

Potential Cost Savings with Terrestrial Rabies Control

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Abstract

Background

The cost-benefit of raccoon rabies control strategies such as oral rabies vaccination (ORV) are under evaluation. As an initial quantification of the potential cost savings for a control program, the collection of selected rabies cost data was pilot tested for five counties in New York State in a three-year period.

Methods

Rabies costs reported to NYS from the study counties were computerized and linked to a human rabies exposure rabies database. Consolidated costs by county and year were averaged and compared.

Results

Reported rabies-associated costs for all rabies variants totaled \$2.1 million, for human rabies postexposure prophylaxes (PEP) (90.9%), animal specimen preparation/shipment to laboratory (4.7%), and pet vaccination clinics (4.4%). The proportion that may be attributed to raccoon rabies control was 37% (\$784,529). Average costs associated with the raccoon variant varied across counties from \$440 to \$1,123 per PEP, \$14 to \$44 per specimen, and \$0.33 to \$15 per pet vaccinated.

Conclusions

Rabies costs vary widely by county in New York State, and were associated with human population size and methods used by counties to estimate costs. Rabies cost variability must be considered in developing estimates of possible ORV-related cost savings. Costs of PEPs and specimen preparation/shipments, as well as the costs of pet vaccination provided by this study may be valuable for development of more realistic scenarios in economic modelling of ORV costs versus benefits.

Background

Rabies, caused by infection with a lyssavirus, has a worldwide distribution and has affected mankind since antiquity. Rabies is almost 100% fatal following serious neurological symptoms and great suffering [1]. Rabies has a significant impact on health system costs, both for animal rabies control and for human postexposure treatment [1]. Costs for rabies prevention have been estimated to be \$230 million to \$1 billion per year in the U.S. [2]. The recent increase in wildlife rabies, particularly in raccoons, has contributed significantly to the economic impact of rabies in the U.S., due to large increases in activities for prevention and control [3-4].

U.S. rabies variants

With the increase in the number of wildlife rabies cases in the last 20 years in the U.S., the epidemiology of rabies has changed from a predominance of rabies in domestic animals to a predominance in wild animals [4]. In the U.S., bat rabies variants are widely distributed, whereas terrestrial rabies variants are more focally distributed. Specific skunk variants are located in California, the northern Midwest, and the southern Midwest; fox variants are located in west Texas and southern Arizona; the dog/coyote variant is concentrated along the U.S./Mexico border; and the raccoon variant is located in eastern states [5]. Raccoon rabies, first identified in Florida in the 1940's, spread to the Mid-Atlantic States in the 1970's, and the northeastern U.S. in the 1990's [6-7]. In 1999, Canada reported its first epizootic of raccoon rabies [8].

In the eleven eastern states from North Carolina to New York, 82% of the counties reported the presence of rabid raccoons during 1977-1997 [9]. Analyses of

the geographic/temporal distribution of cases in those states indicate that the raccoon rabies epizootic led to a subsequent epizootic of raccoon-variant rabies in skunks. Epizootics in both species moved in a similar direction from 1990 to 2000 [10]. Another study found that raccoon rabies spreads with a velocity of approximately 46 kilometers (km) per year [11]. The spread velocity of the raccoon epizootic for New York State (NYS) was estimated at 48 km per year northward [12]. Environmental barriers such as rivers slow the transmission as much as seven-fold from township to township, but do not stop it [11-13].

Human postexposure treatment

One of the major costs associated with rabies is human postexposure prophylaxis (PEP), sometimes referred to as postexposure treatment. In the U.S., PEP consists of a series of five doses of cell culture-derived rabies vaccine plus a single dose of rabies immune globulin [14]. Rabies PEP is expensive with a cost range of \$1,038 - \$4,447 as reported in a Massachusetts study [15]. A recent New York study reported an average cost per person of \$1,136 [16]. Other studies suggest PEP is overused, thus increasing the cost of rabies prevention with unneeded treatments [17-18]. Researchers studying the use of PEP in the U.S. between 1996 and 1998 found that PEP was unnecessary, according to guidelines, for about 40% of patients receiving it, while treatment had been inappropriately withheld in 6.3% of patients with possible rabies exposures [19]. In areas currently free of raccoon rabies, overuse of PEP is already a problem, and the spread of raccoon rabies will likely further increase PEP expenses [20]. When raccoon rabies reached Hunterdon and Warren counties in New Jersey, the cost of PEP was \$1,100 per 100,000 population (pre-epizootic period cost), and by 1990 the cost increased to \$74,734 per 100,000 population (epizootic period cost) [21].

Animal vaccination

Primary prevention of rabies is based on animal vaccination [22], and many states require vaccination of pets [23]. An innovative wildlife rabies vaccination approach has used an oral rabies vaccine (ORV) both in Europe and the U.S. ORV is used in 16 European countries, Israel, and North Africa for several animal species, including dogs, foxes, raccoon dogs, badgers, martens, wolves, and jackals [24,25,26]. In the U.S., the current vaccine used for ORV is a vaccinia-rabies glycoprotein recombinant vaccine (V-RG), known as Raboral V-RGTM manufactured by Merial. The use of ORV for control of raccoon rabies is restricted to use in state or federally-approved rabies control programs and projects [22]. The use of ORV for raccoons is intended to act as a mechanism to reduce rabies-associated costs and prevent further spread of raccoon rabies to previously unaffected areas in the U.S. and Canada [23]. ORV has also been used for coyotes and foxes in Texas [24]. In Ontario, Canada the use of ORV between 1990 and 2000 reduced laboratory-confirmed animal rabies cases due to the fox variant by 90%. During the same period, a reduction of 50% in human PEPs was also documented [8].

Although the use of ORV in Canada and France has been linked with reductions in rabid animals [8, 27], the administration of ORV programs is very expensive [28]. To determine the cost/benefit ratio of ORV, additional studies are required to document the economic impacts associated with raccoon variant rabies (which can be quantified as a 'benefit' of ORV programs in terms of costs avoided), determine the optimal bait density and the optimal distribution of the ORV baits, and better define the costs involved in an ORV program [28-29]. According to a recent study, preventing the westward spread of raccoon rabies in the U.S. is economically

beneficial using ORV, even at an estimated cost between \$58 million and \$148 million for a 20-year control program [30].

Rabies epidemiology and control in New York State

New York State (NYS) is representative of many states with multiple rabies variants and a mixture of urban, suburban and rural areas with a large human population potentially at risk for exposure to rabies [16, 31]. Raccoon variant rabies was first detected in the State in 1990 [12]. Initial studies indicate that raccoon rabies has had a significant impact on the epidemiology of rabies and rabies-associated health care costs in NYS. Raccoons represented 75% of the animals confirmed rabid in NYS from 1993-1998 [16]. Even prior to licensure of Raboral V-RGTM for use in raccoons, NYS began a pilot ORV program for raccoon rabies control in 1994, under the direction of the State's Interdepartmental Rabies Committee and its ORV Task Force, made up of governmental and non-governmental organizations. Initial cost estimates for a NYS wildlife rabies control campaign including ORV were \$10.7 million per year, and \$73 million for a 10-year campaign [12]. The New York State Department of Health (NYSDOH) baited eastern Clinton and Essex Counties between the Adirondack Mountains and Lake Champlain to prevent northward raccoon rabies spread to Quebec, Canada [31]. In 1996 Cornell University, in collaboration with the NYS Department of Environmental Conservation (NYSDEC) and the Ontario Ministry of Natural Resources, Canada, started an additional project to distribute ORV baits in Niagara, Erie and St. Lawrence counties [32]. In recent years, the United States Department of Agriculture's Wildlife Services has played a major role in both the NYSDOH and Cornell control programs.

