2%; 95% CI, 18.3% to 20.0%; Table 2). No animals were found infected with the Texas gray fox RVV in 2016; the last animal reported with this RVV was a cow in 2013.[21]

Other wild animals

During 2016, Puerto Rico reported 11 rabid mongooses of 13 tested, a 37.5% increase from the 8 mongoose cases detected in 2015 (Table 1). Other reported rabid wildlife included 10 bobcats (*Lynx rufus*), 9 coyotes (*Canis latrans*), 7 deer (presumably *Odocoileus virginianus*), 3 fishers (*Martes pennanti*), 2 wolves (*Canis lupus*), 2 antelope (Antilopinae), and 1 otter (*Lontra canadensis*). Rabid rodents and lagomorphs reported in 2016 included 44 groundhogs (*Marmota monax*) and 5 beavers (*Castor canadensis*).

Variant typing was performed on 15 of the 45 (33.3%) other wild animals and 5 of the 49 (10.2%) rodents and lagomorphs (Table 3). For most of these cases, the RVV could only be assumed on the basis of the predominant RVV in the geographic area.

Rabies in Domestic Animals

During 2016, domestic animals accounted for 49.7% of all animal submissions and 8.6% (n = 423) of all rabies cases reported, representing an increase of 0.7%, compared with the 420 reported in 2015 (Table 1). More than half of the 423 rabid domestic animals detected in 2016 were reported from 5 states: Pennsylvania (n = 69), Virginia (48), Texas (46), New York (37), and Maryland (29).

Dogs

In 2016, 21,658 dogs were tested for rabies, and 58 (0.3%) were confirmed rabid. This represented a 13.4% decrease from the 67 reported in 2015. Most rabid dogs were reported from 5 states and 1 territory: Texas (n = 10), Puerto Rico (8), Georgia (8), Tennessee (5), South Carolina (4), and Virginia (4; **Figure 7**). Overall, the percentage of dogs testing positive for rabies among those submitted for testing in 2016 was unchanged from the mean percentage for the previous 5 years (0.3%; 95% CI, 0.3% to

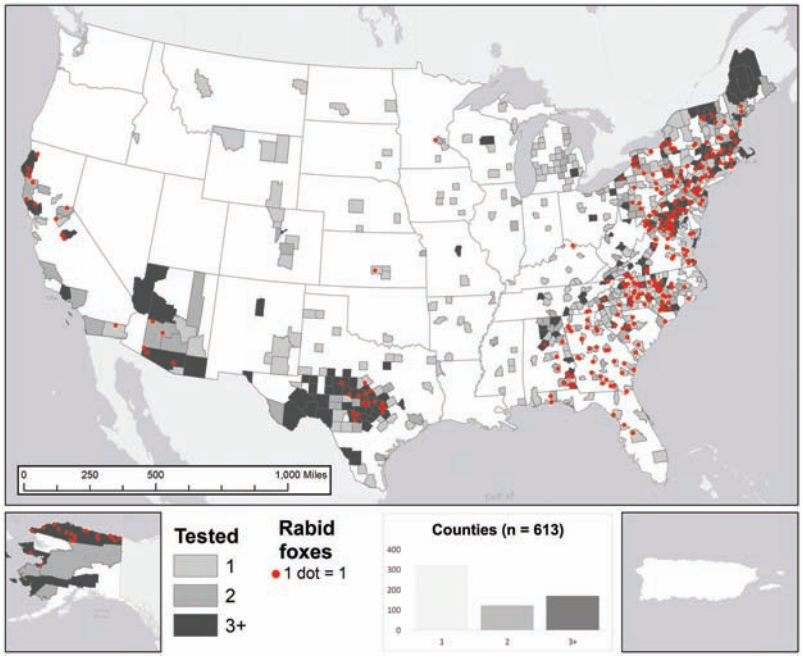

Figure 6—Reported cases of rabies involving foxes, by county, during 2016. Histogram represents number of counties in each category for total number of foxes submitted for rabies testing. Point locations for rabid foxes were randomly selected within each reporting jurisdiction.

