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Food Animal Economics

Costs of raccoon rabies incidents in cattle herds in Hampshire County, West Virginia, and Guernsey County, Ohio

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Objective—To determine direct and indirect costs associated with raccoon rabies incidents involving cattle herds in Hampshire County, WV, in 2008 and Guernsey County, Ohio, in 2010.

Design—Ex post cost analysis.

Animals—1 cattle herd in Hampshire County, WV, in 2008 and 1 cattle herd in Guernsey County, Ohio, in 2010.

Procedures—Data were collected for each incident through telephone and email interviews with 16 federal, state, and county agency personnel involved in the case investigations and coordinated responses for rabies in the cattle herds. To characterize the economic impact associated with rabies in the 2 cattle herds, cost analysis was conducted with 7 cost variables (salary and benefits for personnel involved in the response, human postexposure prophylaxis, indirect patient costs, rabies diagnostic testing, cattle carcass disposal, market value of euthanized cattle, and enhanced rabies surveillance). Estimates of direct costs were determined on the basis of agency records and other relevant data obtained from notes and reports made by agency staff at the time of the incident and from a review of the literature.

Results—Primary costs included the market value of euthanized cattle ($51,461 in West Virginia; $12,561 in Ohio), human postexposure prophylaxis ($17,959 in West Virginia; $11,297 in Ohio), and salary and benefits for personnel involved in the response ($19,792 in West Virginia; $14,496 in Ohio).

Conclusions and Clinical Relevance—These results should provide a basis for better characterization of the economic impact of wildlife rabies in cattle in the United States. (*J Am Vet Med Assoc* 2013;243:1561–1567)

Zoonotic diseases transmitted from domestic animals and wildlife to humans have major socioeconomic impacts involving public health, agriculture, and wildlife conservation.[1] Since the 1980s, numerous

studies[2–10] have been conducted on the economics of rabies and rabies control in North America, but none has clearly defined the impacts of raccoon rabies in cattle. Moreover, little is known about the costs associated with the impact of wildlife rabies on agriculture in the United States, and this issue is recommended for further study in a national plan for rabies management in US wildlife.[11]

In some instances, rabies in a single domestic animal has led to massive human exposure to the rabies virus, which has resulted in substantial socioeconomic impacts. Exposure to a rabid dog in Yuba County, Calif, in 1980 resulted in expenditures for rabies PEP for 70 people ($92,650), vaccination of 2,000 dogs and related veterinary services ($4,190), and responses by a health department and local animal control programs ($8,950), for a total of $105,790.[12] A single kitten con-

firmed with raccoon rabies in a pet store in Concord, NH, in 1994 resulted in rabies exposure of 665 people at an estimated cost of $1.5 million, which included $1.1 million for human PEP, $4,200 for rabies virus diagnostic testing, and $15,000 for responses by federal and state public health agencies.[13,14] Two incidents (1996 and 1998) involving raccoon rabies in cattle in Worcester County, Mass, led to 89 people receiving PEP as a result of drinking unpasteurized milk (80 people) or direct contact with saliva (9 people) from rabid dairy cows.[15] These examples underscore the extensive nature of costs borne by animal owners and the public related to rabies in companion animals and livestock. Moreover, the translocation of raccoon rabies from Florida to areas naïve for the virus in western Virginia and West Virginia in the 1970s,[16] followed by the rapid spread of the virus,[17] has resulted in extensive human and animal health impacts and substantial costs throughout the eastern United States.[4]

Cattle production is an important part of the agricultural industry in the United States, with a value of $51.5 billion in 2010 (determined on the basis of cash receipts from marketing).[18] The US cattle-calf inventory as of January 1, 2011, was 92.6 million animals, with an estimated value of $37 billion[18] that involved approximately 950,000 cattle operations in the United States.[19]

The number of US cattle operations that vaccinate for rabies is not known, but rabies vaccination of cattle is uncommon.[a] In 1 study,[6] it was estimated that only 2% to 5% of animal vaccinations against rabies are administered to livestock in developed countries, and unpublished data from a 2007 report[b] on dairy cattle health and management practices in the United States indicated that a mean ± SE of only 0.8 ± 0.2% of dairy operations vaccinated dairy heifers or cows for rabies. Nevertheless, rabies remains a threat to human and animal health in livestock operations throughout the United States because wildlife rabies is enzootic.

