Public Veterinary Medicine: Public Health

Cost of distributing oral raccoon-variant rabies vaccine in Ohio: 1997–2000

Pirouz Foroutan, MA; Martin I. Meltzer, PhD; Kathleen A. Smith, DVM, MPH

Objective—Analysis of the cost of 8 distributions of oral rabies vaccine (ORV) with strains known to infect raccoons in Ohio between 1997 and 2000.

Design—Original study.

Procedure—Fishmeal bait containing ORV was distributed on foot, by vehicle, and by helicopter and fixed-wing aircraft. The cost of personnel, vehicles, and helicopter and aircraft use and other associated expenses were obtained from field records and interviews with personnel and agencies involved in the ORV program.

Results—Each bait distribution lasted approximately 1 week. Areas baited ranged from 1,701 km^2 to 6,497 km^2. Density varied for each distribution, with means of 79 baits/km^2 for ground baiting and 93 baits/km^2 for aerial baiting. Typically, 72 people participated in the ground portion of each distribution and 32 in the aerial portion. The cost of ground baiting (mean ± SD, \$19.24/km^2 ± \$6.35/km^2) was consistently less than that for air baiting (mean ± SD, \$24.71/km^2 ± \$4.65/km^2) for each distribution. The total cost of distribution varied from \$30,568 to \$145,842 (mean, \$96,791), and bait cost varied from \$150,714 to \$1,029,423 (mean, \$543,839). The total cost of ORV distributions ranged from \$102/km^2 to \$261/km^2 (mean, \$153/km^2).

Conclusions—In the United States, rabies strains that infect raccoons have been responsible for the largest increase in rabies in animals in the past 3 decades. Use of ORV is a promising new tool that can be used to control rabies in raccoons. Documenting the estimated cost of implementing an ORV program may lead to more efficient use of resources to control and limit the spread of rabies. In addition, accurately measured distribution costs can be used to perform an economic cost-benefit analysis for an ORV program. (*J Am Vet Med Assoc* 2002; 220:27–32)

In the past 3 decades, rabies in raccoons has spread north from states where it has been enzootic (eg, Florida, Georgia) to Virginia and Maine in the eastern portion of the United States and recently westward into the northeastern portion of Ohio.[1-8] The western boundary of the current rabies epidemic in raccoons includes the northeastern portion of Ohio, western Pennsylvania, and northwestern West Virginia along the Ohio River (**Fig 1**).[9] One result of such enzootics of rabies in wildlife can be economic losses.[1,2,10,11] Aubert[10] estimated that the economic costs of a rabies epidemic in red foxes for a 12-month period in France were in excess of \$25,000,000. Using this cost estimate as a base, Aubert predicted the cost of rabies in red foxes in France to have been over \$400,000,000 in a 15-year period.[10] Uhaa et al[1] estimated that money used to prevent rabies in humans and domestic animals for 2 counties in New Jersey (area, 2,137 km^2) increased from \$768,500 in 1988 (preepizootic year) to \$1,952,000 in 1990 (an epizootic year).

One method used to control and limit the spread of rabies is to vaccinate wildlife hosts with **oral rabies vaccine (ORV)**.[4,12] An ORV program consists of seasonal distribution of vaccine placed inside baits. The bait for raccoons is made of fishmeal, with a hollow core in which a small plastic bag containing liquid vaccine is placed.[a] Baits are distributed over the designated area so that the healthy susceptible portion of the population that serve as hosts will consume the bait and vaccine and become protected against lethal infection. By vaccinating a critical proportion of the raccoon population, the disease is controlled or eliminated.[6,13] Torrence et al[6] defined this critical proportion of immunized animals needed to stop the spread of the disease as either the threshold (or minimum) ratio of vaccinated to susceptible animals or the minimum density of vaccinated animals per unit area. As an example of the critical portion, empirical observations indicate that a minimum of 1 fox/km^2 must be vaccinated to prevent the spread of rabies in red foxes in Europe.[13] Oral rabies vaccine programs have substantially reduced the prevalence of rabies in foxes in western Europe, rabies in raccoons in Cape Cod, Massachusetts, and Ohio, and rabies in coyotes in south Texas.[3,8,10,14,15]