By law, New York State places responsibility for several activities related to rabies control and surveillance on local health departments (LHDs) in the 57 counties

outside New York City (NYC). With the counties, NYSDOH operates a unique rabies reimbursement and reporting system for authorized PEPs (with third party medical insurance first applied to the cost of treatment), collection, preparation and submission of animal specimens to the State's Rabies Laboratory for testing, and five no-cost rabies vaccination clinics for dogs, cats and ferrets per year for county residents (recently reduced to three per year). NYSDOH reimbursements of county expenses are limited by annual allocations and by type of expense.

LHDs are required to submit quarterly vouchers detailing the expenses for each of these general categories of rabies prevention activity. For human PEP, the vouchers detail the total cost of each treatment, the amount covered by third party insurance, and the amount requested for reimbursement. Costs for human PEP are reimbursed by the State up to a maximum of \$1,000 per patient. Expenses for PEP are reimbursed only if the case has been reported to the Rabies Surveillance System using the NYSDOH-485 reporting form, which includes the details of each rabies incident and the dates of actual treatment. The NYSDOH maintains an electronic database of all NYSDOH-485 reports. Reimbursement vouchers also contain details for every animal specimen sent for testing, including species, laboratory ID number, date of shipment, and cost of preparation and shipping. For decapitation and shipment of the heads of small animals, or shipment of whole bats, costs are reimbursed to a maximum amount of \$60 per specimen (reimbursement for bats was recently reduced to \$25 because decapitation is not required). For large animals, costs for removal of a section of brain (through the foramen magnum) and shipment are reimbursed up to \$75 per specimen. Reimbursement for costs associated with vaccination clinics includes payments to veterinarians and veterinary technicians, supplies, rabies vaccine, and advertising expenses. If additional revenue is required by the county

health departments to host the vaccination clinics, they are permitted to seek donations from pet owners, if it is clear that no payment is required. These donations are expected to cover part of the expenses of clinic operation, and the remaining costs are reimbursed by the State. The maximum reimbursement per year for clinics is \$5,000 per county [33].

Reimbursements are also potentially capped by the specific amount allocated for each county per year for such expenses. Counties may also apply for reimbursement through another general local health assistance program that reimburses 36-100% depending on their population size and other expenditures.

Study objective

Previous studies of NYS rabies PEP and rabies costs did not assess costs by rabies variant [16,17]. Those studies also did not assess variability in costs by geographic location. To address these issues, this study used detailed voucher and reimbursement data and matched the records to the rabies exposure database. Reimbursement data was summarized by fiscal year rather than date of reimbursement.

To pilot test the computerization and analysis of rabies-control costs reported to NYSDOH by LHDs, with emphasis on raccoon-variant associated costs to provide more specific cost estimates for ORV cost-benefit modeling, five NYS counties were selected to represent diverse conditions of demographics, rabies epidemiology and reporting.

Methods

Data used/Process

This study includes reimbursement data from three consecutive fiscal years (April through March): 1999-2000, 2000-2001, and 2001-2002. Five counties from New York State were selected for the analysis, to represent diverse areas of the State: the lower Hudson valley, upper Hudson valley, western NYS, central NYS, and northeastern NYS. One of the counties had an ORV program. Four counties have full service LHDs, meaning they have an environmental health program that is typically responsible for rabies exposure investigations. One county has a partial service LHD. Partial service health departments lack environmental health programs, and usually rely on public health nurses for all rabies follow-up. The counties selected represent 12.9% of the total population in NYS, and 23.5% of the population outside New York City (Census 2000 data). With only one partial service county included in the study, which also was the only county with ORV, the association of cost data with being a partial service county and being exposed to ORV was not examined in this pilot study.

The vouchers of the NYS rabies reimbursement system received from 1999 to 2003 were reviewed and computerized to identify the PEPs begun during the three fiscal years included in the study. Three computerized databases for reimbursement voucher information were created, for human PEPs, specimen preparation/shipments, and pet vaccination clinics. The human PEP reimbursement database was supplemented with data extracted from the NYSDOH-485 database regarding animal species involved in the exposure incident. To combine the exposure data from the NYSDOH-485 form with the cost data from the reimbursement vouchers, the cases were matched using identification codes and names. To protect patient confidentiality

a master list of names and identification codes of the persons receiving PEP was maintained separately. Thus the names of the persons receiving PEP are not seen in the reimbursement vouchers. The master list of names was computerized and used to link the databases. After the data matching, cleaning, and extraction process, patient names were deleted retaining the identification codes from both original data sources.

For this study, PEPs were included if the first day of treatment occurred from April 1, 1999, to March 31, 2002. Specimens were included for analysis when the date of shipment occurred during this same time period. In the same way, pet vaccination clinics held during the same time period were included. PEPs and specimens reported during the study fiscal years for time periods outside the study period were excluded. The documents used for specimen preparation/shipment cost calculations were private carrier bills (UPS/Airborne Express), veterinarian bills/vouchers and information on personnel salaries.

The variables included in the analysis were actual expenses for PEP treatments, specimen preparation and shipment, and vaccination clinics; amount paid by a third party insurer for PEPs; amount of donations collected for vaccination clinics; amount reimbursed to LHDs by the State for PEP, specimen shipment and vaccination clinics; dates of exposure incidents, specimen submission and vaccination clinics; and species involved in incidents or submitted for testing. When the amount of donations collected for vaccination clinics exceeded the cost in a vaccination clinic, the county cost was considered zero and the donation excess was not accounted in the total vaccination clinic cost.

Statistical analyses

To determine which rabies control costs might be reduced or eliminated as a result of a successful ORV program, animal species involved in human rabies

exposures were grouped into bats and non-bats (i.e., terrestrial). Most of the rodents were grouped together with the exception of squirrels and woodchucks because there were laboratory-confirmed rabies cases in these species in recent years in the U.S. [34]. All terrestrial species whose frequencies were lower than ten animals submitted during the study period were grouped as “other.” Analyses were performed either excluding or including bats. More detailed analyses were conducted for costs related to terrestrial rabies.

The NYSDOH Wadsworth Center’s Rabies Laboratory tests the variant for all rabid animals other than raccoons, and for a periodic sample of raccoons. During the previous 20 years (1978-1999), variants other than raccoon (specifically, bat variants) were identified for only 14 (0.1%) of 14,582 terrestrial animals that tested positive for rabies [35]. Thus, for the purposes of this study, all exposures involving terrestrial animals were assumed to involve raccoon variant rabies.

In addition to a calculation of overall costs, summary statistics were calculated by county and fiscal year for costs associated with rabies PEP, vaccination clinics and specimen preparation/shipment. Correlation coefficients were calculated for PEP cost and specimen preparation/shipment cost with population of the counties. A Pareto analysis and graphs were done for PEP costs and for specimen preparation/shipment costs by species. Data management and statistical analyses were conducted using MS Access, MS Excel, and SAS. For graphics S-Plus, MS Excel and MS PowerPoint were used.

