Rabies surveillance in the United States during 2015

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OBJECTIVE
To describe rabies and rabies-related events occurring during 2015 in the United States.

DESIGN
Observational study based on passive surveillance data.

ANIMALS
All animals submitted for rabies testing in the United States during 2015.

PROCEDURES
State and territorial public health programs provided data on animals submitted for rabies testing in 2015. Data were analyzed temporally and geographically to assess trends in domestic and sylvatic animal rabies cases.

RESULTS
During 2015, 50 states and Puerto Rico reported 5,508 rabid animals to the CDC, representing an 8.7% decrease from the 6,033 rabid animals reported in 2014. Of the 5,508 cases of animal rabies, 5,088 (92.4%) involved wildlife. Relative contributions by the major animal groups were as follows: 1,704 (30.9%) bats, 1,619 (29.4%) raccoons, 1,365 (24.8%) skunks, 325 (5.9%) foxes, 244 (4.4%) cats, 85 (1.5%) cattle, and 67 (1.2%) dogs. There was a 4.1% decrease in the number of samples submitted for testing in 2015, compared with the number submitted in 2014. Three human rabies deaths were reported in 2015, compared with only 1 in 2014. A 65-year-old man in Massachusetts was bitten by a rabid dog while abroad. A 77-year-old woman in Wyoming had contact with a bat. A 54-year-old man in Puerto Rico was bitten by a mongoose. The only connection among these 3 cases was that none received postexposure prophylaxis.

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* 2017;250:1117–1130)

The present report provides information on the epidemiology of rabies and rabies-associated events in the United States during 2015. Updates on rabies and rabies-associated events occurring in Canada and Mexico during 2015 are also summarized.

Rabies is a zoonotic disease caused by an RNA virus in the genus *Lyssavirus*.[1] All mammals are susceptible to rabies virus infection. The virus is commonly transmitted through the bite of an infected animal, but can also be transmitted when fresh saliva from an infected animal comes into contact with wounds or mucous membranes. Once clinical signs develop, the disease is almost inevitably fatal. In people, however, rabies can be prevented if postexposure prophylaxis is appropriately administered prior to the onset of clinical signs. For exposed persons in the United States who have never been vaccinated against rabies, appropriate postexposure prophylaxis consists of immediate washing of any wounds with soap and water, passive immunization with human rabies immune globulin, and IM administration of 4 doses of cell culture–derived vaccine over the next 14 days.[2,3] Persons who have been previously vaccinated require 2 booster vaccinations after rabies exposure.

Globally, an estimated 59,000 people die of rabies every year.[4] Greater than 98% of these deaths are due to the rabies virus variant that circulates in domesticated dogs.[5] This canine rabies virus variant has been eliminated from the United States; however, several genetically distinct rabies virus variants are still present in terrestrial carnivores and bats in the United States.[6] Since the 1980s, wildlife species have accounted for > 90% of all rabid animals reported in

ABBREVIATIONS
CI Confidence interval

the United States. The reservoir species responsible for maintaining the 8 terrestrial rabies virus variants in the United States are raccoons (raccoon variant), skunks (south central, north central, and California skunk variants), gray foxes (Texas and Arizona gray fox variants), arctic foxes (arctic fox variant), and mongooses (dog-mongoose variant in Puerto Rico). In addition to the terrestrial rabies virus variants, there are at least 20 variants associated with bats.[7,8] Circulation of distinct rabies virus variants associated with mesocarnivore species (ie, raccoons, skunks, foxes, and mongooses) occurs in geographically definable regions, where transmission is primarily between members of the same species **(Figure 1)**.

The Wildlife Services department of the USDA's APHIS leads a large-scale program to control rabies in select wildlife species, primarily through the delivery of oral rabies vaccine–laden baits targeted at raccoons along the East Coast of the United States. There have been measurable reductions in the prevalence of rabies among wildlife in North America and Europe stemming from vaccination programs using orally administered vaccines targeting primarily raccoons, coyotes, and foxes.[9,10] Vaccination of bats, however, is currently not feasible. Therefore, preventing human infections with bat-associated rabies virus variants relies instead on secondary intervention methods such as health education, exposure prevention, and postexposure prophylaxis.

The reduction over time in the number of rabies cases involving humans in the United States has been directly attributable to the elimination of canine rabies virus variants, vaccination of wildlife, timely administration of postexposure prophylaxis, and education of health-care professionals and the public. Although the number of human rabies deaths has been dramatically reduced, cases continue to occur, primarily as a result of exposure to bats or as a result of exposure to canine rabies virus variants in countries where the virus is still endemic.[11,12]

Appropriate risk assessment, including observation and testing of animals for rabies, continues to play an important role in preventing unnecessary postexposure prophylaxis after potential rabies exposure. A 10-day observation period is routinely recommended in instances of possible human rabies exposures involving cats, dogs, or ferrets.[3,13] Use of an observation period often prevents unnecessary euthanasia of owned animals, specifically those that have a known history of rabies vaccination.[13] Unfortunately, the viral shedding period in other species is not well understood, making immediate euthanasia and rabies testing the most prudent method of determining the necessity of postexposure prophylaxis for persons who may have been exposed.[13,14] Additional precautions and more extensive risk assessment may be necessary following potential contact with bats. The Advisory Committee on Immunization Practices recommends evaluation of all persons who have been bitten by or come into direct contact with bats and also recommends evaluation of persons who may have had unrecognized contact with a bat (eg, if a bat is found in the room with a deeply sleeping person, unattended child, mentally disabled person, or intoxicated person).[2] In these instances, capturing the bat for rabies testing to exclude infection remains the most definitive way to rule out the risk of rabies transmission.

Rabies surveillance in the United States currently serves to inform both point-of-care treatment recommendations for exposed persons and national guidance for disease management and risk assessment. Rabies testing data are aggregated at the state and national levels, and the aggregated data are periodically analyzed to provide an assessment of risk by species and geography. Therefore, when an animal involved in a human exposure cannot be tested, a presumptive indication of risk can be communicated to the exposed individual and his or her health-care provider, which can inform the assessment of the necessity for postexposure prophylaxis. Furthermore, incident animal cases are analyzed spatially and temporally to identify trends in the occurrence of specific rabies virus variants that might increase or decrease human and animal exposure risks. National rabies management decisions, vaccination recommendations, public education, and numerous other rabies activities rely on an accurate portrayal of the national rabies landscape.

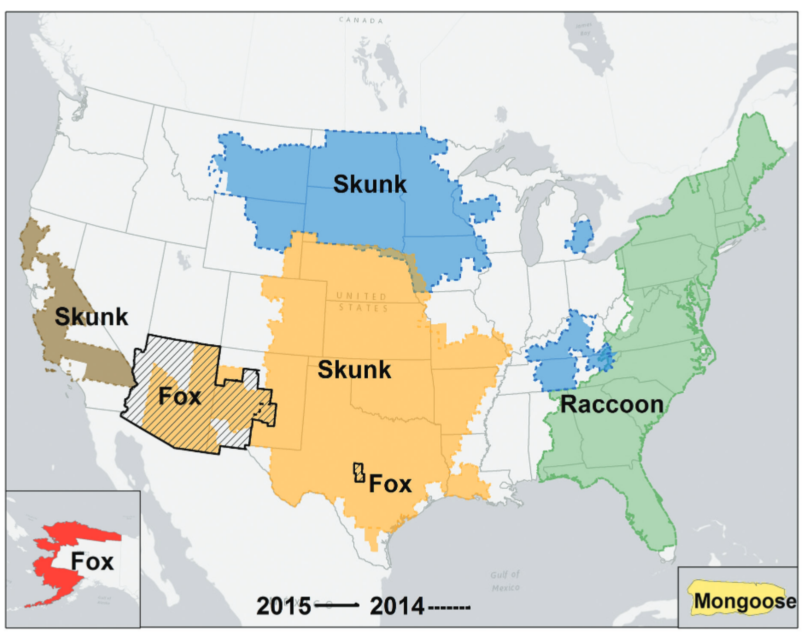

Figure 1—Distribution of major rabies virus variants among mesocarnivores in the United States and Puerto Rico for 2008 through 2014. Black diagonal lines represent fox rabies variants (Arizona gray fox and Texas gray fox). Solid borders represent 5-year rabies virus variant aggregates for 2010 through 2015; dashed borders represent the previous 5-year aggregates for 2009 through 2014.