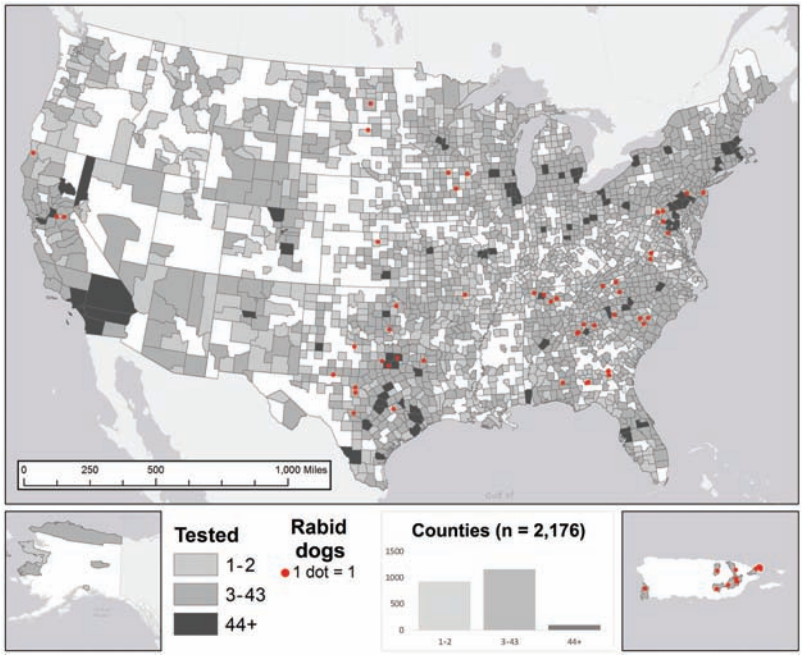

Figure 7—Reported cases of rabies involving dogs, by county, during 2016. Histogram represents number of counties in each category for total number of dogs submitted for rabies testing. Point locations for rabid dogs were randomly selected within each reporting jurisdiction.

0.4%; Table 2). Among the 13 rabid dogs for which vaccination status was reported, none had a history of vaccination. The RVV was reported for 35 of the 58 (60.3%) rabid dogs. They were infected with the raccoon RVV (n = 15), the south central skunk RVV (11), or the north central skunk RVV (9; Table 3).

Cats

There were 21,807 cats submitted for rabies testing in 2016, of which 257 (1.2%) were confirmed rabid. This represented a 5.3% increase in the number of rabid cats, compared with the 244 reported in 2015 (Table 1). The percentage of cats submitted for rabies testing that were found to be rabid (1.2%) was not significantly different from 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 24 of the 257 (9.3%) rabid cats. Twenty-three of the rabid cats had no history of vaccination, and 1 was reported to have been vaccinated. Most of the rabid cats were reported from states where the raccoon RVV was considered enzootic: Pennsylvania (n = 51), Maryland (27), Virginia (27), New York (26), and New Jersey (25; **Figure 8**). Information on the RVV was available for 75 (29.2%) rabid cats (Table 3). Most (n = 49 [65.3%]) were infected with the raccoon RVV, with the remainder infected with the south central skunk RVV (24 [32.0%]) or north central skunk RVV (2 [2.7%]).

Other domestic animals

A total of 1,245 cattle were tested for rabies, of which 70 (5.6%) were confirmed rabid. This represented a 17.6% decrease in the number of rabid cattle, compared with the 85 reported in 2015 (Table 1). The percentage of cattle submitted for testing that were found to be rabid (5.6%) was significantly lower than the mean percentage for the previous 5 years (6.9%; 95% CI, 5.9% to 7.8%). Virginia reported the highest number of rabid cattle (n = 12 [17.1%]), followed by Texas (9 [12.9%]) and Pennsylvania (8 [11.4%]).

Twenty-three rabid horses and donkeys were reported in 2016, a 64.3% increase from the 14 reported in 2015 (Table 1). The percentage of horses and donkeys submitted for testing that were found to be rabid (3.1%) was not significantly different from the mean percentage for the previous 5 years (3.9%; 95% CI, 2.7% to 5.1%; Table 2).