From the Department of Agricultural, Environmental, and Development Economics, College of Food, Agricultural, and Environmental Sciences, The Ohio State University, Columbus, OH 43210 (Foroutan); the Office of Surveillance, Office of the Director, National Center for Infectious Diseases, Centers for Disease Control and Prevention, 1600 Clifton Rd NE, Atlanta, GA 30333 (Meltzer); and the Bureau of Infectious Disease Control, Zoonotic Disease–Rabies Program, Ohio Department of Health, 246 N High St, PO Box 118, Columbus, OH 43266 (Smith).

A portion of the data was presented at the 10th Annual Rabies in the Americas conference in San Diego, Calif, November 1999.

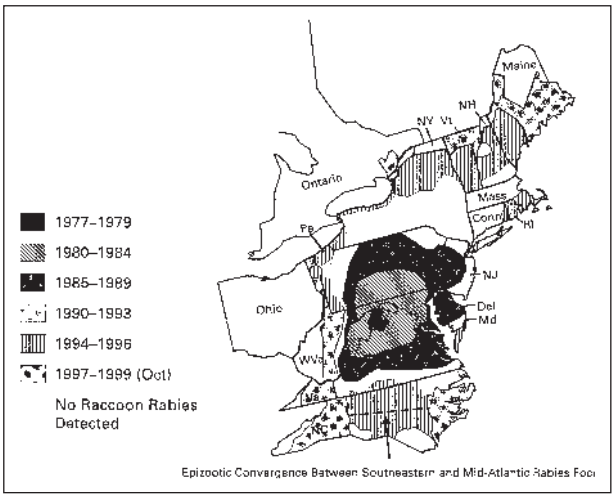

Figure 1—Detection of rabies in raccoons (by year) in the United States and Canada.[9]

Despite these apparent successes, few studies have thoroughly examined the economics of using ORV.[16] One problem preventing such studies is lack of suitable economic data.[16] In the study reported here, we analyzed the costs of distributing ORV baits to prevent rabies carried by raccoons from spreading westward into Ohio.

Materials and Methods

Program description—The Ohio ORV program was implemented by the **Ohio Department of Health (ODH)** in May 1997, 2 months after a raccoon-variant rabies epizootic was confirmed in Mahoning County in northeastern Ohio. Since its inception, seasonal baitings (ORV distributions) have been performed in the spring and fall of each year in an effort to create a barrier of immune raccoons. To date (spring 2000), 6 seasonal baitings have been performed. In addition, 2 smaller emergency baitings were carried out in May 1997 (the initial distribution effort) and in June 1999 (in response to a breach of the immune barrier; **Appendix**).

In the first 2 baitings, ground vehicles and a helicopter were used. In subsequent bait operations, fixed-wing aircraft were also used. The ground delivery method, used in urban and other residential areas, typically includes teams of 2 people distributing baits from an automobile; however, in many areas, baits are distributed on foot. Bait delivery by helicopter requires 2 people: the pilot and a crew member to throw baits from the craft. The crew of each fixed-wing aircraft typically includes the pilot, a navigator, and 3 crew members to operate the automatic bait-dispensing machine. Two crews per airplane alternate their flight duties. Typically, each airplane can carry out 4 flights/d, with each flight lasting 2 to 3 hours. Each seasonal bait distribution lasted approximately 1 week, whereas each emergency baiting lasted approximately 3 days. The target bait density for all methods of distribution was set at 75 baits/km^2, with the exception of the April 1999 baiting, when a bait density study was performed (Appendix).