In the study reported here, costs were estimated for raccoon rabies incidents in cattle herds in West Virginia and Ohio. This information can expand understanding of the dynamics, responses, and costs associated with wildlife rabies in cattle. In addition, it can provide input for a more robust evaluation of the benefits and costs associated with ORV intervention to reduce the risk of future incidents.

Materials and Methods

During 2011, data were collected on raccoon rabies incidents involving cattle herds in Hampshire County, WV, in 2008 and Guernsey County, Ohio, in 2010. Data were collected through telephone and email interviews with federal, state, and county agency personnel involved in the case investigations and subsequent interventions to protect public health and agriculture. Estimates of direct costs were based primarily on agency records. Other relevant data were obtained from notes and reports made by agency staff at the time of each incident as well as for economic components similar to those reported elsewhere.[10]

Interviews were conducted with 16 individuals who represented 4 agencies in West Virginia and 5 agencies in Ohio. Data used for cost estimates associated with the Hampshire County, WV, herd were provided by representatives from the West Virginia Department of Agriculture, West Virginia Department of Health and Human Resources, Hampshire County Health Department, and USDA, APHIS, WS. For the herd in Guernsey County, Ohio, data were provided by the Ohio Department of Health, Ohio Department of Agriculture, Cambridge-Guernsey County Health Department, USDA APHIS WS, and a local veterinarian in private clinical practice.

To derive costs, variables for direct and indirect costs similar to those reported in another study[20] were used. The 7 categories were as follows: salary and benefits for personnel involved in the case investigations, human PEP, rabies diagnostic testing, carcass disposal, market value of cattle, enhanced rabies surveillance, and indirect patient cost of rabies exposure.

Direct and indirect costs (in US dollars) for both herds were calculated by use of the following equation:

$$Cost = salary\ and\ benefits + human\ PEP + rabies\ diagnostic\ testing + carcass\ disposal + market\ value\ of\ cattle + enhanced\ rabies\ surveillance + indirect\ patient\ cost\ of\ rabies\ exposure$$

Cost represented total direct and indirect costs. Direct costs included salary and benefits, human PEP, rabies diagnostic testing, carcass disposal, and market value of cattle. Indirect costs included enhanced rabies surveillance and indirect patient cost of rabies exposure.

Salary and benefits included costs for salaries, benefits, travel, and supplies for personnel involved with case investigations, mitigation of the threat of raccoon rabies, and cattle depopulation; it excluded costs for enhanced rabies surveillance. Human PEP costs were based on actual expenditures for human rabies immune globulin and rabies vaccine in West Virginia in 2008. Costs for Ohio in 2010 were estimated by converting the human PEP costs in West Virginia on a costs-per-incident basis.[21] Human patients in Ohio received human rabies immune globulin and rabies vaccine (human diploid cell vaccine). Rabies diagnostic testing included costs for rabies diagnostic testing of specimens; this included costs for shipping, testing by a state laboratory, and confirmatory testing by the CDC in Atlanta, Ga. Carcass disposal was the cost for disposal of cattle carcasses after depopulation and rendering or on-site burial. Market value of cattle was the market value of cattle euthanized as a result of herd depopulation. Market value for the herd in West Virginia was derived from the indemnity paid to the producer by the West Virginia Department of Agriculture, as determined on the basis of the average full-market value for 329-kg (725-lb) Black Angus feeder heifers reported for the next 2 special feeder calf sales in April 2008. Market value for the herd in Ohio was calculated as 2 times the high ($123.48) and low ($99.69) market price per hundredweight (a hundredweight is equivalent to 45 kg) estimates for 38.6 to 54.5 kg (85 to 120 lb) returned-to-farm Holstein bulls sold in Lancaster, Pa, in 2011.[22]

Enhanced rabies surveillance included costs associated with enhanced surveillance for raccoon rabies

cases. These costs included salaries, benefits, travel, and supplies and testing expenses associated with a direct rapid immunohistochemical test. For the indirect patient cost of rabies exposure, the actual costs associated with exposure to rabies virus for these incidents were unknown. However, the reported mean indirect patient costs from a retrospective study[10] of direct and indirect costs in 2 southern California counties were converted to 2008 US dollars (for the herd in West Virginia) and 2011 US dollars (for the herd in Ohio) on a cost-per-incident basis.[21] This included travel, medical appointments, day care, lost wages, and estimated related costs.