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 laboratories. These laboratories perform the standard direct fluorescent antibody test.[16] Historically, this component of national rabies surveillance has accounted for 95% of all animals tested for rabies. The additional 5% of national rabies testing has been conducted by USDA Wildlife Services through enhanced surveillance in selected geographic regions as part of large-scale oral rabies vaccination programs. Wildlife Services has used the direct rapid immunohistochemical test.[10,17]

On a monthly basis, 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 are primarily submitted through emailed files or electronic messaging. 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 rabies virus variant typing (when performed) are provided when available. Since 2006, all reporting entities have provided individual case reports for all animals tested for rabies.

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. Thus, percentages reported here should not be interpreted to reflect the incidence of rabies in these animal populations because most public health programs only test animals involved in a potential exposure incident and cases reported here likely represent only a subset of the true animal rabies cases within these populations. Furthermore, comparisons between states should take into account differences in available resources and submission protocols.

Geographic ranges of terrestrial rabies virus variants in the United States were produced by aggregating counts of rabid animals from 2008 through 2015 by county and species (Figure 1).[18] Counties were considered free from terrestrial rabies virus variants if they reported identifying no cases in a reservoir species during the past 5 years and met 1 of the following 2 conditions: all bordering counties reported identifying no cases in a reservoir species during the past 5 years, or the county tested ≥ 15 animals from reservoir species or ≥ 30 domestic vector species (eg, cats, dogs, and livestock) and all results were negative.

Annual trends in rabies cases were analyzed by species for the years 1966 through 2015. Owing to the frequent spillover of the raccoon variant into skunks, trends for skunks with skunk rabies virus variants and for skunks with the raccoon rabies virus variant were analyzed separately. Data were analyzed with standard trend analysis software to identify temporal trends.[a] Trends are reported as the annual percentage change in number of reported cases over time, with 95% CI. Only the most recent trend line for each species is displayed **(Figure 2)**.

Summary data for rabies in Canada during 2015 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 Secretaría de Salud (Ministry of Health).

Samples

During 2015, a total of 100,071 animal samples were submitted for rabies testing in the United States and territories, of which 97,866 (97.8%) were considered suitable for testing (this included samples with positive, negative, and indeterminate test results). This represented a 3.8% decrease in the number of animals tested, compared with the 101,708 samples tested during 2014. The USDA Wildlife Services tested 6,359 animals with the direct rapid immunohistochemical test, accounting for 6.4% of all animals submitted in 2015.

Rabies in Wild Animals

Wild animals accounted for 92.4% (5,088/5,508) of the animal rabies cases reported in 2015, representing an 8.9% decrease from the 5,588 rabid wild animals reported in 2014 **(Table 1)**. In 2015, for the

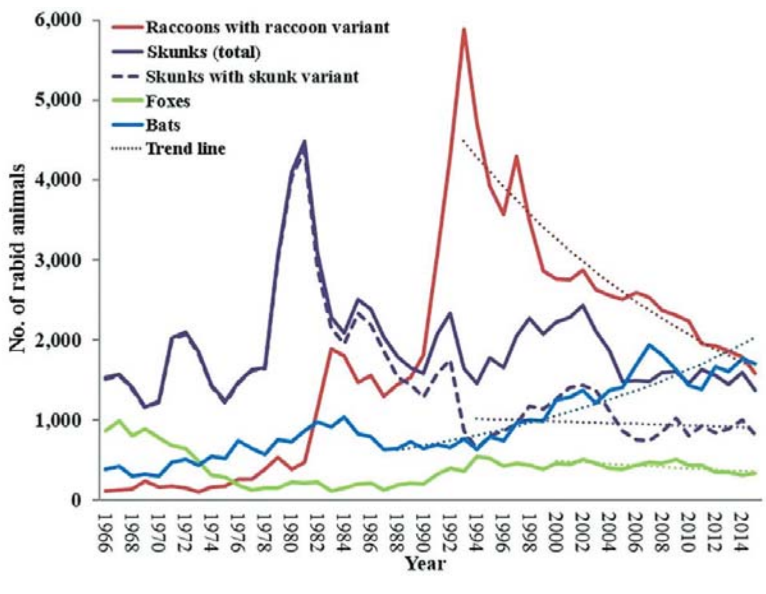

Figure 2—Cases of rabies among wildlife in the United States, by year and species, for 1966 through 2015.

Table 1—Cases of rabies in the United States, by location, during 2015.