Comparison of expenses for PEP

To determine whether the cost of PEP due to terrestrial rabies is the same for patients exposed in the county of treatment and for patients exposed outside the treatment county, the average cost of a human PEP treatment was calculated and

compared for the two groups. The null hypothesis was that the average cost of PEP was the same for both groups. This hypothesis was tested using Students' t-test for comparison of means. For this analysis we assume the exposures are independent events.

Interviews

The analyses performed were complemented with LHD telephone interviews to determine how the LHDs calculated the specimen shipment costs, and the information sources used for the calculations; and to understand the meaning of low values reported in the cost of PEPs and specimen shipments.

Results

Overall costs

Across the five study counties, the total cost of the three monitored rabies prevention activities for both terrestrial and bat rabies during the fiscal years 1999-2001, including PEP, specimen preparation/shipments, and pet vaccination clinics was \$2,143,905. Of this total, \$1,948,008 (90.9%) represented PEP costs, \$100,278 (4.7%) represented specimen preparation/shipment costs, and \$95,618 (4.4%) represented pet vaccination clinic costs. Table 1 presents the proportion of these expenses related to raccoon rabies variant, by individual study county and payor (State, county, third party). Because vaccination clinic costs may be incurred regardless of rabies variant, they are included in Table 1 but cannot be definitively attributed to the presence of raccoon variant rabies.

The total documented expenses that possibly may be attributed to terrestrial rabies in this study were \$784,529 (36.6%) for the three-year study period, if including all vaccination clinic costs. Without clinic costs, the total was \$688,911

(32.1%) (Table 1). By fiscal year the terrestrial rabies-associated expenses (including clinic costs) were \$247,700 in 1999-2000, \$261,805 in 2000-2001, and \$277,140 in 2001-2002 (Table 2). The NYSDOH reimbursement system provided funds to cover 52% of the total terrestrial rabies-associated costs (\$406,428), about 34% was covered by third party health insurers (for PEPs only, not specimens or vaccination clinics), about 8% was covered by donations for vaccination clinics, and about 7% was covered by the LHDs .

The average per capita cost for terrestrial rabies including PEPs, specimen preparation/shipment, and pet vaccination clinics overall (see discussion section on pet vaccination clinics) for the five counties combined during the three-year study period was \$0.32, with a range of \$0.10 to \$0.77.

Costs related to human treatments (PEPs)

PEP treatment was administered to 2,085 persons in the five counties during the 1999-2002 fiscal years. Six hundred fifty seven PEPs (32%) were due to terrestrial animal exposures. The cost of the PEPs related to terrestrial rabies was \$618,274 (32% of all PEP costs) (Table 1). The reported PEP costs differ by fiscal year (Table 2), increasing from \$190,359 in 1999-2000 to \$219,424 in 2001-2002. The State reimbursed \$307,470 (49.7%) of the PEP costs associated with terrestrial rabies exposures, \$263,240 (42.6%) was covered by third party payors, and the remaining \$47,564 (7.7%) was paid by the LHDs (Table 3). The average cost of a PEP treatment for terrestrial rabies was \$941.06. This average also varied by county (Table 3), with a range of \$440.21 to \$1,884.97.

Regarding species of exposure, cats were associated with 43% (281) of the terrestrial rabies PEPs, dogs with 27% (179), and raccoons with 16% (102) (Figure 1). Other species of exposure were reported for 14% of the PEPs; among them were

skunk, fox, woodchuck, cattle, ferret, coyote, beaver, squirrel, monkey, opossum, porcupine, rabbit, tiger, and wolf. The cost of PEPs associated with dogs and cats was \$437,225 representing 70.7% of the total PEP cost related to terrestrial rabies. The only study county with an ORV program had no PEP due to raccoon exposures. A Pareto analysis of the actual cost of PEP by species responsible for terrestrial rabies exposures indicates that about 86% of the PEP expenditures are due to incidents involving cats, dogs and raccoons, and 70% of the PEPs were due to contacts with pets. During the three-year study period, only three dogs were confirmed with rabies in NYS and none in the five study counties, compared to a total of 18 cats (all confirmed to have raccoon variant).

The average cost of PEP was significantly lower for patients exposed to terrestrial rabies outside the county where treatment was received. Forty-three (6.5%) of the patients receiving PEP due to terrestrial rabies exposures were actually exposed in a NYS county other than the one providing the treatment and twenty-nine (4.4%) were exposed outside the State or country. The average cost of PEP for patients exposed in the county providing the treatment was \$959.25, compared to an average cost for patients exposed elsewhere of \$793.19 ($t = 2.08$, $df = 655$, $p = 0.0383$). The association of this factor (treatment within or outside cost of exposure) with completion of treatment (e.g. 5 doses) was not assessed.

The average per capita cost for terrestrial rabies PEPs during the three-year study period was \$0.25, with a range of \$0.08 to \$0.34. The county human population size was highly correlated with the total number of PEPs ($r = 0.86$) and with the total PEP costs ($r = 0.75$), but not with the average cost per PEP ($r = -0.21$). Scatter plots for these associations indicate the influence of a single county with the largest population size on these high correlation coefficients (Figure 2).

One hundred thirty-two terrestrial rabies PEPs were reported to cost below \$300. This low cost was reported by the LHDs as representing patients not receiving a full five-dose vaccine series and immune globulin, PEP for lower weight children (because HRIG costs are based on body weight), or PEP completed but with incomplete submission of bills for estimating total PEP costs. The reasons provided for patients not receiving a full five-dose vaccine series and immune globulin included repeat PEPs that only require two doses of vaccine according to ACIP guidelines, stopping the PEP when the animal was found not to be rabid, and stopping the PEP after it was started by an emergency room, private doctor or health center out of county after subsequently determining it was not needed. Having the exposure and PEP in different counties was also reported as a cause for incomplete submission of bills by the patient/insurer to the LHD.

Costs related to specimen preparation/submission

Between fiscal years 1999-2000 and 2001-2002, 4,393 specimens were submitted for rabies testing from the five study counties, at a cost of \$95,618. About 46% (2,018) of the specimens were terrestrial animals, however these specimens accounted for 70% of the total specimen submission costs (\$70,637) (Table 1). The State reimbursed 91.4% (\$64,596) of the terrestrial animal specimen submission costs.

The average cost of terrestrial animal specimen preparation/shipment was \$35/specimen. The average cost varied among the counties (Table 3). With the specimen preparation/shipment costs for large animal (horse and cattle) specimens being reimbursed at a higher amount than other specimens, the average amount actually requested for reimbursement for large animal specimens was calculated. The total cost for 14 large animal specimens reported in the study period was \$278.34, at

an average cost of \$19.88/specimen. For all other specimens, the total cost was \$70,359.10, at an average cost of \$35/specimen. It is unexpected to find lower reported costs for large animal specimens. Because horses and cattle are found normally on farms, the preparation of the specimens may be assumed as part of the regular veterinary work and not reported as associated with rabies testing.