Results

Results for each herd were summarized. This included a case description and cost analysis.

Hampshire County, WV—On March 1, 2008, a skunk (*Mephitis mephitis*), a common spillover host for raccoon rabies,[23,24] was observed in close proximity to 88 Black Angus feeder heifers in 3 adjacent pens. Several heifers were observed smelling and licking the skunk. The feedlot operation raised feeder cattle heifers. Cattle weighed approximately 136.4 kg (300 lb) when placed in the feedlot in the fall and were sent to market the following spring (6 months later) at an approximate weight of 318.2 to 329.5 kg (700 to 725 lb). The feedlot was located approximately 145 km (90 miles) east of the ORV zone used to prevent raccoon rabies from spreading to the west[25]; the feedlot was located within the enzootic area for raccoon rabies

On March 19, 2008, the owner of the feedlot noticed that 3 heifers appeared sick and had stopped eating. On March 21 and 22, the sick cattle were treated by the owners without an apparent awareness of the potential for rabies; the cattle were subsequently separated from the herd and placed into a trailer. On March 22, one of the sick cattle died and was buried at an on-site location. On March 23, a local veterinarian was called to treat the sick cattle. The next day, that veterinarian contacted the West Virginia Department of Agriculture and recommended that the 2 remaining sick heifers be euthanized so that specimens could be tested for rabies at the West Virginia Department of Health and Human Resources Rabies Laboratory. Veterinarians with the West Virginia Department of Agriculture concurred with this recommendation.

On March 25, 2008, both heifers were confirmed rabid by the West Virginia Department of Health and Human Resources Rabies Laboratory. An additional heifer became ill, was euthanized, and was confirmed rabid by the state rabies laboratory. Three other cattle also had signs of rabies a few days later but were not tested. The CDC confirmed that the cattle were infected with the raccoon rabies virus variant.

None of the cattle on the farm had a history of being vaccinated against rabies. The West Virginia Department of Agriculture ordered the 85 remaining cattle (84 heifers and 1 steer) to be euthanized to prevent the spread of rabies and to protect human health and safety. A 6-month quarantine of the herd was not considered practical because the cattle were scheduled

to be shipped to market between April 12 and April 19, 2008, and long-term feeding was not deemed cost effective. On April 2, 2008, USDA, APHIS, WS assisted the West Virginia Department of Agriculture with depopulation. All euthanized cattle were shipped to a rendering plant in Winchester, Va. The producer was provided compensation for the 88 cattle through an indemnity payment made by the West Virginia Department of Agriculture.

Ten people (4 members of the owner's family, 3 additional adults, and 3 additional children) were evaluated by the Hampshire County Health Department for possible exposure to rabies virus. All 10 received rabies PEP.

The cattle-calf inventory in West Virginia in late 2010 and early 2011 was estimated at 370,000 animals, with a cash receipt value of $115.2 million.[18] The majority (295/382 [77.2%]) of Hampshire County, WV, cattle farms consisted of operations with < 50 animals[26] (**Table 1**). However, these same farms accounted for only 4,523 of 17,033 (26.6%) of the total number of cattle in the county (**Table 2**). There were a large number of small operations (1 to 9 cattle/farm) in Hampshire County. Rabies in livestock is more likely to impact smaller operations with fewer cattle, which have less ability to absorb livestock loss within their operating budgets.

Direct and indirect cost components used to characterize costs to the public and the livestock producer placed the total cost for this herd at $103,985 (**Table 3**). Expenditures included $15,115 for the West Virginia Department of Agriculture and West Virginia Depart-

Table 1—Census of cattle on farms in Hampshire County, WV, and Guernsey County, Ohio, in 2007.[26]

| No. of cattle | Hampshire county, WV | | Guernsey County, Ohio | |
	No. of farms	%	No. of farms	%*
1–9	137	35.9	149	27.6
10–19	70	18.3	142	26.3
20–49	88	23.0	150	27.8
50–99	44	11.5	47	8.7
100–199	27	7.1	32	5.9
200–499	13	3.4	15	2.8
≥ 500	3	0.8	4	0.7
Total	**382**		**539**	

Cattle refers to dairy, beef, and all other types of cattle.
*Column does not total to 100% because of rounding.