Cost data—Distribution cost data from each of the 8 baitings carried out from May 1997 to April 2000 were obtained (and, in some instances, estimated) by interviews, field observations, and data provided by agencies involved in bait distribution efforts. Costs were categorized by method of distribution (ground or air) and calculated in dollars per km^2 covered. In some instances, the areas baited with the use of fixed-wing aircraft and helicopter overlapped; hence, the aerial distribution cost could not be divided between these 2 delivery methods.

Ground distribution costs included automobile cost, valued at $0.31/mile, and the cost of personnel who participated in the ground baiting. The personnel cost was calculated by using the total amount of time each person spent on baiting and other ORV-related tasks (eg, driving to and from baiting areas, doing agency paperwork, etc) multiplied by his or her hourly wages, plus benefits. The amount of time that each person spent during the ORV effort and his or her hourly wage rate were obtained from interviews.

The air distribution costs included helicopter cost, cost of fixed-wing aircraft (collected in dollars per hour of flight time, including maintenance and insurance), cost of flight crews, fuel cost, cost of administrative and support personnel, and miscellaneous costs. Helicopter services, including the aircraft and its pilot and fuel, were contracted from the Ohio Department of Transportation at a lump-sum rate. The cost of administrative and support personnel supplied by ODH and other state and local agencies was recorded separately.

The **USDA-Wildlife Services (USDA-WS)** procured fixed-wing aircraft services from the **Ontario Ministry of Natural Resources (OMNR)** at a fixed contract price. The contract included the use of twin-engine fixed-wing[b] aircraft, each fitted with an ORV bait-delivery mechanism. Contract price for each fixed-wing aircraft included the salaries of 2 pilots, 1 engineer, and 2 bait specialists. However, after discussion with the USDA-WS personnel who arranged the contract, we decided that the negotiated contract price may include an indirect subsidy, in that the USDA-WS may not be charged the full cost of the services provided. To capture the true economic cost, or opportunity cost, of fixed-wing aircraft services, we estimated it by obtaining hourly rental rates of aircraft similar to those used in the bait distribution. The hourly rate charged to rent an aircraft, including operation and maintenance costs, was quoted at $1,000 (Canadian)/h (an average of $0.684 US/$1 Canadian was used for calculation) by a private contractor.[c] Personnel cost was calculated by multiplying the total time each person spent on the ORV project or was compensated for (ie, overtime, time off) by his or her hourly wage. The wages of the flight crew and other payments to them such as car rentals, hotel costs, per diem, and compensation time were estimated or obtained by interviews and field observation.

The ODH paid for the fuel used in the aircraft and also provided personnel for administration of and participation in the ORV program. Wages, travel costs (mileage, hotel, and per diem), and compensation time for ODH personnel and other local, state, and federal agency employees who participated in the aerial distribution effort were included in the aerial distribution costs. Data for such costs were collected by interviewing each person involved and by field observation. Miscellaneous costs were also collected, using the same methods, and included equipment rental, purchases, and incidental costs for each of the baiting events.

The cost of the ORV, delivered to the ODH in bait form, was not included in the estimates of distribution costs, because it represented a fixed cost for the program, but it was included in the calculations for the total cost. The cost of ORV was obtained from the ODH, and the vaccine was purchased directly from the producer.[a] The overall bait density was targeted at no less than 75 baits/km^2, although local area modifications were made by field staff because of variations in raccoon habitats. During the April 1999 baiting, a 1-time study was performed to determine the efficacy of different bait densities, with some areas having a density as high as 300 baits/km^2. Such densities would not be considered typical, and we reasoned that the costs of bait distribution associated with the experiment would be considerably higher than nonexperimental distributions. We therefore considered

the data collected during the April 1999 distribution as having the potential to distort the statistical analysis of the cost data (ie, the April 1999 data are potential outliers). This conclusion led us to add an additional set of calculations to the data analysis.