Rabies in Humans

No cases of human rabies were reported in the United States or its territories in 2016 **(Table 5)**. Samples from a total of 33 human patients in 21 states and the District of Columbia were submitted to the CDC

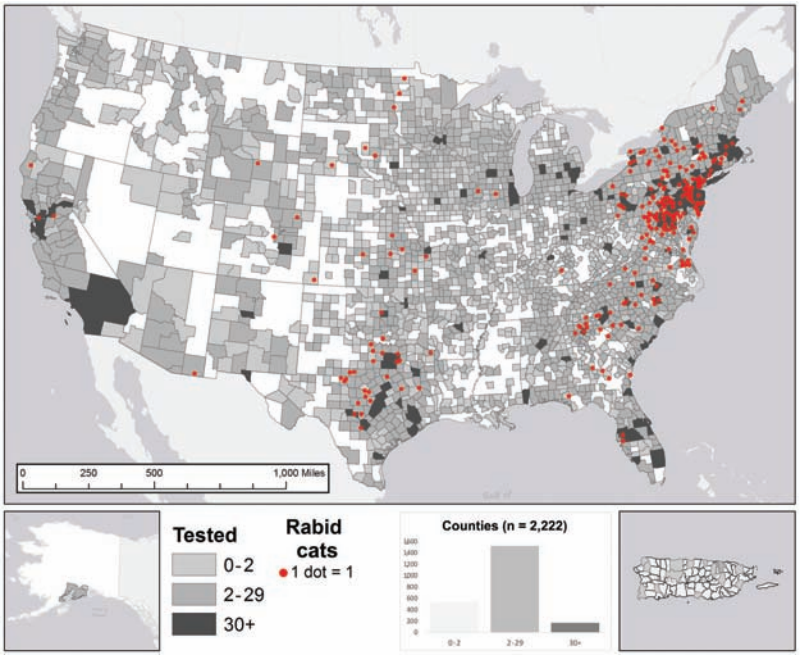

Figure 8—Reported cases of rabies involving cats, by county, during 2016. Histogram represents number of counties in each category for total number of cats submitted for rabies testing. Point locations for rabid cats were randomly selected within each reporting jurisdiction.

for testing because of suspicion of rabies, but results were negative for all 33.

Rabies in Canada and Mexico

Canada

In 2016, the Canadian Food Inspection Agency laboratories tested 3,055 samples for rabies, of which 392 (12.8%) were positive.[19] Of these, 259 were confirmatory tests on wildlife surveillance samples with no known human or animal contacts that had been initially analyzed in provincial laboratories. An additional 11 positive wildlife surveillance samples (10 bats and 1 arctic fox) were reported to the Canadian Food Inspection Agency but not submitted for confirmatory testing. At the Canadian Food Inspection Agency, most samples were analyzed with the direct fluorescent antibody test, with a small number tested by means of immunohistochemical staining (n = 2) or with a quantitative reverse transcription PCR assay (6; all samples were from human patients suspected to have rabies, and all results were negative). Wildlife surveillance samples were tested either with the direct rapid immunohistochemical test[22] or by means of conventional immunohistochemical staining on formalin-fixed, paraffin-embedded tissues. There was a significant increase in the number of rabies cases in 2016, compared with the 151 detected in 2015, that was attributed to an ongoing outbreak with a raccoon RVV in southwestern Ontario (258 cases in 2016).[23] Not surprisingly, given this outbreak, raccoons accounted for the highest proportion of cases in 2016 (44%), followed by skunks (29%) and bats (20%). The province of Ontario also submitted the largest number of samples for testing (n = 1,745), followed by Alberta (394), Saskatchewan (344), Manitoba (154), British Columbia (148), and Quebec (139). With the exception of New Brunswick, which submitted 75 samples for testing, the Atlantic provinces and Northwest Territories each submitted < 20 samples for testing in 2016, with Yukon submitting a single sample.