Table 2—Distribution of cattle in Hampshire County, WV, and Guernsey County, Ohio, in 2007.[26]

| Distribution | Hampshire County, WV | | Guernsey County, Ohio | |
	No. of cattle	%	No. of cattle	%
1–9	672	3.9	835	3.8
10–19	1,019	6.0	1,955	8.9
20–49	2,832	16.6	4,509	20.6
50–99	3,045	17.9	2,966	13.6
100–199	3,787	22.2	4,416	20.2
200–499	3,808	22.4	4,083	18.7
≥ 500	1,870	11.0	3,109	14.2
Total	**17,033**		**21,873**	

Cattle refers to dairy, beef, and all other types of cattle.

Table 3—Summary of costs for raccoon rabies incidents involving cattle in Hampshire County, WV, in 2008 and Guernsey County, Ohio, in 2010.

Cost category	Hampshire County, WV		Guernsey County, Ohio	
	US dollars	%	US dollars	%
County	665	0.6	2,892	6.4
State	15,115	14.5	1,568	3.5
Federal	4,012	3.9	10,036*	22.3
Local veterinarian in private clincal practice	0	0	994	2.2
Human PEP	17,959 (n = 10)	17.3	11,297 (n = 6)	25.1
Indirect patient costs	7,978†	7.7	5,019†	11.2
Laboratory diagnostic testing (or burial)	615 (n = 3)	0.6	309 (n = 1)	0.7
Carcass disposal (rendering)	6,180 (n = 88)	5.9	300 (n = 64)	0.7
Market value of cattle	51,461‡	49.5	12,561	27.9
Total	**103,985**		**44,976**	

*Costs for enhanced rabies surveillance by the USDA APHIS WS. †Estimated on the basis of values reported in another study.[10] ‡Indemnification paid for the 88 cattle by the West Virginia Department of Agriculture.

ment of Health and Human Resources, $665 for the Hampshire County Health Department, and $4,012 for USDA, APHIS, WS. Collectively, these accounted for $19,792 (19.0%) of the total cost.

The Hampshire County Health Department investigated the potential for human exposure to the rabies virus from rabid cattle in the herd. For the 4 family members who received PEP, the estimated cost was $7,184, which was paid by the Hampshire County Health Department and reimbursed by the patient assistance program of the National Organization for Rare Disorders. Detailed information about costs was not available for the additional 3 adults and 3 children who received PEP at the local hospital. Therefore, the mean cost for PEP for each family member ($1,796) was used to calculate the cost for all 10 people who received PEP. This value was $17,960 (17.3% of the total cost).

Actual indirect patient costs related to rabies virus exposure were unknown. Values reported in another study[10] were used to yield estimated costs of $797.84/patient (converted to 2008 US dollars). The total estimated indirect cost for the 10 patients was $7,978 (7.7% of the total cost). Three rabies diagnostic tests associated with this herd were conducted at the West Virginia Department of Health and Human Resources. The samples were subsequently shipped to the CDC for confirmatory testing. Costs for laboratory staff time, sample shipping, and diagnostic supplies were estimated at $615 (0.6% of the total cost). Eighty-seven cattle were sent to Virginia for rendering at a disposal cost of $6,180 (5.9% of the total cost).

An indemnity payment was made to the owner by the West Virginia Department of Agriculture for the 87 euthanized cattle plus the heifer that died. The total market value of the 88 cattle was estimated conservatively at $51,461 (49.5% of the total cost).

This rabies incident occurred in a herd located east of the ORV zone in a raccoon rabies enzootic area. Therefore, no additional coordinated response was required for enhanced rabies surveillance by USDA, APHIS, WS or other agencies.

Guernsey County, Ohio—On November 11, 2010, an apparently healthy Holstein bull calf and 142 other calves from a farm in south-central Pennsylvania were shipped to an auction market. The calf and 6 others were purchased by a large dairy-beef, feeder-calf operation in Guernsey County, Ohio. None of the calves had a history of interactions with raccoons or other wildlife. The Ohio farm that purchased the calves was a starter operation that raised Holstein bull calves. Calves were purchased at a weight of 40.9 to 45.5 kg (90 to 100 lb) and sold to feedlots at an approximate weight of 136.4 to 147.7 kg (300 to 325 lb). The facility consisted of a building with 3 wings; each wing generally contained 272 feeder calves tethered and crated in a closed-barn setting.