					Domestic animals						Wildlife									
Location	**Reservoir**	**Total animal cases**	**Domestic animals**	**Wildlife**	**Cats**	**Cattle**	**Dogs**	**Horses and mules**	**Sheep and goats**	**Other domestic***	**Raccoons**	**Bats**	**Skunks**	**Foxes**	**Other wildlife†**	**Rodents and lagomorphs‡**	**Humans**	**% Pos 2015**	**2014 cases**	**Change (%)**
AK	Arctic fox	7	0	7	0	0	0	0	0	0	0	0	0	7	0	0	0	4.0	3	133.3
AL	Raccoon	87	7	80	2	0	5	0	0	0	56	13	0	8	2[c]	1[u]	0	4.1	86	1.2
AR	Skunk	73	3	70	0	2	1	0	0	0	0	16	53	1	0	0	0	7.0	152	–52.0
AZ	Skunk, Fox	120	0	120	0	0	0	0	0	0	0	64	48	4	4[d]	0	0	13.8	157	–23.6
CA	Skunk	230	2	228	2	0	0	0	0	0	0	198	29	0	1[e]	0	0	3.9	200	15.0
CO	Skunk	119	2	117	2	0	0	0	0	0	1	71	45	0	0	0	0	7.5	131	–9.2
CT	Raccoon	170	6	164	5	0	1	0	0	0	85	27	44	5	1[f]	2[v]	0	7.3	183	–7.1
DC	Raccoon	10	0	10	0	0	0	0	0	0	7	2	0	0	1[g]	0	0	4.1	40	–75.0
DE	Raccoon	11	4	7	4	0	0	0	0	0	2	2	0	3	0	0	0	8.0	9	22.2
FL	Raccoon	85	12	73	8	0	2	0	2	0	47	15	1	10	0	0	0	3.9	95	–10.5
GA	Raccoon	266	16	250	9	1	6	0	0	0	135	22	53	35	5[h]	0	0	11.8	272	–2.2
HI	None	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0	0.00
IA	Skunk	12	4	8	1	0	3	0	0	0	0	7	1	0	0	0	0	0.9	15	–20.00
ID	Bat only	10	0	10	0	0	0	0	0	0	0	10	1	0	0	0	0	2.6	12	–16.7
IL	Bat only	97	0	97	0	0	0	0	0	0	0	97	0	0	0	0	0	2.5	40	142.5
IN	Bat only	13	0	13	0	0	0	0	0	0	0	13	0	0	0	0	0	1.2	12	8.3
KS	Skunk	100	24	76	11	12	0	1	0	0	0	6	67	3	0	0	0	7.9	70	42.9
KY	Skunk	11	2	9	0	0	1	1	0	0	0	7	2	0	0	0	0	1.5	10	10.0
LA	Skunk	5	0	5	0	0	0	0	0	0	0	2	3	0	0	0	0	0.8	5	0.0
MA	Raccoon	145	2	143	2	0	0	0	0	0	57	39	35	8	1[i]	3[w]	0	5.1	148	–2.0
MD	Raccoon	342	21	321	19	0	1	1	0	0	167	119	14	19	1[j]	1[x]	1	8.2	344	–0.6
ME	Raccoon	34	0	34	0	0	0	0	0	0	15	9	8	2	0	0	0	4.2	43	–20.9
MI	Skunk	38	0	38	0	0	0	0	0	0	0	36	1	1	0	0	0	1.2	43	–11.6
MN	Skunk	28	3	25	2	1	0	0	0	0	0	16	8	1	0	0	0	1.4	33	–15.2
MO	Skunk	31	2	29	0	0	2	0	0	0	0	23	6	0	0	0	0	1.6	27	14.8
MS	Bat only	4	1	3	1	0	0	0	0	0	0	3	0	0	0	0	0	1.0	1	300.0
MT	Skunk	22	0	22	0	0	0	0	0	0	0	19	3	0	0	0	0	3.9	16	37.5
MC	Raccoon	342	20	322	9	4	6	0	0	0	170	28	53	69	1[k]	1[y]	0	7.5	355	–3.7
ND	Skunk	6	2	4	0	1	0	0	0	0	0	3	1	0	0	0	0	1.4	18	–66.7
NE	Skunk	28	4	24	1	2	1	0	0	0	0	16	8	0	0	0	0	2.6	21	33.3
NH	Raccoon	24	1	23	0	1	0	0	0	0	7	5	9	2	0	0	0	4.8	23	4.3
NJ	Raccoon	308	16	292	16	0	0	0	0	0	157	78	40	11	2[l]	4[z]	0	9.8	349	–11.7
NM	Skunk, Fox	13	0	13	0	0	0	0	0	0	0	11	0	1	1[m]	0	0	2.5	12	8.3
NV	Bat only	8	0	8	0	0	0	0	0	0	0	8	0	0	0	0	0	2.3	14	–42.9
NY	Raccoon	372	29	343	23	5	0	0	0	0	139	102	67	27	5[n]	3[aa]	0	5.9	372	0.0
NYC	Raccoon	6	0	6	0	0	0	0	0	0	4	2	0	0	0	0	0	1.0	12	–50.0
OH	Raccoon	26	0	26	0	0	0	0	0	0	6	20	0	0	0	0	0	0.6	28	–7.1
OK	Skunk	86	20	66	3	9	6	0	0	0	0	3	62	0	1[o]	0	0	7.5	106	–18.9
OR	Bat only	20	1	19	1	0	0	0	0	0	0	18	0	1	0	0	0	4.9	13	53.8
PA	Raccoon	345	55	290	50	2	2	0	0	0	162	46	38	30	3[p]	11[ab]	0	4.7	402	–14.2
PR	Mongoose	17	9	8	1	0	8	0	0	0	0	0	0	0	8[q]	0	1	15.9	45	–62.2
RI	Raccoon	17	2	15	2	0	0	0	0	0	8	7	0	0	0	0	0	2.4	27	–37.0
SC	Raccoon	130	10	120	6	1	2	1	1	0	61	10	32	15	2[r]	0	0	6.7	140	–7.1
SD	Skunk	29	9	20	2	6	1	0	0	0	0	5	15	0	0	0	0	4.2	21	38.1
TN	Skunk	37	1	36	0	0	1	0	0	0	4	5	27	0	0	0	0	1.9	40	–7.5
TX	Skunk, Fox	952	51	901	16	16	13	1	1	2[a]	33	418	431	18	1[s]	0	0	6.8	1,133	–16.0
UT	Bat only	22	0	22	0	0	0	0	0	0	0	22	0	0	0	0	0	7.6	22	0.0
VA	Raccoon	528	68	460	37	20	5	3	3	1[b]	260	15	137	40	1[t]	7[ac]	0	11.6	528	0.0
VT	Raccoon	25	2	23	2	0	0	0	0	0	11	6	6	0	0	0	0	5.8	55	–54.5
WA	Bat only	10	1	9	1	0	0	0	0	0	0	9	0	0	0	0	0	2.1	15	–33.3
WI	Skunk	22	1	21	0	1	0	0	0	0	0	21	0	0	0	0	0	1.1	27	–18.5
WV	Raccoon	50	7	43	6	1	0	0	0	0	25	1	12	4	0	1[ad]	0	4.9	50	0.0
WY	Skunk	15	0	15	0	0	0	0	0	0	0	9	6	0	0	0	1	3.0	58	–74.1
Total	—	**5,508**	**420**	**5,088**	**244**	**85**	**67**	**14**	**7**	**3**	**1,619**	**1,704**	**1,365**	**325**	**41**	**34**	**3**	**—**	**6,033**	**–8.7**
	% 2015	100.0	7.6	92.4	4.4	1.5	1.2	0.3	0.1	0.1	29.4	30.9	24.8	5.9	0.7	0.6	0.1			
	% Pos 2015	5.5	0.9	10.3	1.1	6.8	0.3	2.0	1.3	4.1	13.1	6.6	28.1	18.8	2.4	2.0	9.7			
	Total 2014	**6,033**	**445**	**5,588**	**272**	**78**	**59**	**25**	**10**	**1**	**1,822**	**1,756**	**1,588**	**311**	**66**	**45**	**1**			
	Change (%)	–8.7	–5.6	–8.9	–10.3	9.0	13.6	–44.0	–30.0	200.0	–11.1	–3.0	–14.0	4.5	–37.9	–24.4	200.0			

*Other domestic includes [a]1 swine and 1 rabbit; [b]1 swine. †Other wildlife includes [c]1 opossum and 1 bobcat; [d]2 coyotes and 2 bobcats; [e]1 coyote; [f]1 bobcat; [g]1 coyote; [h]3 coyotes and 2 bobcats; [i]1 coyote; [j]1 deer; [k]1 coyote; [l]2 coyotes; [m]1 ringtail; [n]2 coyotes, 2 deer, and 1 elk; [o]1 opossum; [p]3 deer; [q]8 mongooses; [r]1 coyote and 1 otter; [s]1 coyote; [t]1 otter. ‡Rodents and lagomorphs include [u]1 squirrel; [v]2 groundhogs; [w]3 groundhogs; [x]1 groundhog; [y]1 beaver; [z]4 groundhogs; [aa]3 groundhogs; [ab]6 rabbits, 4 groundhogs, and 1 beaver; [ac]7 groundhogs; [ad]1 groundhog.

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

Reservoir refers to the major rabies virus variant terrestrial reservoir in the locality.

first time since 1958, when electronic national surveillance records first became available, bats were the most frequently reported rabid animals in the United States, representing 30.9% (n = 1,704) of all animal rabies cases detected, followed by raccoons (29.4% [1,619]), skunks (24.8% [1,365]), foxes (5.9% [325]), other wild animals (0.7% [41]), and rodents and lagomorphs (0.6% [34]).

Bats

A total of 25,799 bats were submitted for testing in 2015, of which 1,704 (6.6%) were confirmed rabid. This represented only a minor (3.0%) decrease in the number of rabid bats reported in 2014 (n = 1,756; Table 1). However, the percentage of bats submitted for testing that were found to be rabid (6.6%) was significantly higher than the mean percentage for the previous 5 years (6.0% [95% CI, 5.8% to 6.2%]; **Table 2**). All 48 contiguous states reported detection of rabid bats **(Figure 3)**. No rabid bats were reported in Alaska, Hawaii, or Puerto Rico. In five states (Idaho, Illinois, Indiana, Nevada, and Utah), bats were the only rabid animals detected in 2015. Thirteen states reported a ≥ 50% increase in the number of rabid bats detected (Delaware [100% increase], Illinois [142% increase], Kansas [50% increase], Maryland [51% increase], Maine [125% increase], Mississippi [200% increase], Montana [72.7% increase], North Dakota [200% increase], Nebraska [60% increase], New Mexico [57% increase], Oregon [80% increase], Vermont [100% increase], and Wyoming [50% increase]). Nationally, the number of rabid bats has increased by a mean of 4.5%/y since 1988 (95% CI, 3.6%/y to 5.3%/y). The rabies virus variant was reported for 358 of the 1,704 (21.0%) rabid bats; all

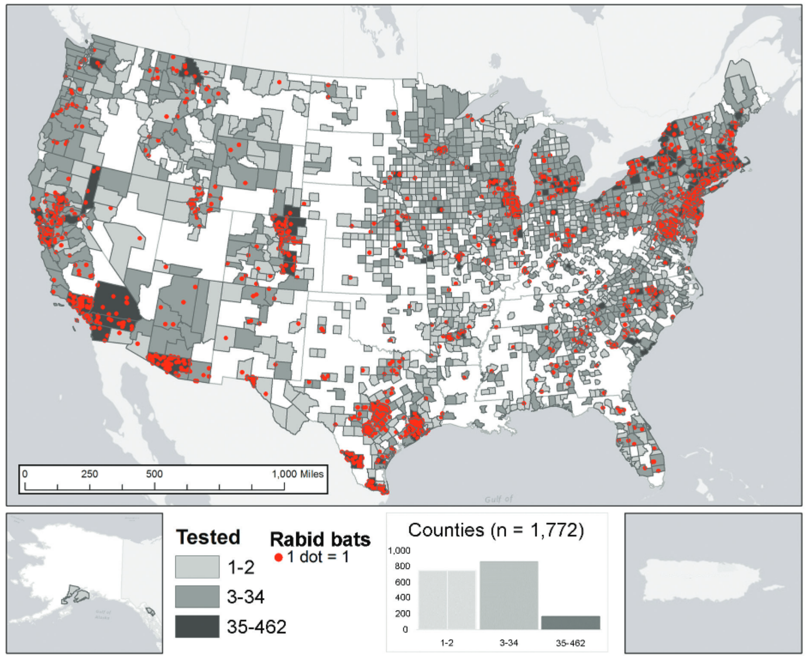

Figure 3—Reported cases of rabies involving bats, by county, during 2015. Histogram represents number of counties in each category for total number of bats submitted for rabies testing. Point locations for rabid bats were randomly selected within each reporting jurisdiction.