As in previous years, spillover of wildlife RVVs into domestic animals was observed, with rabies cases detected in dogs (n = 2), bovids (5), cats (4), goats (2), a horse, a llama, and a sheep. These animals were infected with the skunk RVV in western Canada (n = 13) or the fox RVV (1) or raccoon RVV (2) in southwestern Ontario. In regions north of the 55th parallel north, there was no spillover of fox rabies into domestic dogs for the first time since 2010, with rabies detected only in arctic and red foxes. No cases of rabies due to the fox RVV were detected in mainland Newfoundland and Labrador during 2016, which had experienced an epizootic in 2014 and 2015. The 2014 incursion of rabies caused by the raccoon RVV in New Brunswick continued, but appeared to be waning, with only 3 cases detected in 2016, an 87.5% decrease from the 24 detected during 2015, despite similar surveillance efforts (75 samples tested in 2015, and 85 samples tested in 2016). In contrast, the raccoon rabies outbreak in southwestern Ontario continued to be much more extensive, with 342 cases detected between December 2015 and June 2017. However, relatively few cases of spillover into domestic animals were observed (2 cats and 1 llama), even though the epizootic was centered in a highly urbanized area.

Mexico

The Mexico Rabies Prevention and Control Program did not detect any dog-transmitted human rabies cases in 2016 and had not detected any such cases since 2006. This was the result of coordinated strategies carried out by the Ministry of Health at the federal and state levels and in conjunction with municipal authorities, local health sectors, and other sectors such as agriculture. Although human deaths from wildlife-mediated rabies decreased, 2 cases were recorded in 2016, the first in Guerrero state and the second in Tamaulipas state. Both deaths were attributed to rabies virus transmission from bats. More than 103,000 people reported a suspected ra-

Table 5—Cases of rabies in humans in the United States and Puerto Rico, January 2003 through October 2017, by circumstances of exposure and RVV.

Date of onset	Date of death	Reporting state	Age (y)	Sex	Exposure*	Rabies virus variant†
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	22 Oct 17	FL	56	F	Bite	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. ‡The date of death was erroneously reported as August 21, 2011, in previous surveillance reports. §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*.

bies exposure in 2016, and PEP was recommended for 20,000 (19.9%), which was slightly lower than the percentage for 2015 (22%).

In Mexico, laboratory surveillance for rabies virus is carried out through the public health laboratory in each state. In 2016, these laboratories tested 34,000 samples from aggressive, sick, or feral animals. Overall, 0.4% (n = 129) of these samples were positive for rabies. Rabid animals were infected with the Chihuahua skunk (n = 1), vampire bat (99), central Mexico skunk (23), or *Tadarida brasilensis* (4) RVV or with an atypical variant (2).

A decrease in the number of dogs with rabies was observed, from 7 in 2015 to 4 in 2016. These 4 rabid dogs were from 3 states; 3 (2 from Chiapas and 1 from Tabasco) were infected with the canine RVV, and 1 (from Baja California Sur) was infected with a skunk RVV. Although the canine RVV is nearing elimination in Mexico, the goal had not yet been realized, and canine and feline rabies vaccination campaigns continued. These campaigns consisted of a 3-phase strategy: a national rabies vaccination week in March, a reinforcement week in September, and a year-long campaign to distribute > 18 million doses of rabies vaccine. Vaccination campaigns

were complemented by population control efforts, with > 695,000 dogs and cats neutered during 2016, a 6% increase, compared with the 655,000 neutered in 2015.

Discussion

The CDC has requested information on all rabies-positive animals since 1944. 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.[24]

Following several decades of decline, the number of rabid raccoons continued to decrease in 2016. The percentage of raccoons submitted for rabies testing in 2016 that were found to be rabid (11.7%) was significantly lower than the mean percentage for the previous 5 years (14.4%; 95% CI, 13.3% to 15.5%). In contrast, the percentage of bats submitted for rabies testing in 2016 that were found to be rabid (6.9%) was significantly higher than the mean percentage for the previous 5 years (6.2%; 95% CI, 5.9% to 6.5%), and bats were the most frequently reported rabid animal in the United States during 2016. Factors accounting for these observed trends may have included the impact of oral rabies vaccination of raccoons, population fluctuations in reservoir species, and alteration in public perceptions of the risk of rabies.