Data analyses—For each of the 8 bait operations and for each type of distribution (ground or air), cost and input data were distributed into categories representing the most important cost components (ie, wages, automobile mileage, helicopter fees). Costs were then added and divided by the total area covered to provide a mean cost per km^2 for each bait operation. Means and SD were then calculated for the 8 bait operations. Furthermore, because the first seasonal operation (September 1997) and the April 1999 operation may both be described as atypical, the means and SD were recalculated, excluding the data from those operations (Appendix). All data are reported as mean ± SD.

Results

Ground distribution costs—For ground distribution, 72 (± 22) people were used, representing 744 (± 290) total personnel hours (**Table 1**). The September 1997 distribution had the highest mean costs, because that operation used the most personnel hours for ground distribution. Personnel costs for the September 1997 distribution accounted for approximately 30% of all ground distribution costs ($19.24/$km^2$ ± $6.35/$km^2$). When the September 1997 and April 1999 data were removed (because they were atypical), the cost for ground distribution was $16.34/$km^2$ (± $0.82/$km^2$).

Air distribution costs—Air distribution required 32 (± 14) people, representing a mean of 1,310 hours (± 476; **Table 2**). The data analyzed included the personnel flying and staffing the helicopter and fixed-wing aircraft, who were paid under contracts. The largest single cost was for the fixed-wing aircraft, at $40,248 (± $17,560)/baiting, which accounted for approximately 37% of the total costs, or $24.71/$km^2$ (± $4.65/$km^2$). When the September 1997 and April 1999 data were removed (atypical), the cost for air distribution was $22.47/$km^2$ (± $2.93/$km^2$).

Total distribution costs—The total distribution costs ranged from $17.17/$km^2$ (May 1997) to a maximum of $32.11/$km^2$ (September 1997), with a mean of

Table 1—Ground distribution costs of the Ohio oral rabies vaccine (ORV) program

Cost	May 1997	Sep 1997	Apr 1998	Oct 1998	Apr 1999	Jun 1999	Sep 1999	Apr 2000	Mean (SD)
Wages	20,152	37,321	11,010	10,066	13,019	1,446	10,807	12,830	14,581.06 (9,833.38)
Automobile mileage	1,524	1,821	904	858	1,324	174	1,406	1,468	1,184.81 (484.34)
Ground distribution costs	21,675	39,142	11,914	10,923	14,343	1,619	12,213	14,297	15,765.87 (10,226.05)
No. of people	NA	73	92	73	85	20	75	87	72.14 (22.39)
No. of personnel hours	NA	1,057	738	689	872	93	818	945	744.46 (289.83)
Ground distribution costs/km^2	15.32	35.58	17.26	16.14	20.33	16.82	15.29	17.23	19.24 (6.35)

All costs are in US dollars. May 1997 data estimates were obtained from an external source. May 1997 and June 1999 baiting events took place as a result of the initial outbreak and breach of immune barrier (emergency baiting events). April 1999 baiting included a special bait density study.
NA = Data not available.

Table 2—Air distribution costs of the Ohio ORV program

Cost	May 1997	Sep 1997	Apr 1998	Oct 1998	Apr 1999	Jun 1999	Sep 1999	Apr 2000	Mean (SD)
Helicopter (eg, fuel, pilot)	6,392	60,606	8,495	2,385	5,744	3,277	2,500	13,265	12,833.06 (18,371.95)
Administrative and support crew	2,500	21,472	31,487	32,338	28,423	5,019	28,250	34,682	23,021.29 (11,718.30)
Aircraft personnel (OMNR) cost	N/A	N/A	9,685	10,394	16,134	3,454	11,880	16,308	11,309.29 (4,354.68)
Aircraft running cost	N/A	N/A	27,648	29,660	59,983	13,404	53,152	57,641	40,247.99 (17,559.10)
Aircraft fuel cost	N/A	N/A	5,445	7,574	9,641	3,149	8,890	9,292	7,331.99 (2,335.16)
Other costs	N/A	3,104	0	1,265	699	912	1,695	357	1,147.41 (951.79)
Total air distribution costs	**8,892**	**85,182**	**82,761**	**83,617**	**120,624**	**29,215**	**106,366**	**131,545**	**81,025.28 (39,807.30)**
No. of people	NA	10	25	41	41	14	48	45	32.00 (14.36)
No. of personnel hours	NA	908	1357	1,416	1,852	364	1,557	1,714	1,309.66 (476.21)
Air distribution costs/km^2	**24.36**	**30.73**	**25.10**	**25.26**	**32.11**	**18.21**	**18.67**	**23.21**	**24.71 (4.65)**