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 2010 through 2015.

	2015		2010 to 2014			
			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	244*	1.1	276	254–299	1.1	1.1–1.2
Cattle	85	6.8	83	60–100	6.7	5.7–7.7
Dogs	67	0.3	74	64–85	0.3	0.3–0.4
Horses and mules	14*	2.0*	37	29–45	4.3	3.6–5.1
Sheep and goats	7*	1.3*	10	8–12	2.0	1.4–2.6
Wildlife						
Raccoons	1,619*	13.1*	1,980	1,839–2,121	14.9	13.9–15.9
Bats	1,704*	6.6*	1,569	1,428–1,710	6.0	5.8–6.2
Skunks	1,365	28.1*	1,530	1,459–1,601	30.5	28.6–32.3
Foxes	325*	18.8	370	323–418	20.4	18.0–22.8
All rabid animals	5,508	5.5*	6,049	5,943–6,154	6.0	5.9–6.1
Rabid domestic animals	420*	0.9	483	458–508	1.0	0.9–1.0
Rabid wildlife	5,088	10.3*	5,566	5,472–5,660	11.11	0.9–11.2

Total number of submitted animals was not available for California in 2013.
*Significantly ($P < 0.05$) different from mean value for 2010 through 2014.

358 were infected with a bat variant **(Table 3)**. Of the 25,799 bats submitted for testing, 12,109 (46.9%) were described beyond the taxonomic level of order **(Table 4)**.

In light of the increase in the percentage of bats submitted for testing that were found to be rabid, an exploratory analysis of spatial trends at the county level was conducted. Mean number of bats positive for rabies was calculated for each county from 2010 through 2014 and compared with the number identified in 2015. Counties that tested, on average, < 5 bats/y were excluded from this subanalysis, with 243 of 3,141 counties eligible for inclusion on the basis of this criterion. Of these 243 counties,

Table 3—Rabies virus variants identified in domestic and wild animals in 2015.

	Domestic animals						Wildlife						
Variant	**Cats**	**Cattle**	**Dogs**	**Horses and mules**	**Sheep and goats**	**Other domestic***	**Raccoons**	**Bats**	**Skunks**	**Foxes**	**Other wild†**	**Rodents and lagomorphs‡**	**Total**
Raccoon	43	20	18	2	3	1	272	0	134	40	2	7	**542**
South central skunk	15	16	13	3	1	1	32	0	429	18	1	1	**530**
North central skunk	1	0	6	0	0	0	0	0	31	1	0	0	**39**
California skunk	0	0	0	0	0	0	0	0	0	0	1	0	**1**
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	0	0	0	**0**
Texas gray fox	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Bat	3	2	1	0	0	0	0	358	0	3	0	0	**364**
Egyptian dog	0	0	1	0	0	0	0	0	0	0	0	0	**1**
No variant reported	182	47	28	9	3	1	1,315	1,346	771	266	37	26	**4,031**
Total infected	**244**	**85**	**67**	**14**	**7**	**3**	**1,619**	**1,704**	**1,365**	**325**	**41**	**34**	**5,508**
Variant typed (%)	25.4	44.7	58.2	35.7	57.1	66.7	18.8	21.0	43.5	18.2	9.8	23.5	**26.8**

*Other domestic includes 2 pigs with the raccoon and south central skunk rabies virus variants. †Other wild includes 1 coyote with the California skunk rabies virus variant, 1 coyote with the south central skunk rabies virus variant, and 2 otters with the raccoon rabies virus variant. ‡Rodents and lagomorphs include 7 groundhogs with the raccoon rabies virus variant and 1 rabbit with the south central skunk rabies virus variant.

Table 4—Species of bats submitted for rabies testing in the United States during 2015.

Species (common name)	**No. tested**	**No. positive**	**Percentage positive**
Order Chiroptera (not specified)	13,690	882	6.4
Eptesicus fuscus (big brown bat)	10,069	368	3.7
Myotis lucifugus (little brown bat)	586	16	2.7
Tadarida brasiliensis (Mexican free-tailed bat)	407	295	72.5
Lasionycteris noctivagans (silver-haired bat)	211	13	6.2
Nycticeius humeralis (evening bat)	198	11	5.6
Lasiurus borealis (red bat)	170	40	23.5
Myotis spp (not further differentiated)	84	12	14.3
Myotis californicus (California myotis)	83	0	0.0
Lasiurus cinereus (hoary bat)	67	33	49.3
Myotis yumanesis (Yuma myotis)	59	2	3.4
Myotis evotis (long-eared myotis)	48	4	8.3
Nyctinomops macrotis (big free-tailed bat)	32	9	28.1
Muptos volans (long-legged myotis)	13	1	7.7
Myotis keenii (Keen myotis)	11	0	0.0
Perimyotis subflavus (tricolored bat)	10	0	0.0
Lasiurus intermedius (northern yellow bat)	8	7	87.5
Myotis thysanodes (fringed myotis)	8	2	25.0
Antrozous pallidus (desert pallid bat)	7	2	28.6
Myotis austroriparius (southeastern myotis)	7	1	14.3
Myotis ciliolabrum (western small-footed myotis)	7	0	0.0
Lasiurus ega (southern yellow bat)	4	2	50.0
Myotis sodalis (Indiana myotis)	4	0	0.0
Lasiurus seminolus (Seminole bat)	3	2	66.7
Parastrellus hesperus (canyon bat)	3	1	33.3
Plecotus townsendii (Townsend big-eared bat)	3	0	0.0
Desmodus rotundus (common vampire bat)	1	0	0.0
Idionycteris phyllotis (Allen big-eared bat)	1	0	0.0
Lasiurus xanthius (western yellow bat)	1	0	0.0
Molossus ater (black mastiff bat)	1	0	0.0
Myotis leibii (eastern small-footed myotis)	1	0	0.0
Myotis velifer (cave myotis)	1	1	100.0
Rousettus aegyptiacus (Egyptian fruit bat)	1	1	0
Total	**25,799**	**1,704**	**6.6**

143 had a ≥ 100% increase in the number of rabid bats reported in 2015, compared with the reference period **(Figure 4)**. In several areas, the increase in the number of rabid bats could not be attributed to increased testing; these areas include central Maryland, central and eastern Massachusetts, the Adirondacks region of New York, and the northeast quadrant of Illinois.

Only 4 states reported increases in the number of raccoon rabies cases (Alabama, Massachusetts, Maine, and Virginia). Historically, the number of raccoon rabies cases peaked in 1993, at 5,912. From 1993 through 2015, states in which the raccoon rabies virus variant was enzootic had an annual 4.5% decrease (95% CI, –6.2% to –2.7%) in the number of raccoon rabies cases.

Raccoons

There were 12,359 raccoons submitted for rabies testing in 2015, of which 1,619 (13.1%) were confirmed positive. This represented an 11.1% decrease, compared with the 1,822 rabid raccoons detected in 2014 (Table 1). The percentage of raccoons submitted for testing that were found to be rabid (13.1%) was significantly lower than the mean for the previous 5 years (14.9% [95% CI, 13.9% to 15.9%]; Table 2). States in which raccoon rabies was considered enzootic accounted for 97.3% (1,575/1,619) of all rabid raccoons reported in 2015 **(Figure 5)**. Variant typing was conducted on 272 of these 1,575 raccoons, all of which were determined to be infected with the raccoon rabies virus variant (Table 3). The remaining 44 (2.7%) rabid raccoons were detected in states where the raccoon rabies virus variant was not enzootic, including Colorado (n = 1), Ohio (6), Tennessee (4), and Texas (33). Variant typing was performed on 32 of the 33 rabid raccoons from Texas, and all were found to be infected with the south central skunk variant.

