The Economics of a Successful Raccoon Rabies Elimination Program on Long Island, New York

Short title: The Economics of a Rabies Elimination Program

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Abstract

Raccoon rabies is endemic in the eastern U.S., but had not spread to Long Island, New York until 2004. An aggressive oral rabies vaccination (ORV) program was initiated soon after the first rabies-positive raccoon was discovered, and continued until raccoon rabies was eliminated from the vaccination zone. The cost-effectiveness and economic impact of this rabies control program were unknown. A public health surveillance data set was evaluated following the ORV program on Long Island, and is used here as a case study in the health economics of rabies prevention and control efforts. A benefit-cost analysis was performed to determine the cost-effectiveness of the program, and a regional economic model was used to estimate the macroeconomic impacts of raccoon rabies elimination to New York State. The cost of the program, approximately $3 million, was recovered within eight years by reducing costs associated with post-exposure prophylaxis (PEP) and veterinary diagnostic testing of rabies suspect animals. The benefit-cost ratio reached 2.39, meaning that for every dollar spent on the program $2.39 was saved. Regional economic modeling estimated employment growth of over 100 jobs and a Gross Domestic Product (GDP) increase of $9.2 million through 2019. This analysis suggests that aggressive baiting to eliminate rabies in a geographically constrained area can provide positive economic returns.

Author Summary

Raccoon rabies, a type of rabies found most frequently in raccoons, is common is the eastern U.S. Raccoon rabies is at times controlled through oral rabies vaccination (ORV) programs, in which baits containing rabies vaccine are distributed throughout the affected area to be consumed by wildlife, which then develop immunity limiting their ability to spread the disease. Nassau and Suffolk Counties on Long Island had been free of raccoon rabies until 2004, when an ORV program was rapidly initiated in response to the discovery of a rabies-positive raccoon. As a result, raccoon rabies was eliminated in January 2009. Some questioned whether the benefits of the ORV program outweighed its costs. To find out, we performed a benefit-cost analysis of the program using avoided medical and animal testing costs to value the benefits. We also used a regional economic model to estimate the effect of the program on the economy of New York State. The results of both analyses indicated that the program had a positive impact, increasing employment and income in the region. This study provides insight into the economic value of a program to eliminate rabies from an isolated area.

Introduction

The raccoon variant of rabies virus (raccoon rabies) is endemic throughout most of the eastern seaboard of the U.S. In New York, raccoon rabies became endemic in 1990. The epizootic did not enter Long Island (Nassau County) until August 2004. This delay was due to the presence of geographic barriers (East River and New York City) at the west end of the island (1). The number of rabies-positive raccoons increased from zero in 2003 to ten in 2004 and 35 in 2005. To combat the growing number of rabid raccoons, a modified point infection control program similar to raccoon rabies control programs conducted in Ontario (2) was initiated by the New York State Department of Health in 2004. In 2006, the management of the Long Island Oral Rabies Vaccine (ORV) Program was transferred to the N.Y.S. Veterinary Diagnostic Laboratory at Cornell University. From 2005-2010, raccoon populations were vaccinated by ground or aerial distribution of ORV-filled baits containing RABORAL V-RG® rabies vaccine throughout the affected area. Raccoon rabies was eliminated from the ORV zone in 2009, reducing its impacts to human and animal health and the economy of New York State.

In the U.S., interactions between people and companion animals are the primary cause of human rabies exposure. Typically, a rabid raccoon comes into contact with an unvaccinated dog or a cat which bites or scratches its owner. Given that the case-fatality rate of rabies is nearly 100% and the disease is completely preventable through timely post-exposure prophylaxis (PEP), many individuals who are at very low risk of developing the disease still seek PEP, regardless of the recommendation of health professionals (3). Therefore, the direct economic impacts of rabies are associated predominantly with human PEP (4). Potential rabies exposure also has indirect impacts including vaccination of livestock and companion animals, livestock mortality, time off work to receive treatment, and testing of domestic and wild animals that may be infected with the virus (4, 5).