OMNR = Ontario Ministry of Natural Resources. N/A = Not applicable.
See Table 1 for key.

$23.23/km^2 (± $5.20/km^2; **Table 3**). When the September 1997 and April 1999 data were removed (atypical), the cost for total distribution was $20.58/km^2 (± $2.78/km^2). Most of the costs were for aerial distribution (mean, $81,025; Table 2), which were 5.1 times greater than ground distribution costs (mean, $15,766; Table 1).

Number of baits distributed ranged from 99,154 in May 1997 to a maximum of 751,404 in April 1999 (Table 3). When the cost of these baits was added to distribution costs, the total cost for a single bait operation was $153.20/km^2 (± $44.16/km^2). The cost of the bait accounted for a mean of 85% of the total financial cost per km^2 baited.

Area baited and bait densities—The area designated for seasonal ORV baiting had increased from 3,872 km^2 in September 1997 (1,100 km^2 by ground; 2,772 km^2 by air) to 6,497 km^2 in April 2000 (830 km^2 by ground; 5,667 km^2 by air; **Fig 2**). The expansion in area covered was achieved with a major change in the way bait was distributed. In May 1997, 79% of the area covered was done by the hand baiting method, but in April 2000, 87% of the area baited was done from the air. It was not possible to subdivide the area baited from the air into areas baited exclusively by helicopter and those baited exclusively by fixed-wing aircraft, because in some areas, to ensure a higher density of baits, helicopters covered the same ground (ie, increased the bait density) covered by fixed-wing aircraft.

A bait density of 91.00/km^2 (± 32.10/km^2) was achieved, with higher bait densities by aerial distribution (Fig 2). When the April 1999 data were removed (atypical), the bait density was 79.94/km^2 (± 14.11/km^2)

Discussion

The ORV program for wildlife is the first immunologic tool to fight rabies in animal hosts since vaccination of dogs became widely available in the 1940s. Although successful application of ORV for rabies in foxes in Europe is well recognized, its use for rabies in raccoons in the United States is still emerging.[1,3,4,10,14] The lack of data regarding the long-term effectiveness of the ORV used in situations such as those described here prevents us from comparing the cost of various distribution methods to the reduction of rabies (ie, performing a cost-effectiveness analysis of the various distribution methods).

These distribution costs can be used to perform an economic cost-benefit analysis of an ORV program.[1,2,16,17] In addition, the distribution costs can help us determine the most efficient means of distributing ORV in the future.

Uhaa et al[1] provided an estimate of $100/km^2/y for the "distribution systems costs," which they assumed include baiting by helicopter, fixed-wing aircraft, and ground (similar to our study). They did not, however, describe how they arrived at such a figure. Moreover, in their sensitivity analyses, they did not alter this cost estimate even though they varied bait density. This implies that they assumed that the distribution cost is fixed. We found the mean cost of distribution in the Ohio ORV program to be $23.23/km^2 (± SD, $5.20/km^2/distribution), well below the assumed value