Nineteen states, the District of Colombia, and New York City remained enzootic for the raccoon rabies virus variant. Sixteen of these states and jurisdictions reported a decrease in the number of raccoon rabies cases detected in 2015, compared with 2014 (Connecticut [11.5% decrease], District of Colombia [74.1% decrease], Florida [11.3% decrease], Georgia [2.2% decrease], Maryland [13.0% decrease], North Carolina [9.6% decrease], New Hampshire [12.5% decrease], New Jersey [18.7% decrease], New York [16.3% decrease], New York City [60.0% decrease], Ohio [7.1% decrease], Pennsylvania [24.7% decrease], Rhode Island [11.1% decrease], South Carolina [12.9% decrease], Vermont [60.7% decrease], and West Virginia [19.4% decrease]).

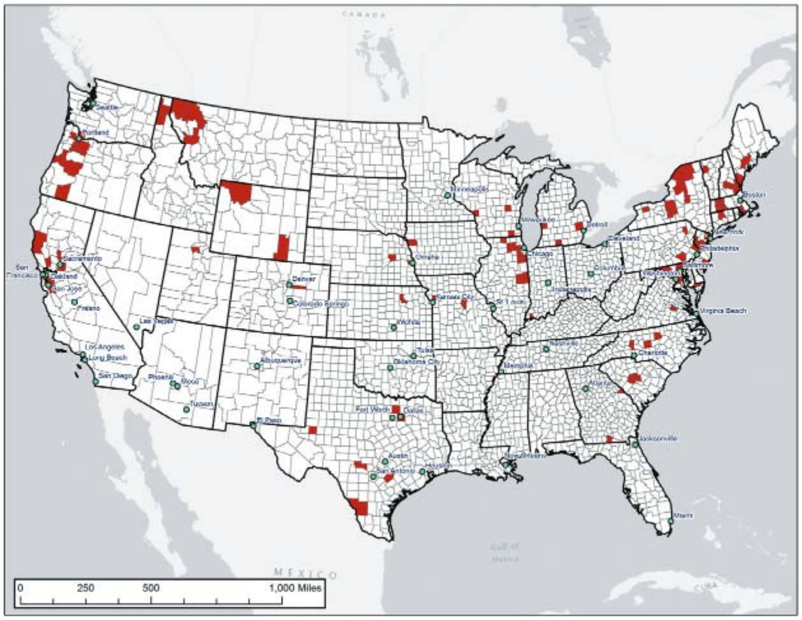

Figure 4—Counties with a ≥ 100% increase (red) in the number of rabid bats reported in 2015, compared with mean number reported annually for 2010 through 2014 (only counties that tested, on average, ≥ 5 bats/y were considered).

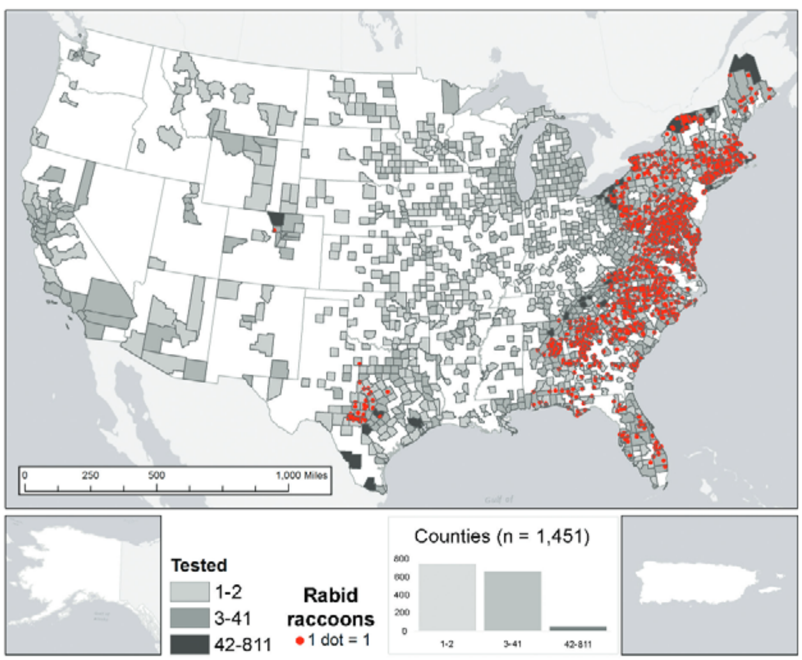

Figure 5—Reported cases of rabies involving raccoons, by county, during 2015. Histogram represents number of counties in each category for total number of raccoons submitted for rabies testing. Point locations for rabid raccoons were randomly selected within each reporting jurisdiction.

Skunks

A total of 4,857 skunks were submitted for testing in 2015, of which 1,365 (28.1%) were positive **(Figure 6)**. This represented a 14.0% decrease from the 1,588 rabid skunks reported during 2014 (Table 1). The percentage of skunks tested during 2015 that were found to be rabid (28.1%) was significantly lower than the mean for the previous 5 years (30.5% [95% CI, 28.6% to 32.3%]; Table 2).

Thirteen of the 21 (61.9%) states where skunk rabies virus variants were considered enzootic reported a decrease in the number of rabid skunks identified during 2015, compared with 2014 (Arkansas [51.8% decrease], Arizona [21.3% decrease], Iowa [50.0% decrease], Kentucky [33.3% decrease], Michigan [75.0% decrease], Missouri [33.3% decrease], Montana [40.0% decrease], North Dakota [91.7% decrease], New Mexico [100% decrease], Oklahoma [10.1% decrease], Tennessee [6.9% decrease], Texas [14.5% decrease], and Wyoming [88.0% decrease]). The number of skunks infected with a presumed skunk rabies virus variant has been decreasing at a rate of 0.6%/y since 1994; however, this estimate of the annual percentage decrease was not significantly different from 0 (95% CI, –2.1%/y to 1.1%/y). The number of skunks infected with a presumed raccoon rabies virus variant has been significantly decreasing since 1997 at an annual rate of 3.5%/y (95% CI, –5.2%/y to –1.8%/y).

Foxes

During 2015, 1,732 foxes were tested for rabies, of which 325 (18.8%) were positive **(Figure 7)**. This represented a 4.5% increase, compared with the 311 rabid foxes reported in 2014 (Table 1). The percentage of foxes submitted for testing that were found to be rabid (18.8%) was slightly lower than the mean for the previous 5 years (20.4% [95% CI, 18.0% to 22.8%]; Table 2). Nationally, the number of rabid foxes decreased at a rate of 2.3%/y from 2000 through 2015; however, this estimate of the annual percentage decrease was not significantly different from 0 (95% CI, –4.8%/y to 0.4%/y). No animals were found to be infected with the Texas gray fox rabies virus variant in 2015; the last animal reported with this rabies virus variant was a cow in 2011.