Macroeconomic impacts of endemic disease burdens such as rabies can be estimated by examining changes in different economic sectors that result from the direct and indirect impacts of the disease (6). For example, reductions in consumer spending throughout the economy can result from income lost when seeking PEP treatment. As these impacts spread through the regional economy, they affect members of the community who were not directly impacted by the disease.

The purpose of this study is to quantify the costs associated with the Long Island ORV program and the benefits gained from the resulting decrease in human and animal rabies exposure. Additionally, a regional economic model is used to estimate the macroeconomic impacts of the program in New York State. This study provides an assessment of the economic impacts of rabies and an estimate of the potential benefits that could be realized if the prevalence of raccoon rabies was reduced or eliminated in other regions of the U.S.

Methods

Benefit-cost analysis (BCA) is a tool frequently used by economists to evaluate the efficiency of projects and government programs. Valuation of the benefits of projects that prevent disease spread is generally based on estimation of the damages avoided. It is posited that the ORV program described here decreased the prevalence of (and ultimately eliminated) raccoon rabies. The benefits of this ORV program were calculated as the savings from reducing the number of PEP and animal testing (AT) necessary, and the associated costs borne by individuals as a result of human rabies exposure (e.g., expenditures on over-the-counter medications, lost work time and travel to receive treatment). These avoided costs make up the majority of benefits derived from rabies control programs (7-9).

Benefit-Cost Analysis

The annual total benefits (*TB*) equal PEP and AT costs avoided due to raccoon rabies cases avoided. To determine cost savings it was necessary to estimate the extent to which raccoon rabies was likely to spread on Long Island. For this analysis, it was assumed that the disease would not severely impact Queens and Kings Counties due to the high level of urbanization, but would have spread east through Nassau and Suffolk Counties (10). As a result, with no effort to control raccoon rabies on Long Island, the total possible human population at risk ($HPR_{baseline}$) comprises the populations of both Nassau and Suffolk Counties (Figure 1). Rabies prevention benefits are derived as the ORV program reduces the number of potentially rabid raccoons, thereby reducing the human population at risk to HPR_{ORV} which ultimately reduces the number of PEPs and ATs.

Individuals' perceived risk of rabies exposure may not decrease for several years after the actual prevalence of rabies declines (11), meaning people will continue to seek PEP even when treatment is unnecessary. Given this time lag, we assumed that HPR_{ORV} is not driven down for five years after the initiation of the program; therefore, no benefits accrue during this period. We further assumed that HPR_{ORV} declines at a linear rate, reaching its minimum in ten years and that without the program it is expected that the rabies epizootic would have continued indefinitely. Lagging benefits also provides a more conservative estimate of benefits.

The difference between $HPR_{baseline}$ and HPR_{ORV} represents the number of people no longer at risk (HPR_{saved}) of rabies exposure due to the ORV program. *TB* of the program in a specific year was calculated as

$$TB_t = PEP_{saved,t} + AT_{saved,t} = \frac{HPR_{saved,t}}{100,000}[(PEP \cdot PEP_{cost}) + (AT \cdot AT_{cost})] \quad (1)$$

where PEP and AT are estimates of the average rate of incidence of PEP and AT respectively per 100,000 people based on documented previous rabies epizootics in New Jersey, New York, and New Brunswick, and adjusted for pre-epizootic rates on Long Island. These estimates were used to determine the hypothetical case frequency that could have existed in the absence of a raccoon rabies ORV program (12). New Jersey, New York and New Brunswick raccoon rabies epizootic PEP rates were reported as 66, 43.5, and 14; AT rates were reported as 483, 65, and 45 per 100,000 people, respectively. PEP_{cost} represents the total cost of rabies exposure per case, including direct and indirect costs, and was $4,203 (4). Direct costs of PEP include vaccine costs and health professional salaries. Indirect costs include lost wages from missed work, travel time to receive treatment, and animal control measures. AT_{cost} reflects the costs associated with capture and testing of a suspected rabid animal and was estimated as $483. All dollar amounts are in 2008 U.S. dollars.