The Pennsylvania-sourced calf first had signs of illness on December 18, 2010. The calf had difficulty swallowing and excessive drooling and refused to eat or drink. Caretakers performed oral examinations and initial treatments; the caretakers did not wear protective gloves during these procedures. On December 22, the calf was released from its crate and allowed to roam freely in an area of the barn. The calf potentially had contact with up to 63 other calves. The calf, which was 49 days old, died on December 23, 2010. A necropsy was performed by a local veterinarian who detected no notable gross pathological lesions. However, the behavior of the calf described by the caretakers raised concerns about rabies, and the brain was sent to the Ohio Department of Health Laboratory for testing. Rabies was confirmed on December 27, 2010. The CDC confirmed that the calf was infected with the raccoon rabies virus variant.

The entire facility was quarantined on December 28, 2010, by the Ohio Department of Agriculture. The owner decided to euthanize 63 of the 272 calves that may have been exposed to the rabid calf rather than to quarantine the entire herd.

The inventory in Ohio in 2011 was approximately 1,230,000 cattle and calves, with a cash receipt value of $415.3 million.[18] The majority (441/539 [81.8%]) of Guernsey County, Ohio, cattle farms consisted of operations with < 50 animals[26] (Table 1). However, these same farms accounted for only 7,299 of 21,873 (33.4%) of the total number of cattle in the county (Table 2). The herd size (number of animals/farm) was more evenly distributed, compared with the herd size in Hampshire County, WV.

Direct and indirect cost components used to characterize costs to the public and livestock producers placed the total cost for this single incident at $44,974 (Table 3). Expenditures included $1,568 for the Ohio Department of Health and Ohio Department of Agriculture, $2,892 for the Cambridge-Guernsey County Health Department, and $994 for a local (attending) veterinarian in private clinical practice. Expenditures to protect public health and agriculture were estimated at $5,454 (12.1% of the total cost).

Six people (the attending veterinarian, the barn manager, and the primary animal caretaker and his wife and 2 sons) received PEP. The cost for PEP for each patient was $1,883; thus, human PEP cost was $11,297 (25.1% of the total cost).

Actual indirect patient costs related to rabies virus exposure were unknown. Values reported in another study[10] were used to yield estimated costs of $836.45/patient (converted to 2011 US dollars). The total estimated indirect cost for the 6 patients was $5,019 (11.2% of the total cost).

One rabies diagnostic test was performed at the Ohio Department of Health Laboratory, and a sample was later shipped to the CDC for confirmatory testing. The estimated cost for laboratory staff time, sample shipping, and diagnostic supplies was $309 (0.7% of the total cost).

The 63 euthanized bull calves were buried at an on-site location. A backhoe was used to dig a burial pit and to transport the dead calves. Carcass disposal required approximately 4 hours at a cost of $75/h for the equipment and the backhoe operator. Thus, estimated cost for carcass disposal was $300 (0.7% of the total cost).

Mean weight of each of the 63 euthanized bull calves was approximately 90.9 kg (200 lb). The estimated market value of each calf ranged from $199.38 to $246.96. Therefore, total market value was conservatively estimated at $12,561 (27.9% of the total cost).

Raccoon rabies is common in Pennsylvania and eastern Ohio as well as throughout the United States, south of a line that extends from northeast Ohio to southwest Alabama.[24] However, in southeastern Ohio, raccoon rabies has never been detected as far west as Guernsey County. Therefore, there was added importance with regard to current and historical rabies control efforts because the farm with the rabid calf was located approximately 40 km (25 miles) west of the ORV zone established to prevent the spread of raccoon rabies to naïve areas to the west. In 2010, 765,353 vaccine-laden baits were distributed over approximately 11,240 km² in 14 Ohio counties.[27] Translocation represents a risk of rabies becoming established in abundant raccoon populations west of the current viral distribution.[28] Unintentional or intentional human-assisted movement of raccoon rabies to naïve areas would be expected to increase control costs, jeopardize sustainability of the national wildlife rabies management program, and result in impacts on human and animal health in a broader geographic region.