Other wild animals

During 2015, Puerto Rico reported that 9 mongooses were tested for rabies, with 8 found to be rabid, representing a 75% decrease from the 32 rabid mongooses reported in 2014 (Table 1). Other rabid wildlife identified during 2015 included 6 bobcats (*Lynx*

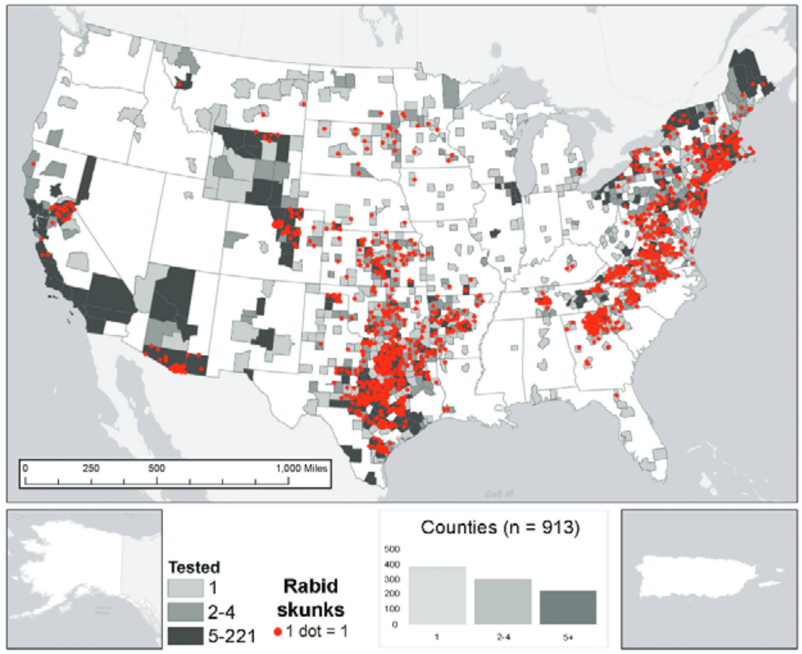

Figure 6—Reported cases of rabies involving skunks, by county, during 2015. Histogram represents number of counties in each category for total number of skunks submitted for rabies testing. Point locations for rabid skunks were randomly selected within each reporting jurisdiction.

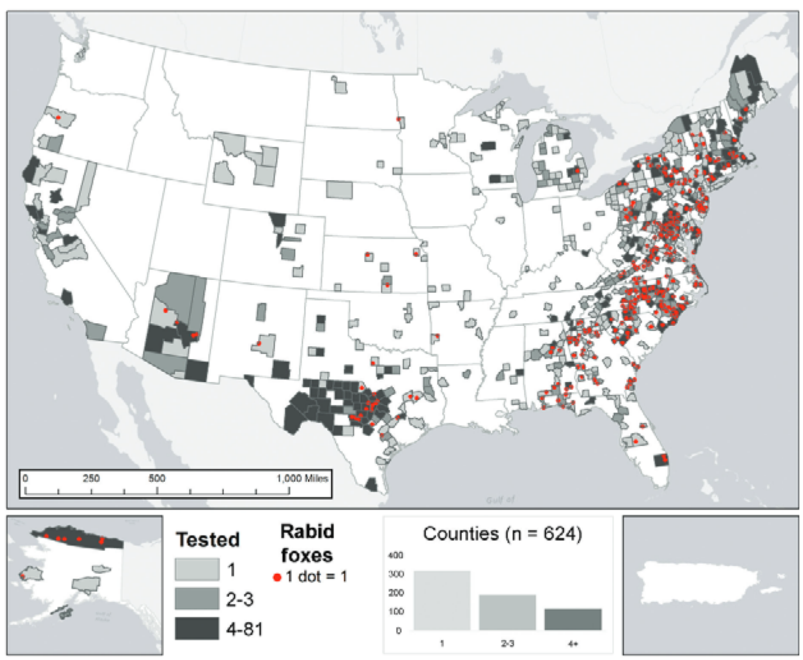

Figure 7—Reported cases of rabies involving foxes, by county, during 2015. Histogram represents number of counties in each category for total number of foxes submitted for rabies testing. Point locations for rabid foxes were randomly selected within each reporting jurisdiction.

rufus), 15 coyotes (*Canis latrans*), 6 deer (presumably *Odocoileus virginianus*), 2 opossums (*Didelphis virginiana*), 2 otters (presumably *Lontra canadensis*), 1 elk (*Cervus elaphus*), and 1 ringtail (*Bassariscus astutus*). Rabid rodents and lagomorphs reported in 2015 included 25 groundhogs (*Marmota monax*), 6 rabbits (species not specified), 1 squirrel (not specified), and 2 beavers (*Castor canadensis*).

Variant typing was performed on only 4 of the 41 (9.8%) other wild animals and 8 of the 34 (23.5%) rodents and lagomorphs (Table 3). Thus, for most of these cases, the rabies virus variant could only be assumed on the basis of the predominant rabies virus variant in the geographic area.

Rabies in Domestic Animals

During 2015, domestic animals accounted for 48.7% of all animals submitted for rabies testing. Of these, 420 (7.6%) were positive, representing a decrease of 5.6%, compared with the 445 rabid domestic animals reported in 2014 (Table 1). More than half of the rabid domestic animals identified in 2015 were reported from 5 states: Virginia (n = 68), Pennsylvania (55), Texas (51), New York (29), and Kansas (24).

Dogs

During 2015, 22,478 dogs were tested for rabies, of which 67 (0.3%) were confirmed rabid **(Figure 8)**. This represented a 13.6% increase from the 59 rabid dogs reported in 2014. Most of the rabid dogs were reported from 4 states and 1 territory: Texas (n = 13), Puerto Rico (8), North Carolina (6), Georgia (6), and Oklahoma (6). Overall, the percentage of dogs tested for rabies that were positive (0.3%) was unchanged from the mean percentage for the previous 5 years (0.3% [95% CI, 0.3% to 0.4%]; Table 2). Of the 22 rabid dogs for which vaccination status was reported, only 2 (9.1%) had a history of vaccination. The remaining 20 (90.9%) had no record or verified report of vaccination. The rabies virus variant was reported for 39 of the 67 (58.2%) rabid dogs. Most were infected with the raccoon (n = 18), south central skunk (13), or north central skunk (6) rabies virus variant (Table 3). One dog was infected with the big brown bat rabies variant, and 1 dog, which had been imported from Egypt, was infected with a canine rabies virus variant.[20]

Cats

A total of 23,101 cats were tested for rabies in 2015, of which 244 (1.1%) were confirmed rabid **(Figure 9)**. This represented a 10.3% decrease in the number of rabid cats, compared with the 272 reported in 2014 (Table 1). The percentage of cats submitted for testing that were found to be rabid (1.1%) was

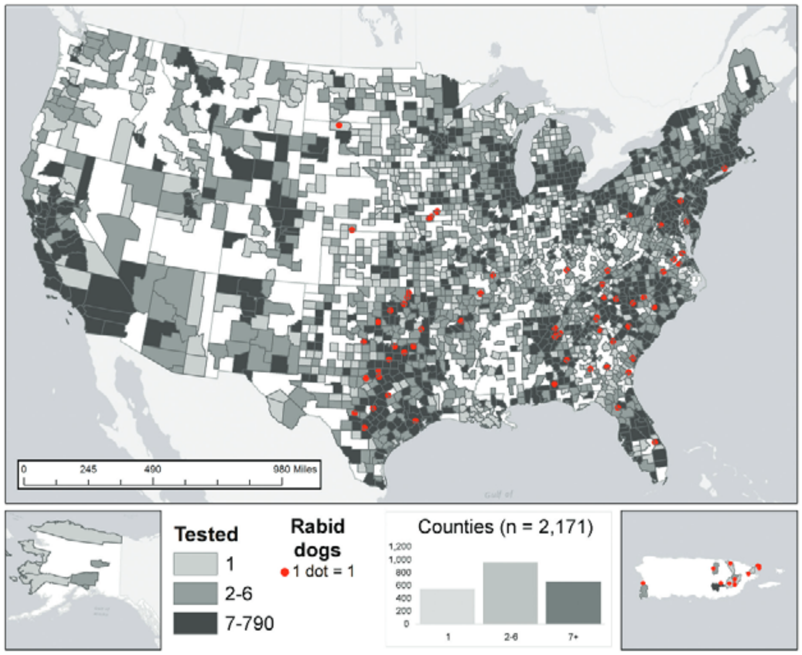

Figure 8—Reported cases of rabies involving dogs, by county, during 2015. Histogram represents number of counties in each category for total number of dogs submitted for rabies testing. Point locations for rabid dogs were randomly selected within each reporting jurisdiction.