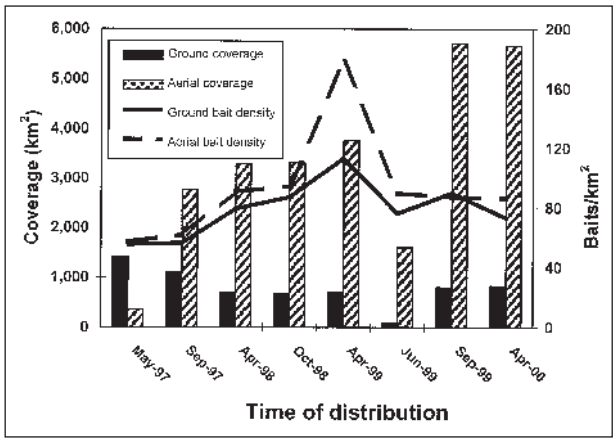

Figure 2—Area covered and density of oral rabies vaccine distributed in Ohio, May 1997 through April 2000.

Table 3—Distribution and cost of the Ohio ORV program

Cost	May 1997	Sep 1997	Apr 1998	Oct 1998	Apr 1999	Jun 1999	Sep 1999	Apr 2000	Mean (SD)
Unit cost of bait	1.52	1.52	1.52	1.40	1.37	1.47	1.37	1.37	1.44 (0.07)
No. of baits	99,154	233,577	354,222	371,581	751,404	151,653	569,998	549,691	385,160.00 (210,895.15)
Aerial bait cost	31,733	260,741	455,211	437,535	919,866	212,142	682,452	669,709	458,673.59 (271,570.36)
Ground bait cost	118,981	94,296	83,206	82,678	109,558	10,788	98,445	83,367	85,165.07 (30,707.11)
Total bait cost	150,714	355,037	538,417	520,213	1,029,423	222,930	780,897	753,077	543,838.66 (280,520.25)
Total distribution cost	30,568	124,324	94,674	94,541	134,967	30,834	118,579	145,842	96,791.15 (41,595.66)
Distribution cost/km^2	17.17	32.11	23.75	23.71	30.25	18.13	18.25	22.45	23.23 (5.20)
Total cost*	181,282	479,361	633,092	614,754	1,164,390	253,764	899,476	898,919	640,629.81 (315,325.18)
Total cost/km^2	**101.84**	**123.80**	**158.79**	**154.19**	**260.96**	**149.19**	**138.44**	**138.36**	**153.20 (44.16)***

*Total cost = Total bait cost + total distribution cost.
See Table 1 for key.

in the aforementioned study.[1] Results of our study also revealed that a number of factors, including differing bait densities, may cause the cost of distribution to change notably (Tables 1–3). Aubert[10] provided the only other specific estimate for the cost of distribution: $9/km^2 (bait delivery by helicopter of $7/km^2; surveillance systems cost of $2/km^2) for distributing ORV to control rabies in red foxes in Europe. Unfortunately, that report did not contain an explanation of how the estimate was obtained. Furthermore, because the density of red foxes appears to be much lower than raccoons, the density of ORV needed to control rabies in red foxes is probably much lower than that needed to control rabies in raccoons.[1,10,13,14] And because our results demonstrated that differences in densities of ORV impact costs of distribution, our data cannot be directly compared with Aubert's estimate. We, therefore, consider our results to be the first explicit attempt to document the actual costs of distributing ORV to control rabies in raccoons.

The data collected from 8 baiting operations revealed that although the costs of distribution approximated only 15% of the total costs, they may vary considerably (Table 3). For example, the September 1997 baiting had the highest distribution cost of $32.11/km^2, whereas distribution costs in May 1997, June 1999, and September 1999 were less than $20/km^2. The high cost in September 1997 may be attributed to the fact that it was the first large-scale ORV operation undertaken (double the area covered in May 1997; Fig 2) by the agencies involved, and certain inefficiencies in a start-up operation are expected. In addition, the entire air operation (2,772 km^2) was performed by helicopter and proved to be costly at $30.73/km^2 (Table 2).