Regarding species submitted for testing, cats comprised 36% (733) of specimens; dogs comprised 19% (392); raccoons 15% (305), and skunks 11% (218) (Figure 3). Rodents, rabbits, opossum, woodchuck, fox, and deer comprised less than 4% each, with other species making up less than 3% of all shipments. A Pareto analysis of the actual cost of specimen preparation/shipment indicates that about 82% of the terrestrial specimen expenditures were for cats, raccoons, skunks, and dogs. The average per capita cost for terrestrial rabies specimen preparation/submission during the three-year study period was \$0.03 (range = \$0.0003-\$0.05). The county human population size was highly correlated with the number of specimens ($r = 0.80$), the total specimen preparation/shipment costs ($r = 0.81$), and the average cost per specimen ($r = 0.76$). A scatter plot for the association of average county specimen preparation/shipment cost for terrestrial rabies specimens with the county human population size indicates the influence of a single large population (Figure 2). LHD interviews indicated that veterinarians are contracted for preparation of the specimens in three counties. One county uses its own personnel for specimen preparation. In two counties, veterinarians are paid according to the species, whereas in a third county veterinarians are paid a \$63 fixed fee per specimen. However, the reimbursement vouchers for that county did not itemize the veterinarian fee and the vouchers varied in the costs above and below that amount.

In one county, veterinarians ship the specimens and report the cost to the local health department. For some specimens, usually bats, two counties are sometimes able to ship at no cost. Shipment costs typically depend on the weight of the shipment. Although shipment costs vary based on weight of the specimen, one county calculates a fixed-cost per specimen for reimbursement purposes. The formula is based on the average time to prepare a specimen, staff salary for that time, and average shipping costs, at a final cost of \$21.34 for any specimen.

Costs related to pet vaccination clinics

There were 26,185 animals vaccinated for rabies in county-sponsored clinics in the five counties. The total cost of rabies vaccination in clinics was \$95,618, of which \$34,362 (36%) was reimbursed by the State (Table 1). Donations from pet owners using the clinics covered \$62,758 (66%) of the cost and \$614 (1%) was covered by the county health departments. Little change was observed in the annual cost for clinics through the study period (Table 2). The total vaccination costs under this system varied by county, from \$1200 to \$44,764 (Table 2).

Information regarding species vaccinated was available for four counties. In these counties, 57% of the vaccinated animals were dogs and 43% were cats. The average cost per animal vaccinated was \$3.65. By county the average varied from \$0.33/animal to \$15.00/animal. Because vaccine alone would cost ~\$1.07 for one animal, lower values than this possibly indicate incomplete data. The average per capita cost for pet vaccination clinics was \$0.04 (range = \$0.004-\$0.53). The county human population size was not correlated with the number of animals vaccinated ($r = -0.02$), but was inversely correlated with the total cost of the pet vaccination clinics ($r = -0.57$) and partially correlated with the average cost per animal vaccinated ($r =$

0.32). Scatter plots for these associations again indicates the influence of the largest population county (Figure 2).

Discussion

The cost summary presented in this pilot study is an initial quantification of rabies reimbursement data in NYS for PEPs, specimen preparation/shipment, and pet vaccination for five counties over a three-year time period. This data may assist in determining the parameters for the potential savings to be achieved if ORV or some other prevention/control program is used to reduce or eliminate the raccoon rabies virus variant in an eastern U.S. state. This study found that terrestrial rabies accounts for more than a third (37%) of the reimbursed rabies prevention and control costs. The study found that in NYS, the State bears the largest proportion of the reported costs. About half of all expenses were covered by the State in the five counties studied. The LHDs covered 7% of the total expenses. While the amount spent by LHDs is a small proportion of the total costs of terrestrial rabies control reported in this study, for some counties this may represent an important impact to the LHD budget.

The per-capita cost of terrestrial rabies including PEP, specimen cost and pet vaccination clinics costs was estimated to be \$0.32. However, use of this average in estimates of potential savings from use of ORV may considerably over- or underestimate the potential savings as indicated by the county variation in average costs from \$0.10 per person to \$0.77 per person. Although counties with larger human population sizes had greater PEP and specimen costs, the per capita cost was highest in the smallest county, perhaps reflecting economies of scale in larger counties able to prorate their costs over a larger number of exposures. The fact that total terrestrial-variant reimbursed costs are increasing despite a relatively stable enzootic state of

rabies in NYS, and active prevention and control programs, should be considered when estimating the future savings potentially associated with use of control programs.

Human post-exposure prophylaxis (PEP)

PEP expenses account for about 90% of the overall costs reported in this study. Thus, PEP is a large component of possible cost savings to be produced by public health intervention to control raccoon rabies. If ORV is used effectively to eliminate the raccoon variant, raccoon attacks are likely to be minimized and there will be no spillover of rabies to other species from this variant, thus reducing the total number of rabid animals and human exposures. In this study about 16% of the PEPs attributed to raccoon variant rabies were related directly to raccoon incidents, and 4% were due to skunk incidents. With raccoons and skunks unlikely to attack people if not rabid, it can be assumed that raccoon rabies elimination would eliminate most of the PEPs related to these species. Exposure to these two species represented 131 incidents for the 5 counties in the 3-year study period, at an estimated PEP cost of \$125,271 representing 16% of the total terrestrial-associated costs.

Humans have more frequent contact with domesticated species than with wildlife, and bites to humans from these species frequently occur for reasons unrelated to rabies. In this study bites from dogs and cats accounted for 70% of the total terrestrial-associated PEP costs. Although elimination of the raccoon variant with ORV would reduce the number of rabid pets and other domestic animals and thus exposures to rabies, bites from pets will continue. Thus elimination of raccoon variant would result in a reduction in PEP costs associated with dog and cat incidents, but the reduction may not be substantial because most dog and cat bites are not due to the animal being rabid. PEP costs associated with pet exposures will likely not decline

significantly until there is sufficient assurance that the raccoon variant has truly been eliminated and the probability of a pet being rabid is sufficiently low that PEP is not warranted even when the pet's rabies status cannot be verified. Changes in policies about providing PEP when a pet's rabies status cannot be determined would require a sufficient period without raccoon variant and without it encroaching from neighboring areas. These changes also assume no other terrestrial variants with frequent spillover to pets. If the raccoon variant had been eliminated from these five counties during the three-year study period and there was sufficient confidence that terrestrial animal-related exposures did not require PEP consideration, the maximum potential savings would have been 657 PEPs avoided at an estimated cost savings of \$618,274.

Animal specimen preparation/shipment

As indicated above, with control of raccoon variant rabies we would expect a decreased number of rabid wild animals attacking people. Therefore, there would be fewer wildlife specimens to submit. This study found that 70% of the specimens submitted for testing were for terrestrial species, primarily dogs, cats, raccoons and skunks. If all raccoon and skunk submissions were eliminated by eliminating raccoon variant rabies, the cost savings for 1999-2000 to 2001-2002 would have been 26% of the total cost for terrestrial rabies specimen preparation/shipment, representing a savings of 523 specimens that would not have been prepared and shipped, at an estimated cost savings of \$24,228, accounting for 3% of the total terrestrial-associated costs.

Dog and cat specimens are submitted when the animal is showing signs of rabies, because neurologic animals must be euthanized and tested after a bite to a human. Even with elimination of the raccoon variant, there will be occasional bites from neurologic pets due to bat rabies or other diseases. However, specimen

shipments are likely to be considerably reduced. In NYS, avoiding 4,393 specimen shipments for all species at a cost savings of \$95,618 is an upper limit of the potential savings in five counties over a three-year period.