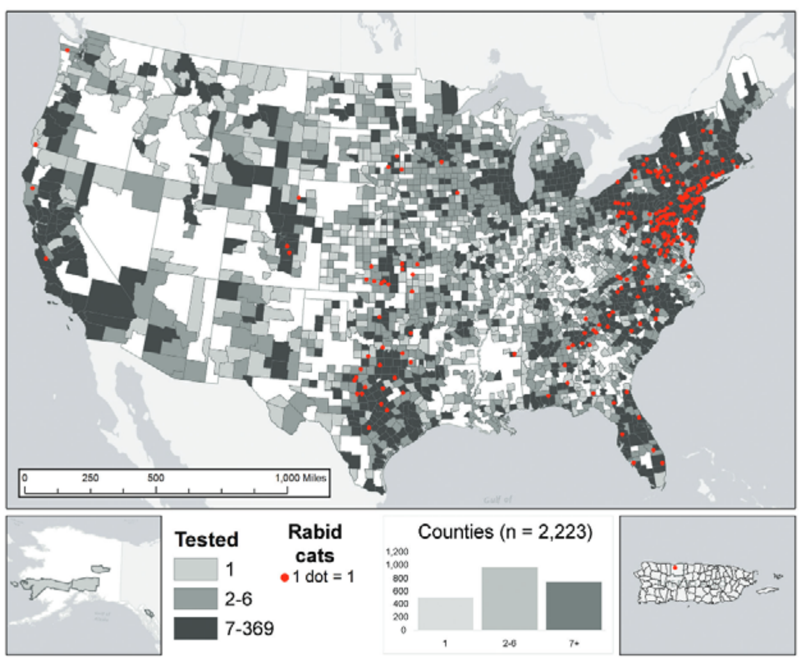

Figure 9—Reported cases of rabies involving cats, by county, during 2015. Histogram represents number of counties in each category for total number of cats submitted for rabies testing. Point locations for rabid cats were randomly selected within each reporting jurisdiction.

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 42 of the 244 (17.2%) rabid cats. Forty (95%) had no history of vaccination, 1 was reported to have been up-to-date for rabies vaccination, and 1 had an expired status. Most of the rabid cats were reported from states where the raccoon rabies virus variant was considered enzootic: Pennsylvania (n = 50), Virginia (37), New York (23), and Maryland (19). Rabies virus variant typing was performed on 62 (25.4%) rabid cats (Table 3). Most (n = 43) were infected with the raccoon rabies virus variant, with the remainder infected with the south central skunk (15), north central skunk (1), or bat (3) rabies virus variant.

Other domestic animals

There were 1,257 cattle tested for rabies during 2015, of which 85 (6.8%) were confirmed rabid. This represented a 9.0% increase in the number of rabid cattle, compared with the 78 reported in 2014 (Table 1). The percentage of cattle submitted for testing that were found to be rabid (6.8%) was not significantly different from the mean for the previous 5 years (6.7% [95% CI, 5.7% to 7.7%]; Table 2). Virginia reported the highest number of rabid cattle (n = 20), followed by Texas (16) and Kansas (12).

Fourteen rabid horses and mules were reported in 2015, a 44% decrease from the 25 reported in 2014 (Table 1). The percentage of horses submitted for testing that were found to be rabid (2.0%) was significantly decreased, compared with the mean for the previous 5 years (4.3% [95% CI, 3.6% to 5.1%]).

Rabies in Humans

During 2015, samples from 31 persons suspected of having rabies were submitted to the CDC for diagnostic testing. These samples came from 17 states and Puerto Rico. Three persons (9.7%) were confirmed to have rabies **(Table 5)**.

The first case involved a 65-year-old man who sought care in Massachusetts because of vomiting and epigastric pain. He had recently returned from a trip to the Philippines where, on June 30, 2015, he had suffered a dog bite. The dog died shortly after this exposure but was not tested for rabies, and the man did not receive postexposure prophylaxis. Following hospital admission on August 5, the patient deteriorated rapidly, and antemortem diagnostic testing confirmed infection with a rabies virus variant associated with dogs in the Philippines. The patient died on August 24, 2015.

The second case involved a 77-year-old woman from Wyoming. She initially sought health-care services on September 22, 2015, because of a 5-day history of progressive weakness and ataxia. Her condition deteriorated rapidly, and following admission to the hospital, she was transferred to a tertiary care center in Utah on September 27, 2015. Antemortem rabies diagnostic testing was pursued when family members relayed an incident involving the patient being awoken by a bat on her neck, which she swatted away with her hand. No postexposure prophylaxis was administered after this exposure. Laboratory testing confirmed infection with a rabies virus variant associated with the silver-haired bat (*Lasionycteris noctivagans*). The patient died on October 3, 2015.

The third case involved a 54-year-old man living in Puerto Rico who presented for health-care services on November 30, 2015. Clinical signs at that time included fever, difficulty swallowing, and hand paresthesia. After leaving the hospital against medical advice on December 1, 2015, he returned that afternoon with worsening symptoms and subsequently died while being transferred to the intensive care unit. His wife reported that he had been bitten by a mongoose in early October but did not seek care or receive postexposure prophylaxis. Samples collected at autopsy confirmed infection with a rabies virus variant associated with Caribbean mongooses.

Rabies in Canada and Mexico

Canada

In 2015, the laboratories of the Canadian Food Inspection Agency tested 2,295 samples for rabies, of which 151 (6.6%) were positive. This represented a 19.7% increase, compared with the 1,918 samples tested in 2014, and a 62.4% increase, compared with the 93 positive samples in 2014. These increases in number of samples tested and number of positive samples were attributed to a decrease in the total number of samples submitted for testing in 2014 as a result of a shift in responsibility for sample collection from the federal to the provincial governments, combined with an increase in new rabies outbreaks in wildlife. Of the positive samples, 40 (26.5%) were confirmatory tests on wildlife surveillance samples, with no known human or animal contacts. Bats accounted for the highest proportion of cases (33%), followed by raccoons (22.5%), skunks (16.6%), and arctic foxes (9.3%). The provinces of Ontario and New Brunswick had the highest number of cases (n = 24 each), followed by Saskatchewan (23), Manitoba (18), Quebec (18), and Nunavut (17). However, the number of samples submitted for testing varied greatly, from just 26 in Nunavut (65.4% positive) to 1,124 in Ontario (2.1% positive), the result of a predominantly passive rabies surveillance system that resulted in a submission bias from regions with large human populations.

Spillover of wildlife rabies virus variants into domestic species exhibited patterns similar to those of previous years, with rabies detected in 9 dogs, 3 cattle, 2 cats, and 1 horse. All these infections were a result of either a skunk rabies virus variant in western Canada or a fox rabies virus variant in the northern provinces. A fox rabies virus variant outbreak first detected in the province of Newfoundland and Labrador in 2014 continued into 2015, with 34 total cases detected, including 17 in Nunavut, 4 in Quebec, and 1 in Ontario.

Table 5—Cases of rabies in humans in the United States and Puerto Rico, January 2003 through September 2016, by circumstances of exposure and rabies virus variant.

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, Caribbean

*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 information about known contact with an animal was elicited during case investigation). †Rabies virus variants 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. Rabies virus variants 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*.

Three independent reincursion events of the raccoon rabies virus variant from the United States into Canada occurred in 2015. In 1 event, the raccoon rabies virus variant was found in New Brunswick, with 24 cases detected. In another event, 1 raccoon infected with the raccoon rabies virus variant was detected in the province of Quebec, on the Mohawk Nation at Akwesasne, within several hundred meters of the Canada-US border. In the third event, the raccoon rabies virus variant was detected in and around the southwestern Ontario city of Hamilton, with 10 cases reported in December after a decade of the province being free from this rabies virus variant. Whole genome sequencing showed that the Hamilton virus clustered most closely with isolates from southeastern New York. This was very distinct from isolates from western New York, suggesting that the source of the Hamilton outbreak was a long-distance translocation event, rather than a gradual undetected spread. This outbreak continued into 2016, with a total of 212 cases (150 raccoons, 60 skunks, 1 cat, and 1 red fox) detected up to October 11, 2016.

Mexico

Mexico's Ministry of Health carries out laboratory-based rabies surveillance, mainly with the direct fluorescent antibody test, through a national network of 25 state public health laboratories distributed across the country. Currently, 7 of 32 states do not have testing capacity (Baja California Sur and Baja California on the Baja Peninsula, Sinaloa on the northwestern coast, the states of Colima and Michoacán in the central west coast, Mexico City, and the state of Yucatan located near the border with Central America). These states submit samples for rabies diagnostic testing on a regular or sporadic basis to the national reference laboratory in Mexico City.