Even the ground baiting in the September 1997 operation, although it covered a smaller area than the May 1997 ground baiting, was much more costly per km^2 ($35.58/km^2) than the May 1997 baiting ($15.32/km^2; Fig 2). This finding may be attributable to the fact that the September 1997 baiting was more labor-intensive. A more highly populated area (Youngstown, Ohio, and suburbs) was baited in September 1997, compared with the area baited in May 1997, which focused on the main roads outside of Youngstown. Another potentially atypical baiting operation was performed in April 1999, when several variations in strategies were tested, then adopted or abandoned. Consequently, the April 1999 mean aerial baiting density (179 baits/km^2) and ground baiting density (113 baits/km^2) were much higher than the remaining baiting events (means: 81 baits/km^2 for air, 74 baits/km^2 for ground). This increased the total cost per km^2 by more than $100/km^2 to $261/km^2 (Table 3).

The increase in area baited increased total costs and was attributable to cases of rabid raccoons within the immune barrier and breach of the immune barrier in June 1999. Despite the higher distribution cost of aerial bait delivery, this method is indispensable in areas with large tracts of farmland and forests where ground support is limited or potential raccoon habitats are not easily accessible. In addition, to be fully effective, baits must be distributed in a timely manner at critical periods of the year to accommodate behavior of the raccoon population (ie, mating, foraging). Thus, despite the expense, bait distribution by use of fixed-wing aircraft will continue to be the most commonly used method of ORV distribution in Ohio.

Some economy of scale can be achieved by buying large quantities of baits. For example, the reduction of bait cost by $0.15/unit ($1.52 in May 1997 to $1.37 in April 1999) resulted in savings of $112,710 for the 751,404 baits purchased in April 1999. The net result is that the total cost of the Ohio ORV project appears to have stabilized at approximately $140/km^2 (September 1999, April 2000; Table 3).

Distribution costs may be further decreased as an optimal bait density strategy is achieved. However, reduction in the amount of baits used per unit area will not affect distribution costs with the same magnitude as it affects the total costs. For example, increasing or decreasing aerial bait density will not substantially increase or decrease the amount of personnel, personnel hours, equipment, or material required to distribute bait.

Although changes in bait density may not have notably impacted distribution costs, it appeared that as the strategy matured, more consistent distribution costs were evident, in the range of $18 to $22/km^2. Changes in distribution costs over time indicated that there was a "learning curve" for establishment of an ORV program, and many local, state, and federal agencies and organizations need to collaborate. Cost estimates for the last 2 baitings (September 1999 and April 2000) are perhaps more representative of an established ORV program than earlier operations. The costs incurred in earlier operations, however, serve as a reminder to other agencies in other locales contemplating similar programs of the need to learn and improve upon delivery systems as a program progresses through time.

Rabies in wildlife is typically a regional and persistent health problem; therefore, the economic costs and benefits of an ORV program should be considered over a broad region and over a long period. Collaboration among different regions could result in several economies of scale such as reduced price of ORV from purchasing large quantities of baits. Regional cooperation could also lead to economies of scale by hiring new personnel and purchasing new equipment and material, both of which are currently being contracted out to external agencies (eg, fixed-wing aircraft, pilots, etc).

The information presented here can be combined with knowledge of raccoon ecology and epidemiologic characteristics of rabies in raccoons to predict future spread of rabies as well as the economic impact of using ORV. Several scenarios may need to be evaluated, and they will be important in determining the feasibility of regional and national efforts and in designing future interventions to control this public health problem.

[a]Raboral (Rhone Merieux), Merial Inc, Athens, Ga.
[b]Twin Otter aircraft, De Havilland Corp, Taylor, Mich.
[c]Rudy Kellar, First Air, Ottawa, ON, Canada: Personal communication, 1998.

References

1. Uhaa LJ, 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.

2. Kreindel SM, McGuill M, Meltzer M, et al. The cost of rabies postexposure prophylaxis: one state's experience. *Public Health Rep* 1998;13:247–251.