Costs related to pet vaccination clinics

New York State law requires rabies vaccination of pet dogs, cats and ferrets. This requirement would not be modified in a scenario where ORV controlled or eliminated raccoon rabies because other rabies variants (specifically, bats) are present in the State and surrounding areas. The possibility of translocation or reintroduction of rabies in wildlife remains, therefore pets will continue being vaccinated.

An elimination of terrestrial rabies certainly could lead to a reconsideration of the need for State resources to pay for pet vaccination clinics. Thus, the State-associated costs of \$34,362 could be considered a possible savings to be achieved with ORV. However, if pet vaccination continues as recommended by national guidelines and required by state laws, total vaccination costs may potentially increase if the costs associated with individual vaccinations at veterinarians are higher than the costs associated with mass clinics. The current study clearly indicates a wide disparity in the per-animal cost of rabies vaccination, ranging from \$0.33/animal for a large county that offers mass vaccination clinics to \$15.00/animal for a large county that reimburses a flat fee to veterinarians for vaccinating pets at their regular practice.

Conclusions

An initial pilot study of the reimbursements provided for rabies costs in five New York State counties over a three-year period indicates a wide variability in costs by county. Counties with larger human populations experienced larger PEP and specimen shipment/preparation costs. The study indicated that there are wide

variations in the ways that LHDs estimate rabies-associated costs. Such potential variation must be considered in developing estimates of possible ORV-related cost savings. Within the limitations of LHD estimations of cost data, this study offers specific cost data for two critical factors, PEPs and specimen preparation/shipments, as well as the costs of pet vaccination. Actual data such as that obtained in this pilot study are critical for basing the parameters chosen for economic modeling of potential ORV benefit on realistic scenarios.

Limitations

Some limitations apply to this pilot study. Interviews with counties provided indications that cost data is not universally complete, or accurate if estimated based on overall costs rather than reported for each PEP or specimen. There is potential for inaccuracy in specific per-year costs with lags in reporting the PEP costs while waiting for clearance of insurance paperwork. The study period was selected to include recent and reliable data while minimizing the effect of reporting lag by not including the most recently completed fiscal year due to concern about completeness of the data set.

Issues of data accuracy were illustrated by the low costs reported for some PEPs and vaccination clinics. Although PEPs for children were offered as one explanation by the LHDs, even low weight children should have costs exceeding \$300 when each of five vaccine doses approximates \$100. Overall averages for specimen preparation/shipment were artificially lowered by the inclusion of a county with the NYSDOH Rabies Laboratory which can hand deliver specimens and thus incurs almost no specimen shipment costs. The unexpected lower average cost for large size animal specimen preparation/shipment also leads to an underestimate of the average cost for all specimens preparation/shipments. Problems in completeness of the data

were also evident in the case of pet vaccination clinics, where species vaccinated was not reported for one county, and where one county's reported cost per animal vaccinated was below the actual cost of the vaccine and other supplies needed to perform the vaccinations.

With only five of 57 upstate New York counties included in the study to pilot the computerization and analysis of these data sets, the results may not be representative of other areas, although they represent almost a quarter of the State's non-New York City population. With a larger study including additional counties, factors associated with counties such as population density, health care access, capabilities of the local health departments, animal rabies incidence, and other factors influencing cost could be assessed for their impact on rabies-associated costs. The influence of ORV itself could not be estimated with only one ORV county in the study.

Assuming that these costs associated with raccoon rabies would all be saved if ORV eliminated the raccoon variant applies to areas with no other terrestrial variants. In most of the area currently impacted by raccoon rabies, there are no other terrestrial variants. With bats having an insignificant impact on rabies in most other species (except humans), eliminating the raccoon variant could indeed result in elimination of most of the costs associated with the current raccoon-variant outbreak. However, PEP costs are clearly the largest component of the costs documented in this study. Until health care and public health professionals are sufficiently confident of the low risk of rabies from terrestrial animal exposures in areas where terrestrial variants have been eliminated, PEPs will continue to occur in relation to these exposures. With the evidence of raccoon variant in skunks tracking similarly to the raccoon variant in raccoons [10], estimating that all of the costs associated with raccoon variant could be

eliminated with ORV for raccoons may also be inaccurate if skunks are now serving as an alternative reservoir for this variant. Skunks do not readily take the raccoon ORV bait nor are they as responsive to immunization with Raboral V-RGTM. The most significant limitation on potential PEP savings from terrestrial variant control is the increasing phenomenon of bat exposures accounting for most of the PEPs. In New York State only 31% of the PEPs were due to terrestrial animal exposures, representing only 29% of the total PEP costs.

The most important limitation of the study is that it could only include rabies-associated costs required for reporting in the State—PEPs, specimen preparation/shipment, and pet vaccination clinics. There are many other rabies-associated costs that require better data in order to appropriately model potential ORV-associated savings, including costs associated with animal confinements, quarantines, and euthanasias, personal costs to those receiving PEP including time lost, pain and suffering, and costs to governmental agencies for managing the rabies cases and the consequent consulting, investigation, and prevention/control measures.

Future research

The current study has demonstrated the feasibility of obtaining actual cost data for several important rabies-associated cost variables, and the variability in such costs across time and geographic area. Additional studies are required to address the limitations of the current pilot study, to include a larger number of counties and additional important cost variables. In the interim, the data from this pilot study may be helpful in refining the parameters used in any additional ORV cost-benefit analyses for the elimination or reduction of raccoon-variant rabies. In addition to including data from a larger sample of counties, future studies that assess the geospatial variability of raccoon rabies in a diverse state like New York would be valuable.

Patterns of rabies cases associated with geographical features would help to identify areas where ORV needs to be focused and areas where ORV is not required.

Distribution of ORV baits using such data could result in a considerable cost savings compared to a uniform ORV bait distribution, as long as the costs required for contingency responses are factored in for any disease breaks.

Competing interests

The authors declare that they have no competing interests.

Authors' contributions

SR carried out the computerization of the cost data, performed statistical analysis and drafted the manuscript. BC participated in the analysis design and result interpretation. ME conceived of the study, and participated in its design and coordination and helped to draft the manuscript. All authors read and approved the final manuscript.

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Figures

Figure 1 - Terrestrial species associated with PEPs, five counties of NYS, Fiscal Years 1999-2000 to 2001-2002

Figure 2 - Correlations of PEP, specimen preparation/shipment, and vaccination clinics with county human population size in five counties of NYS, fiscal years 1999-2000 to 2001-

Figure 3 - Species submitted for laboratory testing associated with terrestrial rabies incidents, five counties of NYS, 1999-2000 to 2001-20022

Tables

Table 1 - Raccoon-variant rabies costs, fiscal years 1999-2000 to 2001-2002, in five selected counties of NYS (with percentage total cost across all variants attributable to raccoon rabies)

Table 2 - Terrestrial rabies costs by fiscal year and county

Table 3 - Terrestrial rabies costs by payor and county, NYS Fiscal years 1999-2000 to 2001-2002