Confirmation of raccoon rabies in the bull calf in Guernsey County represented a potentially important geographic expansion of raccoon rabies, especially if the virus were to become established and spread rapidly to the west. It also would have represented a threat to established ORV control efforts conducted annually by USDA, APHIS, WS in cooperation with state, county, and federal partners. Thus, 6 USDA APHIS WS staff conducted enhanced rabies surveillance for 28 days over a 4-month period (January 1 to April 29, 2011). Samples from rabies suspects were tested with the direct rapid immunohistochemical test.[29] No additional rabid animals were detected. Estimated costs included salary and benefits ($7,286), vehicles ($1,935), supplies for the direct rapid immunohistochemical test ($324), and equipment ($490). Total estimated indirect costs for enhanced rabies surveillance were $10,035 (22.3% of the total cost).

Discussion

Rabies in cattle results in a variety of socioeconomic impacts to producers and the public that have not been definitively characterized. However, in Ontario, Canada, annual indemnity payments for livestock losses attributable to rabies averaged $247,000 (Canadian dollars) annually prior to fox rabies control,[30] which was achieved primarily through the use of ORV. After ORV baiting for fox rabies control was initiated during 1990 to 2000, there was a 41% reduction in indemnity payments.[30]

The analysis for the study reported here involved the systematic use of 7 direct and indirect cost components linked to agriculture, but that were also separate from the cattle production process, to estimate the costs of rabies in cattle. Market value of euthanized cattle was the single largest cost for both herds, accounting for 27.9% and 49.5% of total costs in Ohio and West Virginia, respectively. Expenses associated with government responses differed between the 2 states, with more public resources expended in West Virginia for agency staff salaries and benefits, supplies, and travel ($19,792 [19.0%]), compared with those expenditures in Ohio ($14,496 [32.2%]). These expenditures at the federal, state, and local level represent an economic burden on government agencies that is often difficult to predict and to include in budgets, given the frequent variation in the number of rabies cases and associated number of rabies exposures each year. In fact, the overall costs for government responses for both states exceeded estimated human PEP costs that usually represent the single biggest reported cost in rabies exposure cases. Investigators in another study[10] found similar results in terms of a substantial economic burden on local municipalities and county governments as a result of suspected rabies exposures in 2 counties in southern California. In addition, laboratory diagnostic support was likely undervalued in the rabies incidents in West Virginia and Ohio.

In contrast to the rabies incident in West Virginia, in which rabies was confirmed in a cattle herd within a raccoon rabies enzootic area (east of the ORV zone), the rabid calf in Ohio was located 40 km (25 miles) west of the raccoon rabies epizootic zone. This single translocation incident had the potential to result in extensive spread of raccoon rabies throughout the United States, with the initial source emerging from a raccoon

or skunk exposed to rabid cattle. Such an event could have resulted in the expenditure of millions of dollars to protect public and animal health, jeopardized the current rabies management program that relies on ORV to prevent spread of raccoon rabies, and increased social costs associated with fear and anxiety related to rabies. The indirect costs associated with the planning and implementation of enhanced rabies surveillance in Ohio was estimated at $10,036 (22.3% of the total cost). Enhanced (active) surveillance costs were warranted to complement local public health (passive) surveillance to provide for greater assurance that raccoon rabies had not become established in local wildlife populations west of the current epizootic zone.

In the present study, we did not attempt to quantify indirect costs attributable to loss of income for related businesses as a result of these rabies cases. Furthermore, we did not attempt to characterize cost impacts related to consumer fears regarding food safety or impacts to the reputation of producers or the local cattle industry. Although it is important (but extremely difficult to quantify), no attempt was made to characterize costs related to anxiety or fear caused by human exposure to rabies in these cattle or as a result of livestock depopulation.[3,31,32] Finally, we did not attempt to explore likely alternative scenarios that might have resulted in similar or even greater costs had producers elected to quarantine their herds rather than to depopulate.

In addition, had raccoon rabies been identified in the local area as a result of the surveillance efforts, intensified management action would have likely been implemented, which would have included distribution of ORV at 150 baits/km^2 and a trap-vaccinate-release project to immunize a portion of the local raccoon population.[25] Contingency actions that involve trap-vaccinate-release in localized areas are expensive ($\geq$ 2.5 times as great as the cost for ORV baiting programs alone).[33] For example,[34] it has been reported that costs per km^2 for ORV programs targeting raccoons could range from $102 to $262 (1991 US dollars), compared with $450 to $1,150 (1991 Canadian dollars) for trap-vaccinate-release operations.