3. Robbins AH, Borden MD, Windmiller BS, et al. Prevention of the spread of rabies to wildlife by oral rabies vaccination of raccoons in Massachusetts. *J Am Vet Med Assoc* 1998;213:1407–1412.

4. Winkler WG, Jenkins SR. Raccoon rabies. In: Baer GM, ed. *The natural history of rabies*. 2nd ed. Boca Raton, Fla: CRC Press Inc, 1991;325–340.

5. Fischman HR, Grigor JK, Horman JT, et al. Epizootic of rabies in raccoons in Maryland from 1981 to 1987. *J Am Vet Med Assoc* 1992;201:1883–1886.

6. Torrence ME, Jenkins SR, Glickman LT. Epidemiology of raccoon rabies in Virginia, 1984 to 1989. *J Wildl Dis* 1992;28: 369–376.

7. Krebs JW, Rupprecht CE, Childs JE. Rabies surveillance in the United States during 1999. *J Am Vet Med Assoc* 2000;217: 1799–1811.

8. Smith KA. Update on rabies in Ohio. *Ohio Vet Med Assoc Newslett* 1998;29:5.

9. Wandeler A, Rosatte RC, Williams D, et al. Update: raccoon rabies epizootic—United States and Canada, 1999. *MMWR Morb Mortal Wkly Rep* 2000;49:31–35.

10. Aubert MFA. Costs and benefits of rabies control in wildlife in France. *Rev Sci Tech* 1999;18:533–543.

11. Nelson RS, Cooper GH, Carter ML, et al. Rabies postexposure prophylaxis—Connecticut, 1990–1994. *MMWR Morb Mortal Wkly Rep* 1996;45:232–234.

12. Rupprecht CE, Wiktor TJ, Johnston DH, et al. Oral immunization and protection of raccoons (*Procyon lotor*) with a vaccinia-rabies glycoprotein recombinant virus vaccine. *Proc Natl Acad Sci U S A* 1986;83:7947–7950.

13. Anderson RM, Jackson HC, May RM, et al. Population dynamics of fox rabies in Europe. *Nature* 1981;289:765–771.

14. Wandeler AI. Oral immunization of wildlife. In: Baer GM, ed. *The natural history of rabies*. 2nd ed. Boca Raton, Fla: CRC Press Inc, 1991;485–503.

15. Fearneyhough MG, Wilson PJ, Clark KA, et al. Results of an oral rabies vaccination program for coyotes. *J Am Vet Med Assoc* 1998;212:498–502.

16. Meltzer MI, Rupprecht CE. A review of the economics of the prevention and control of rabies. *Pharmacoeconomics* 1998; 14:365–383.

17. Meltzer MI. Assessing the costs and benefits of an oral vaccine for raccoon rabies: a possible model. *Emerg Infect Dis* 1996; 2:336–342.

Appendix

Ohio oral rabies vaccine distribution effort: 1997–2000

Baiting	Date	Type	Area baited by air (km²)	Area baited by ground (km²)	Total area (km²)	Bait delivery method
1	May 1997	Emergency	365	1,415	1,780	Helicopter, ground
2	Sep 1997	Seasonal	2,772	1,100	3,872	Helicopter, ground
3	Apr 1998	Seasonal	3,297	690	3,987	Aircraft, helicopter, ground
4	Oct 1998	Seasonal	3,310	677	3,987	Aircraft, helicopter, ground
5	Apr 1999	Seasonal	3,757	705	4,462	Aircraft, helicopter, ground
6	Jun 1999	Emergency	1,605	96	1,701	Aircraft, helicopter, ground
7	Sep 1999	Seasonal	5,698	799	6,497	Aircraft, helicopter, ground
8	Apr 1999	Seasonal	5,667	830	6,497	Aircraft, helicopter, ground