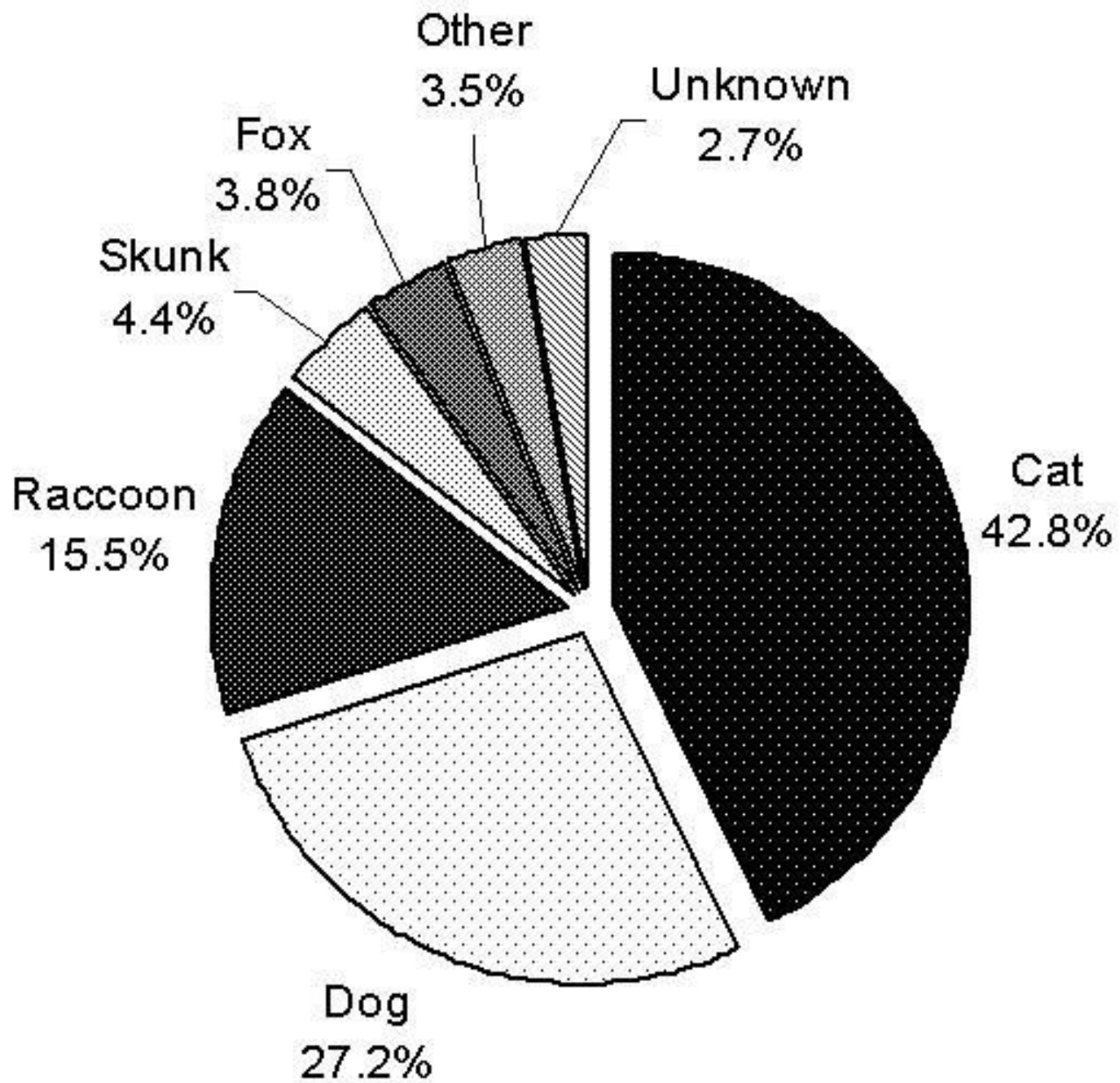
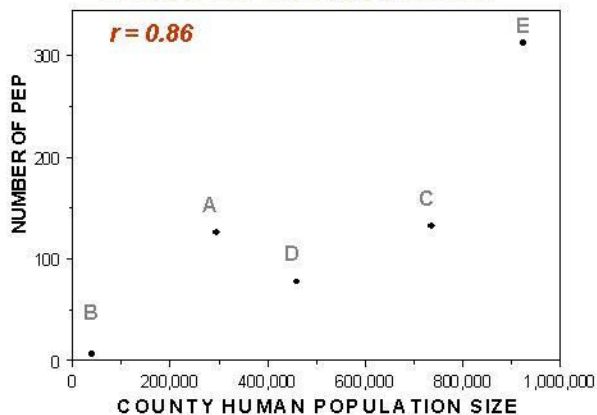
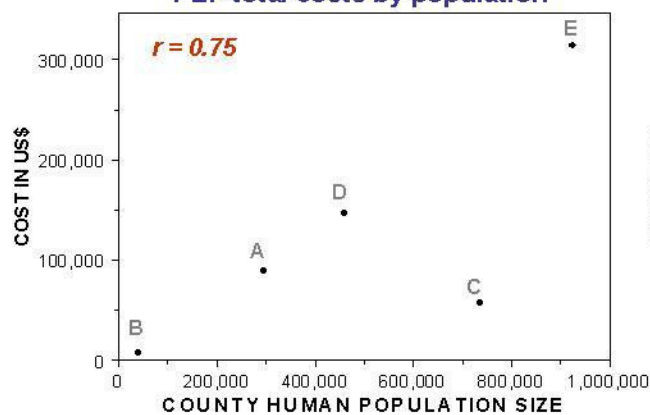