Interestingly, 2016 was the first year since 1999 during which no cases of human rabies were reported in the United States or its territories. In addition, the last 2 cases of domestically acquired human rabies occurred on October 6, 2017, and September 17, 2015, representing a span of 750 days. Although this decrease in human rabies cases corresponded with a decrease in the number of reported animal rabies cases during the same period, it is difficult to infer causality given the passive nature of rabies surveillance in the United States. It is quite possible that additional cases occurred but were not detected, and clinicians should continue to consider the diagnosis of rabies in any case of acute, progressive encephalitis of unknown etiology.[11]

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 7 terrestrial RVVs is due to sustained host shifts from canine RVVs as well as extant chiropteran variants.[6] Three decades ago, the epidemiology of rabies in the United States was very different, with canine and coyote RVVs present in the Southern United States, a raccoon RVV sequestered to the Southeastern and mid-Atlantic United States, and a red fox RVV present in the Northeastern states. As animal populations move and viruses evolve, the epidemiology of zoonotic diseases may shift. 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 public health messaging. In 2016, the proportion of samples that were variant typed was significantly greater than the previous 3-year mean percentage. Significant increases in typing for rabid dogs, foxes, raccoons, and other wildlife species are an encouraging sign. However, more than two-thirds of rabies-positive animals were not further characterized, potentially masking the presence of host shifts. Although typing of all rabies-positive animals is not currently cost-effective, improved guidance for virus characterization on high-priority animals may help improve detection of important epidemiological events.

The United States is considered to be free from the canine RVV. This status has been earned twice previously: once in the 1970s and again in 2006.[25] As part of the World Organisation for Animal Health (OIE) and World Health Organization recommendations for declaration of a country as canine RVV free, the country must have designated rabies as a reportable disease and must have established a surveillance system sufficient to detect reincursion.[26] According to the Council of State and Territorial Epidemiologists position statement,[27] RVV is a disease-specific data element that should be included in the initial case report; however, in 2016, results of variant typing for 24 of 58 (41.4%) rabies-positive dogs were not reported to the national program. It is possible that state programs conducted virus typing on these animals, but did not report results to the national program. To comply with OIE recommendations for canine RVV–free status, further efforts should be made to ensure that all cases of rabies-positive dogs are thoroughly investigated, including RVV typing, and that results of RVV typing are reported to the national program.

Wildlife rabies testing conducted by USDA APHIS Wildlife Services supports national rabies management goals focused on preventing the spread of, and eventually eliminating, specific RVVs in mesocarnivores to reduce threats to human and animal health and the cost of living with rabies. Enhanced rabies surveillance has been conducted since 2004 and targets areas in close proximity to established zones where oral rabies vaccination programs are being carried out, areas of high risk of rabies spread, and other areas where rabies research and management occur. Enhanced rabies surveillance includes focused efforts to test abnormally behaving rabies vector species with no known human or domestic animal exposure as well as road-killed specimens, target species collected in a localized rabies focus area, and nuisance or hunter-collected animals.[10] Enhanced surveillance serves as a complement to public health surveillance because efforts are concentrated on testing wildlife that would not likely be tested through exposure-based surveillance. As a result, when evaluated in tandem, a more comprehensive spatial and temporal picture concerning the geographic distribution of rabies is achieved, which facilitates real-time science-based decision-making.

During 2016, Wildlife Services implemented a programmatic initiative to improve rabies surveillance efforts, including the development of standardized sample categories within a stratified point system

to assess sampling efforts in a more meaningful way.[28] Abnormally behaving wild animals with no known human or domestic animal exposure and animals found dead with no obvious signs of trauma were considered to have the highest likelihood of being rabid and were assigned the highest number of points. Assessment of this program initiative is ongoing; nevertheless, applying point values to public health surveillance data may represent a logical next step to further refine sample category weights as part of a more comprehensive wildlife rabies surveillance system.