It has been documented in previous case reports[7,12–15,35] that the large costs associated with rabid animal incidents are driven primarily by human exposure to the rabies virus and the subsequent public and private expenditures related to the number of people receiving PEP. National statistics for human exposure to rabies associated with cattle and the number of those humans receiving PEP are not available. However, 81% of rabies incidents in cattle in Texas resulted in human exposure to rabies.[c,d] For cases in which humans were exposed to rabies, there was a mean of 3.4 human exposures/incident. Extrapolating the Texas data to the entire United States, we would expect 90 incidents/y, whereby rabid cattle events would lead to 306 human exposures. If all exposures resulted in human PEP, we estimate that the typical total costs for PEP and indirect patient expenses would be $832,102/y.

In the United States, there is an estimated mean of 118 rabid cattle/y, with approximately 1.06 rabid cattle/incident. We estimate there are approximately 111 incidents each year in which cattle producers are involved

with the inconvenience and cost of managing rabies in cattle on their operation. Each rabid cattle event is likely to differ on the basis of the type of operation as well as with the level of response by government agencies and the producer. However, the mean number of cattle per farm has increased by 36% (to almost 100 cattle/farm) since 1989.[19] Increased cattle density elevates the potential of disease outbreaks as well as the cost of disease control efforts by producers and government agencies. Nevertheless, the range and composition of cost components are likely to be similar for most rabid cattle incidents.

On the basis of the costs identified in the present study, we estimate the annual overall cost of rabies in US cattle per year to range from $4.9 million to $11.5 million. Although the overall economic impacts reported in this study may be small in relation to the value of the cattle industry and the often cited cost of $300 million/y to coexist with rabies in the United States,[2,4,36] rabies in cattle continues to strongly impact individual producers and burden state and local agencies with limited resources and has the potential to negatively affect a large-scale federally coordinated program to stop the westward spread of raccoon rabies.

References

1. Cleaveland S, Laurenson MK, Taylor LH. Diseases of humans and their domestic mammals: pathogen characteristics, host range and the risk of emergence. *Philos Trans R Soc Lond B Biol Sci* 2001;356:991–999.
2. Fishbein DB, Arcangeli S. Rabies prevention in primary care. A four-step approach. *Postgrad Med* 1987;82:83–90, 93–95.
3. Stehr-Green JK, Schantz PM. The impact of zoonotic diseases transmitted by pets on human health and the economy. *Vet Clin North Am Small Anim Pract* 1987;17:1–15.
4. Uhaa IJ, Dato VM, Sorhage FE, et al. Benefits and costs of using an orally absorbed vaccine to control rabies in raccoons. *J Am Vet Med Assoc* 1992;201:1873–1882.
5. Meltzer MI. Assessing the costs and benefits of an oral vaccine for raccoon rabies: a possible model. *Emerg Infect Dis* 1996;2:343–349.
6. Meltzer MI, Rupprecht CE. A review of the economics of the prevention and control of rabies. Part 2: rabies in dogs, livestock and wildlife. *Pharmacoeconomics* 1998;14:481–498.
7. Chang HGH, Eidson M, Noonan-Toly C, et al. Public health impact of reemergence of rabies, New York. *Emerg Infect Dis* 2002;8:909–913.
8. Kemere P, Liddel MK, Evangelou P, et al. Economic analysis of a large scale oral vaccination program to control raccoon rabies. In: Clark L, Hone J, Shivik JA, et al, eds. *Human conflicts with wildlife: economic considerations.* Fort Collins, Colo: USDA, 2002;109–116.
9. Recuenco S, Cherry B, Eidson M. Potential cost savings with terrestrial rabies control. *BMC Public Health* 2007;7:47.
10. Shwiff SA, Sterner RT, Jay MT, et al. Direct and indirect costs of rabies exposure: a retrospective study in southern California (1998–2002). *J Wildl Dis* 2007;43:251–257.

11. USDA. *U.S. National Plan for Wildlife Rabies Management (2008–2012). (Strategies revised March 30–April 1, 2010)*. Concord, NH: USDA, APHIS, Wildlife Services, 2008;42.