Figure 1

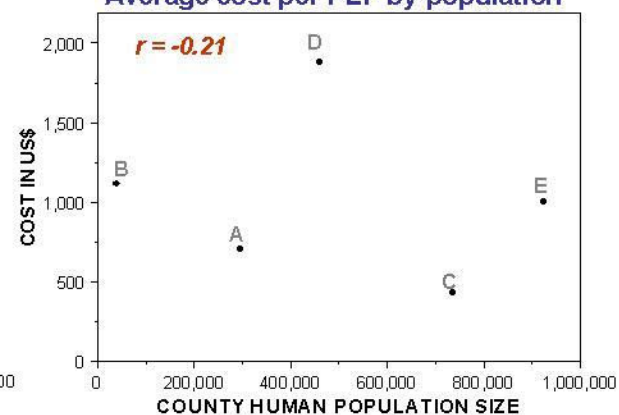
Number of PEPs by population



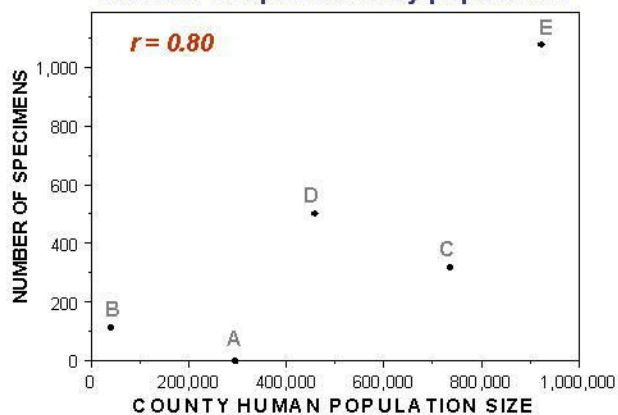
PEP total costs by population



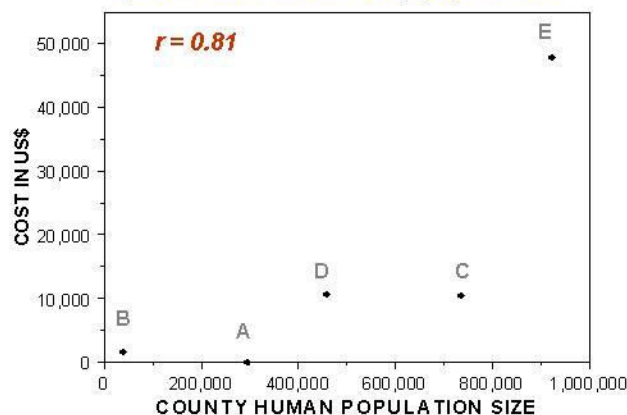
Average cost per PEP by population



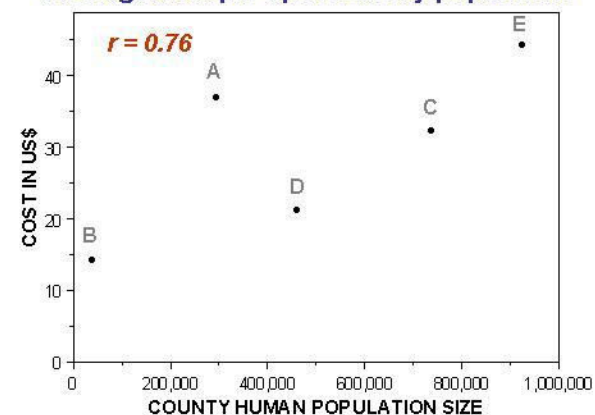
Number of specimens by population



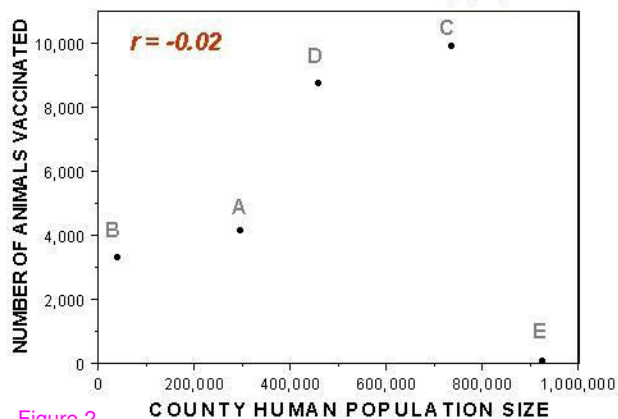
Specimen total costs by population



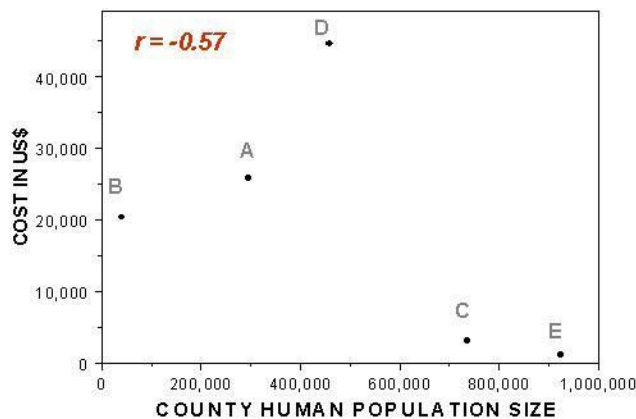
Average cost per specimen by population



Number of animals vaccinated by population



Vaccination clinic total costs by population



Average cost per animal vaccinated by population

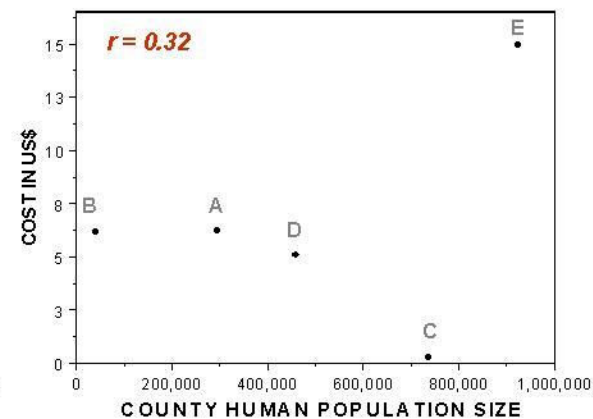


Figure 2

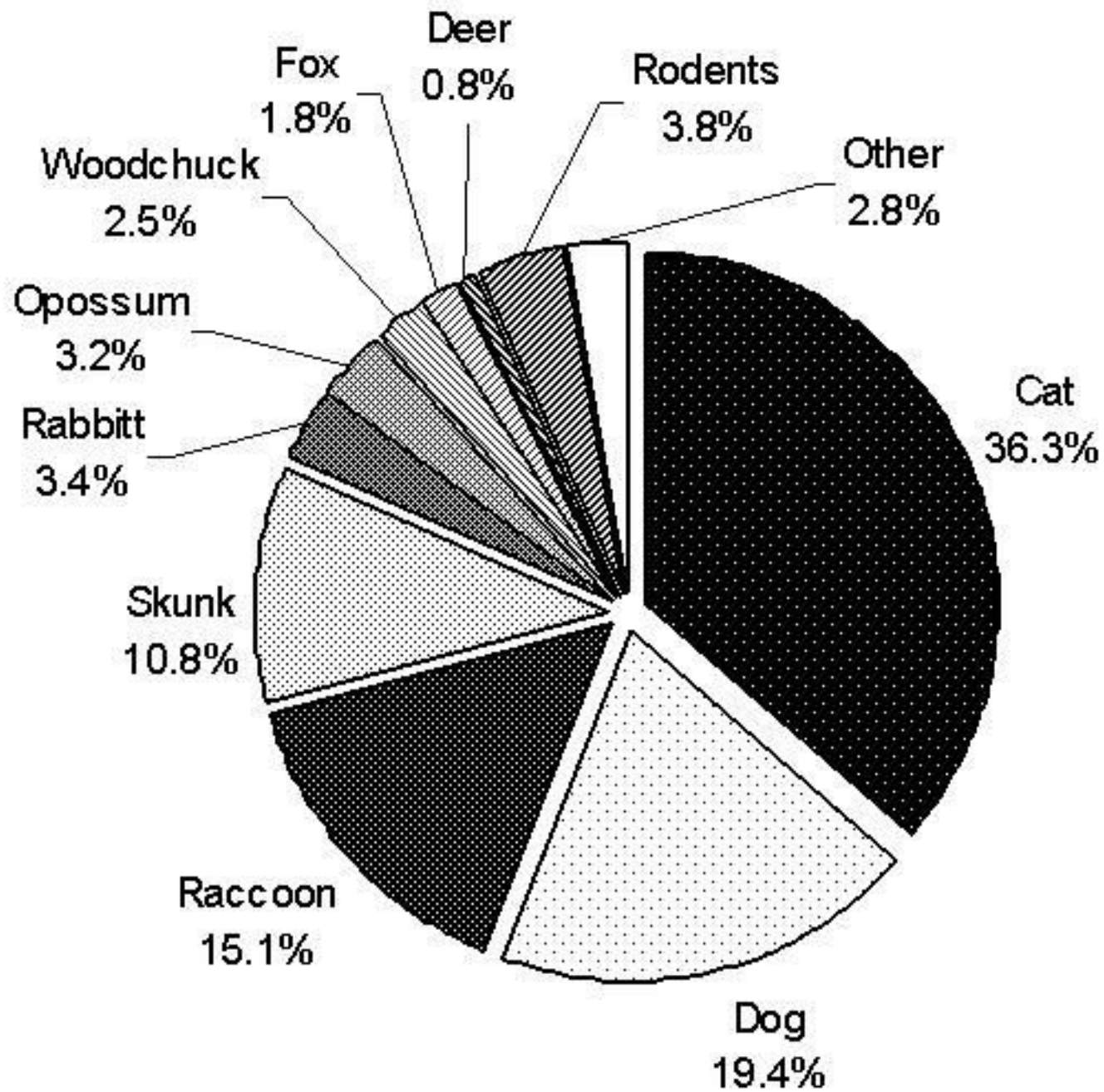


Figure 3

		County A		County B		County C		County D		County E		Total	
		\$	%	\$	%	\$	%	\$	%	\$	%	\$	%
PEPs	Total	\$89,801.05	39.99%	\$7,861.71	12.15%	\$58,547.63	48.39%	\$147,027.28	54.57%	\$315,036.04	24.84%	\$618,273.71	31.74%
	State	\$53,303.38	41.65%	\$723.21	6.07%	\$23,723.80	47.12%	\$36,590.63	69.35%	\$193,128.73	27.84%	\$307,469.75	32.83%
	County	\$5,735.18	32.99%	\$0.00	0.00%	\$7,327.49	59.32%	\$12,692.44	73.54%	\$21,808.87	32.83%	\$47,563.98	40.93%
	Third party	\$30,762.49	38.85%	\$7,138.50	14.28%	\$27,496.34	47.16%	\$97,744.21	49.01%	\$100,098.44	19.70%	\$263,239.98	29.41%
Specimens	Total	\$74.00	100.00%	\$1,631.95	75.94%	\$10,401.16	60.40%	\$10,734.02	62.80%	\$47,796.31	74.98%	\$70,637.44	70.44%
	State	\$74.00	100.00%	\$1,579.25	75.61%	\$9,569.26	58.48%	\$10,734.02	62.80%	\$42,639.89	74.00%	\$64,596.42	69.28%
	County	\$0.00	0.00%	\$52.70	87.22%	\$831.90	97.05%	\$0.00	0.00%	\$5,156.42	84.20%	\$6,041.02	85.79%
Vaccination Clinics	Total	\$25,946.24	(N.A.)	\$20,470.83	(N.A.)	\$3,237.50	(N.A.)	\$44,763.60	(N.A.)	\$1,200.00	(N.A.)	\$95,618.17	(N.A.)
	State	\$6,501.74	(N.A.)	\$9,832.54	(N.A.)	\$3,213.75	(N.A.)	\$13,614.08	(N.A.)	\$1,200.00	(N.A.)	\$34,362.11	(N.A.)
	County	\$0.00	(N.A.)	\$0.00	(N.A.)	\$23.75	(N.A.)	\$589.78	(N.A.)	\$0.00	(N.A.)	\$613.53	(N.A.)
	Donations*	\$19,685.00	(N.A.)	\$10,638.29	(N.A.)	\$0.00	(N.A.)	\$32,435.29	(N.A.)	\$0.00	(N.A.)	\$62,758.58	(N.A.)

*Donations for vaccination clinics. The excess in donations reported in counties A and D were not accounted for in the vaccination total cost.

NA: Proportion attributable to raccoon variant is not applicable to vaccination clinic costs.

County	1999-2000	2000-2001	2001-2002	Total
<i>Postexposure Prophylaxis</i>				