Widespread use of the direct rapid immunohistochemical test by Wildlife Services since 2005 has maximized the program's ability to make critical management decisions in support of oral rabies vaccination programs and wildlife rabies management. From 2005 through 2016, Wildlife Services collected approximately 100,000 enhanced rabies surveillance samples from 26 states and tested 82% of those specimens with the direct rapid immunohistochemical test; a mean of 1.9% of those samples were confirmed positive.[28]

The current national protocol for rabies diagnosis requires 2 anti-rabies virus conjugates to be used for reliable testing. However, one of the conjugates produces a considerably higher rate of nonspecific binding, leading to the need for a higher number of confirmatory rabies diagnostic tests.[29] Another concern was reports of periodic shortages in the supply of 1 manufacturer's 3 anti-rabies virus conjugates and its specificity control conjugate in 2016 and 2017. During the past 2 years, a pan-lyssavirus real-time reverse transcriptase PCR assay, the LN34 assay, has been validated by the CDC and is Clinical Laboratory Improvement Amendments certified for routine rabies diagnostic testing in combination with direct fluorescent antibody testing. This assay allows for rapid, high-throughput testing, which improves the rabies diagnosis process considerably. In a recently completed pilot study[30] involving 15 US and international laboratories, > 3,000 samples from animals suspected to be rabid (> 1,000 positive results) were tested with both the LN34 assay and the direct fluorescent antibody test. The LN34 assay produced no false-negative results and 1 possible false-positive result with a threshold cycle value near the cutoff value and reduced the percentage of indeterminate results by > 80%, compared with direct fluorescent antibody testing. On the basis of an adapted diagnostic algorithm, the LN34 assay achieved 99.31% diagnostic specificity and 99.87% diagnostic sensitivity. With the rapid advances in handheld integrated PCR assay systems, a field-ready rabies molecular diagnostic assay will be possible in the near future, allowing for real-time diagnostic test results. In addition, the amplicon of the LN34 assay can be used directly for rapid genetic typing of LN34-positive samples.

Current antigenic virus characterization methods have low resolution and provide little information on the evolution and migration of RVVs in geographic areas. Advances in next-generation sequencing technology have reduced the cost of sequencing clinical samples dramatically.[31] Thus, it is now possible to increase the coverage of RVV typing on the basis of partial genomic sequences and to build an RVV-sequence database covering most variants present in North America at a reasonable cost. A sequence-based comprehensive RVV database would be invaluable for rabies surveillance and control.

The lack of real-time electronic surveillance for animal rabies often results in a delay in multistate analysis ranging from a minimum of 9 months to up to 18 months. This may impede 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, decreasing the lag time in standard reporting, improving data quality, and reducing the need for duplicate data entry from states. Four states have engaged in pilot testing and 3 have started sending production data as of September 2017. The CDC and Association of Public Health Laboratories will continue working with additional states to enroll laboratories in this program. This system is also expected to improve regional access to surveillance data related to the national oral rabies vaccination program, providing timely data that can be used for making management decisions by Wildlife Services, the CDC, and state health departments.

2017 Rabies Update

Two human rabies cases were reported in the United States during 2017. The first case involved a 65-year-old woman who presented for medical care in Virginia in May 2017 after developing right arm paresthesia followed by shortness of breath, anxiety, and dysphagia. She had recently traveled to India, where she was bitten by a dog in March 2017 but did not receive PEP. Following hospital admission, her condition deteriorated rapidly, and she died on May 21, 2017. Samples collected prior to death were tested at the CDC and confirmed infection with an RVV associated with dogs in India. The second case involved a 56-year-old woman in Florida who developed right arm and neck pain with fever on October 6, 2017. The woman initially sought health care on October 9, 2017, but her condition deteriorated rapidly, and she was hospitalized on October 10, 2017, then transferred to another hospital the following day. She reported having been bitten by a bat on her right hand on August 11, 2017. Samples collected and tested by the CDC confirmed infection with an RVV associated with *T brasiliensis*. The patient died on October 22, 2017.

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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

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