12. CDC. The cost of one rabid dog—California. *MMWR Morb Mortal Wkly Rep* 1981;30:527.

13. CDC. Mass treatment of humans exposed to rabies—New Hampshire, 1994. *MMWR Morb Mortal Wkly Rep* 1995;44:484–486.

14. Noah DL, Smith MG, Gotthardt JC, et al. Mass human exposure to rabies in New Hampshire: exposures, treatment, and cost. *Am J Public Health* 1996;86:1149–1151.

15. CDC. Mass treatment of humans who drank unpasteurized milk from rabid cows—Massachusetts, 1996–1998. *MMWR Morb Mortal Wkly Rep* 1999;48:228–229.

16. Nettles VF, Shaddock JH, Sikes RK, et al. Rabies in translocated raccoons. *Am J Public Health* 1979;69:601–602.

17. CDC. Extension of the raccoon rabies epizootic—United States, 1992. *MMWR Morb Mortal Wkly Rep* 1992;41:661–664.

18. USDA. Meat animals production, disposition, and income 2010 summary April 2011. Available at: usda.mannlib.cornell.edu/MannUsda/viewDocumentInfo.do?documentID=1101. Accessed Oct 4, 2013.

19. USDA. *Overview of the United States cattle industry*. Washington, DC: USDA, 2010;1–15.

20. Sterner RT, Sterner BS. Relative factor costs of wildlife rabies impacts in the U.S, in *Proceedings*. 21st Proc Vertebrate Pest Conf 2004;185–189.

21. Coin News. Inflation calculator: money's real worth over time. 2012. Available at: www.coinnews.net/tools/cpi-inflation-calculator/. Accessed Apr 5, 2013.

22. USDA. Market news portal splash. Available at: marketnews.usda.gov/. Accessed Apr 10, 2013.

23. Guerra MA, Curns AT, Rupprecht CE, et al. Skunk and raccoon rabies in the eastern United States: temporal and spatial analysis. *Emerg Infect Dis* 2003;9:1143–1150.

24. Blanton JD, Palmer D, Rupprecht CE. Rabies surveillance in the United States during 2009. *J Am Vet Med Assoc* 2010;237:646–657.

25. Slate D, Algeo TP, Nelson KM, et al. Oral rabies vaccination in North America: opportunities, complexities, and challenges. *PLoS Negl Trop Dis* 2009;3:e549.

26. National Agricultural Statistics Service. Census of agriculture 2007. Available at: www.agcensus.usda.gov/Publications/2007/Full_Report/Census_by_State/. Accessed Jun 25, 2013.

27. USDA, APHIS. FY2010 Ohio ORV distribution. 2010. Available at: www.aphis.usda.gov/wildlife_damage/oral_rabies/oral_rabies_info_by_state/ohio/index.shtml. Accessed Aug 29, 2013.

28. Riley SPD, Hadidian J, Manski DA. Population density, survival, and rabies in raccoons in an urban national park. *Can J Zool* 1998;76:1153–1164.

29. Lembo T, Niezgoda M, Velasco-Villa A, et al. Evaluation of a direct, rapid immunohistochemical test for rabies diagnosis. *Emerg Infect Diag Infect Dis* 2006;12:310–313.

30. Rosatte RC. Rabies control in wild carnivores. In: Jackson A, ed. *Rabies: scientific basis of the disease and its management*. 3rd ed. London: Academic Press Inc, 2013;617–670.

31. Rupprecht CE, Smith JS, Fekadu M, et al. The ascension of wildlife rabies: a cause for public health concern or intervention? *Emerg Infect Dis* 1995;1:107–114.

32. Slate D, Chipman RB, Rupprecht CE, et al. Oral rabies vaccination: a national perspective on program development and implementation, in *Proceedings*. 20th Proc Vertebrate Pest Conf 2002;232–240.

33. Rosatte R, Donovan D, Allan M, et al. Emergency response to raccoon rabies introduction into Ontario. *J Wildl Dis* 2001;37:265–279.

34. Sterner RT, Meltzer MI, Shwiff SA, et al. Tactics and economics of wildlife oral rabies vaccination, Canada and the United States. *Emerg Infect Dis* 2009;15:1176–1184.

35. Krebs JW, Long-Marin SC, Childs JE. Causes, costs, and estimates of rabies postexposure prophylaxis treatments in the United States. *J Public Health Manag Pract* 1998;4:56–62.

36. CDC. Cost of rabies prevention. Available at: www.cdc.gov/rabies/location/usa/cost.html. Accessed Jan 7, 2013.