A	\$25,782.27	\$48,655.38	\$15,363.40	\$89,801.05
B	\$2,122.21	\$2,103.25	\$3,636.25	\$7,861.71
C	\$20,828.65	\$13,441.87	\$24,277.11	\$58,547.63
D	\$59,738.40	\$62,359.17	\$24,929.71	\$147,027.28
E	\$81,887.23	\$81,931.73	\$151,217.08	\$315,036.04
All counties	\$190,358.76	\$208,491.40	\$219,423.55	\$618,273.71
<i>Specimen Submission</i>				
A	\$0.00	\$74.00	\$0.00	\$74.00
B	\$411.00	\$666.50	\$554.45	\$1,631.95
C	\$6,250.16	\$1,516.96	\$2,634.04	\$10,401.16
D	\$4,310.68	\$3,307.70	\$3,115.64	\$10,734.02
E	\$13,592.06	\$15,450.43	\$18,753.82	\$47,796.31
All counties	\$24,563.90	\$21,015.59	\$25,057.95	\$70,637.44
<i>Vaccination Clinics</i>				
A	\$8,778.75	\$9,552.84	\$7,614.65	\$25,946.24
B	\$6,101.45	\$6,924.33	\$7,445.05	\$20,470.83
C	\$1,023.75	\$1,153.75	\$1,060.00	\$3,237.50
D	\$15,046.67	\$13,807.77	\$15,909.16	\$44,763.60
E	\$0.00	\$570.00	\$630.00	\$1,200.00
All counties	\$30,950.62	\$32,008.69	\$32,658.86	\$95,618.17

Figure 5

County	Number of persons treated, specimens submitted, or animals vaccinated	State Cost	Third Party Cost	Donations	County Cost	Average Cost*
<i>Post exposure prophylaxis</i>						
A	126	\$53,303.38	\$30,762.49	-	\$5,735.18	\$712.71
B	7	\$723.21	\$7,138.50	-	\$0.00	\$1,123.10
C	133	\$23,723.80	\$27,496.34	-	\$7,327.49	\$440.21
D	78	\$36,590.63	\$97,744.21	-	\$12,692.44	\$1,884.97
E	313	\$193,128.73	\$100,098.44	-	\$21,808.87	\$1,006.50
All counties	657	\$307,469.75	\$263,239.98	-	\$47,563.98	\$941.06
<i>Specimen Submission</i>						
A	2	\$74.00	-	-	\$0.00	\$37.00
B	114	\$1,579.25	-	-	\$52.70	\$14.32
C	321	\$9,569.26	-	-	\$831.90	\$32.40
D	503	\$10,734.02	-	-	\$0.00	\$21.34
E	1078	\$42,639.89	-	-	\$5,156.42	\$44.34
All counties	2,018	\$64,596.42	-	-	\$6,041.02	\$35.00
<i>Vaccine Clinics</i>						
A	4140	\$6,501.74	-	\$19,685.00	\$0.00	\$6.27
B	3309	\$9,832.54	-	\$10,638.29	\$0.00	\$6.19
C	9915	\$3,213.75	-	\$0.00	\$23.75	\$0.33
D	8741	\$13,614.08	-	\$32,435.29	\$589.78	\$5.12
E	80	\$1,200.00	-	\$0.00	\$0.00	\$15.00
All counties	26,185	\$34,362.11	-	\$62,758.58	\$613.53	\$3.65
<i>All Categories</i>						
A	-	\$59,879.12	\$30,762.49	\$19,685.00	\$5,735.18	-
B	-	\$12,135.00	\$7,138.50	\$10,638.29	\$52.70	-
C	-	\$36,506.81	\$27,496.34	\$0.00	\$8,183.14	-
D	-	\$60,938.73	\$97,744.21	\$32,435.29	\$13,282.22	-
E	-	\$236,968.62	\$100,098.44	\$0.00	\$26,965.29	-
All counties	-	\$406,428.28	\$263,239.98	\$62,758.58	\$54,218.53	-

Figure 6 * Average cost = (cost/n)