In 2015, state public health laboratories received 40,807 specimens for rabies testing, of which 257 (0.6%) were positive, 632 (1.5%) were unsuitable for diagnostic testing, and 39,918 (97.8%) were negative. The most frequently tested animals in 2015 were domestic dogs (n = 31,000), followed by cats (6,000), bats (1,062), livestock (445), opossums (49), and skunks (39). A small number of animals (< 10) submitted for testing each year consisted of a large variety of other animals such as squirrels, armadillos, weasels, rabbits, coyotes, ferrets, raccoons, mice, rats, badgers, moles, woodchucks, and foxes.

Over the past decade, Mexico has seen remarkable improvement in rabies control and prevention, particularly in domestic dogs and, consequently, in humans. Between 2001 and 2008, approximately 18 million dogs and cats (mostly dogs) were vaccinated against rabies, and these vaccination efforts continued through 2016.

During 2015, 7 rabid dogs were reported from 3 Mexican states, representing a 30% decrease from the 10 rabid dogs reported in 2014. Five of the 7 rabid dogs were reported to have originated from 3 municipalities in Chiapas, which borders Guatemala. The remaining rabid dogs originated from the Yucatan and San Luis Potosi regions. Rabies virus variants for all 6 rabid dogs in Chiapas and Yucatan consisted of variants associated with domestic dogs. The rabid dog that originated from San Luis Potosi was determined to be infected with a rabies virus variant associated with Mexican north central skunks.

No human deaths from rabies were reported from Mexico during 2013 and 2014. However, during 2015, 1 human rabies case with a history of skunk exposure was reported from the state of Chihuahua, which borders Texas and New Mexico. The rabies virus variant for this case was found to be consistent with a skunk-maintained variant that is genetically closely related to the Texas gray fox rabies virus variant. An additional clinically confirmed human death from rabies occurred in the state of Guerrero in early 2016. The patient was confirmed to have been infected with a vampire bat rabies virus variant.[21]

Discussion

The CDC has requested information on all rabies-positive animals since 1944. The number of animals submitted for rabies testing in the United States and territories during 2015 (n = 100,071) was comparable to the mean number submitted during the previous 5 years (102,979; 95% CI, 99,557 to 106,401). 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.[22]

For the first time since public health surveillance for rabies began in 1944, bats were the most frequently reported rabid animal in the United States, supplanting raccoons. This was likely due to 2 opposing long-standing trends: the number of rabid bats detected has been increasing at a rate of 4.5%/y since 1988, and the number of rabid raccoons detected has been decreasing at a rate of 4.5%/y since 1993. Numerous factors could account for these observed trends, including changes in the overall acuity of surveillance for either species, modifications in sample testing policies, alterations in public perceptions of the risk of rabies in bats, and population fluctuations.

Four regions were identified in which increases in the numbers of rabid bats were most pronounced (central Maryland, central and eastern Massachusetts, the Adirondacks region of New York, and the northeast quadrant of Illinois). One potential association that should be further explored is the relationship between these regions and the introduction of white-nose syndrome. These 4 regions have all been impacted by white-nose syndrome, with the east coast first reporting cases in 2008 and Illinois first reporting cases in 2012.[23] To our knowledge, no studies have addressed the potential population impact that white-nose syndrome may have on zoonotic diseases of bats. Anecdotally, bats with white-nose syndrome are more likely to act erratically and come into contact with people, which may increase their likelihood of becoming eligible for rabies testing. However, the evidence for this association is scant and requires further investigation.

In 2015, 2 events were detected that may have had a substantial impact on domestic rabies epidemiology. In May, the New Mexico Department of Health confirmed rabies in a fox that had attacked a woman. As part of ongoing efforts to monitor for the Arizona and Texas gray fox rabies virus variants, this sample was submitted to the CDC for routine variant typing. Unexpectedly, the rabies virus variant isolated from this fox was determined to be unique but most closely associated with rabies viruses of bats. Active roadkill surveillance and enhanced vigilance for atypical wildlife were conducted in the area, and no further cases have since been identified. In June of 2015, a dog that had been imported to the United States from Egypt was found to be infected with the canine rabies virus variant.[20] The ensuing public health investigation identified 15 dogs and 9 other animals that had potentially been exposed to the canine rabies virus. These animals were vaccinated and quarantined in accordance with state regulations, and no additional canine rabies virus cases have since been identified. Variant typing provides important epidemiological information about transmission dynamics of the rabies virus, emergence of novel variants, and apparent host shift events. In the past decade, we have observed resurgences of the Flagstaff rabies virus variant in northern Arizona gray foxes during 2009 and a bat rabies variant with multiple transmission events in Oregon foxes during 2010.[24,25]

Both of the aforementioned events highlight a limitation inherent to the current national rabies surveillance system. Only 58% of rabid dogs and 18% of rabid foxes reported in 2015 were submitted for rabies virus variant typing. Timely variant typing of virus from animals that present a risk for reintroduction of certain rabies virus variants or animals that have been associated with previous host shift events is critical for preventing important changes in the landscape of domestic rabies. This low rate of viral typing may predispose the national program to a delayed ability to detect important changes in regional rabies epidemiology. The reintroduction of raccoon rabies into Ontario, Canada, in 2015 serves as a reminder that animals can be translocated and, with them, the viruses they harbor.[26] There are currently no comprehensive guidelines for which submissions should be routinely considered for variant typing. This may result in inconsistencies in our ability to describe rabies epidemiology across the national landscape and may decrease our ability to detect important epidemiological events in a timely manner.

Detection of cross-boundary changes in rabies trends may also be delayed because of the manual processes currently used for data collection and entry at the national level. The lack of real-time electronic surveillance for animal rabies often results in a lag in multistate analysis that is at least 9 months and can be up to 18 months long. This may impede the CDC's ability to monitor regional and national trends. To rectify 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 near real-time reporting of diagnostic activity 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. Two states have engaged in pilot testing, and 1 has started sending production data as of November 2016. The CDC and Association of Public Health Laboratories will continue working with additional states to enroll laboratories in this system. This system is also expected to improve regional access to surveillance data in relation to the national oral rabies vaccination program, providing timely data that can be used for making management decisions by USDA Wildlife Services, the CDC, and state health departments.

Passive rabies surveillance, which represents 95% of the rabies testing in the United States, uses the direct fluorescent antibody test. This test is highly sensitive and highly specific for in vitro detection of rabies virus antigen in brain tissues. Results of passive surveillance testing have both clinical and public health implications. The reliability of the direct fluorescent antibody test depends on the availability of optimal reagents. During 2015 and the first quarter of 2016, shortages of high-quality, commercial, anti–rabies virus reagents occurred, involving products from 2 US manufacturers. As was the case when similar shortages occurred in 2014, 2015 saw an increase in the number of indeterminate rabies test results. These inconclusive results often required diagnostic laboratories to expend additional resources to verify test results or necessitated sending samples elsewhere for external confirmatory testing. This places an additional burden of time and cost on laboratories with minimal resources for rabies diagnostic testing, and the delay in reporting results can impede the proper public health response to a rabies case.

In response to these problems, the National Working Group on Rabies Diagnosis has monitored the availability and quality of anti–rabies virus reagents used in testing and has provided updates to the state public health laboratories through the Association of Public Health Laboratories during periods of shortage. In addition, the CDC has worked with manufacturers to resolve issues regarding affinity and reactivity of some reagents through premarket evaluation of these products. As of early 2017, there appeared to be no shortage of quality anti–rabies virus reagents for the first time in 3 years.

Shortages of anti–rabies virus reagents required for the direct fluorescent antibody test highlight the need to investigate new diagnostic technologies. Future rabies diagnostic testing will likely be based on techniques that have the ability to provide accurate results even when used in the field. With the advancement of molecular techniques, reverse transcription PCR and quantitative real-time reverse transcription PCR assays have increasingly been used for the detection of rabies virus RNA. Conventional reverse transcription PCR assays are time- and labor-intensive and require confirmation by sequence analysis of the amplified nucleic acid. Thus, there is a need for development of quantitative real-time reverse transcription PCR assays to detect lyssaviruses. Lateral flow devices based on immunochromatographic techniques are easy to use but in their current format lack diagnostic sensitivity and specificity. Improved lateral flow devices and quantitative real-time reverse transcription PCR assays have the potential to improve rabies surveillance in the United States and elsewhere.

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No human rabies cases had been reported in the United States through November 2016.

Acknowledgments

The authors declare that there were no competing interests.

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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