Total costs (*TC*) of the ORV program were calculated as the sum of bait and distribution costs. Actual costs were available for baits and a portion of the air distribution. However, the remaining air distribution and all of the ground distribution costs were provided by in-kind donations to the program and were not tracked. As a proxy, we used estimates of ground and air distribution costs of \$20.43/km^2 and \$28.09/km^2, respectively (13).

Program efficiency can be measured in two ways: benefit-cost ratios (BCRs) and net benefits. BCRs were calculated as total benefits divided by total costs, providing an indication of the returns for every dollar spent. Thus, a BCR greater than one indicates an efficient use of resources because the program's benefits outweigh the costs. Similar information is provided by the measurement of net benefits, which is simply the total benefit minus the total cost.

Macroeconomic Impacts

Reducing human exposure to raccoon rabies can produce regional macroeconomic impacts including changes in income and employment that arise from multiple sources. Macroeconomic impacts illustrate how reducing the prevalence of rabies affects people who were not at direct risk of the disease. Macroeconomic models, such as REMI PI+ (Regional Economic Models, Inc.), allow the estimation of impacts in terms such as income and employment, which are important to the general public. We estimated macroeconomic impacts arising from two sources: less income lost due to fewer people receiving PEP and shifts from healthcare spending to spending in other sectors of the economy.

The loss of income while seeking PEP reduces consumer spending throughout other sectors of the economy and leads to income and employment declines in those sectors. Thus, when the prevalence of the disease is reduced this harmful impact is lessened and regional income and employment will rise. Positive macroeconomic effects associated with a decrease in spending on PEP arise because a large portion of spending on PEP immediately leaves the state (rabies vaccines are produced outside New York State). Based on prices obtained from rabies vaccine manufacturers, it was estimated that 84% of the direct costs of PEP are for vaccine and the remaining 16% are for other medical costs (physician's salary, etc.). Therefore, when PEP spending is reduced there will be a significant shift in spending to in-state businesses, ultimately resulting in an increase in income and employment in those industries. However, this positive impact is partially offset by a decrease in spending in the healthcare sector in New York, equal to the non-vaccine portion of PEP costs.

The REMI model that was used to estimate the impact of the ORV program on New York State's economy was a 70-sector REMI PI+ model of the New York economy. REMI is a computer-based simulation model of the US economy that allows modeling at both the national and sub-national scales. This structural economic forecasting model uses a non-survey based input-output (I-O) table like other widely-used, ready-made models, but links its I-O table to thousands of simultaneous equations to overcome the rigidness of static I-O models. By incorporating the strengths of input-output, computable general equilibrium, and econometric methodologies, REMI is able to overcome the limitations of using a single methodology. This dynamic forecasting and policy tool has the ability to generate annual forecasts and simulations that detail behavioral responses to compensation, price, and other economic factors. The structure of the model incorporates inter-industry transactions, endogenous final demand feedbacks, substitution among factors of production in response to changes in expected income, wage responses to changes in labor market conditions, and changes in the share of local and export markets in response to the change in regional profitability and production costs (14). The model is constructed based on national, state, and county level data from the Bureau of Economic Analysis, Bureau of Labor Statistics, and the Bureau of the Census, as well as forecasts from the Research Seminar in Quantitative Economics at Michigan State University.

Results

Total benefits resulting from the ORV program were the savings from avoided PEPs and ATs over the course of the program (2005-10) and projected eight years into the future (Table 1). The first five years of the program show no benefits due to the assumed time lag between initiation of the program and the reduction of the human population at risk. Benefits then increase linearly over the next ten years ultimately reaching the maximum, pre-epizootic level. Costs of the ORV program totaled approximately three million dollars. Broad-scale rabies intervention ended in 2010; accordingly, costs for subsequent years are zero.

1 Table 1. Benefits, costs, and BCRs of the Long Island ORV program in 2008 dollars.

	Benefits						Costs				BCR	
Year	#PEP	PEP Savings	#AT	AT Savings	Total/year	Cumulative	Baits	Distribution	Total/year	Cumulative	BCR	BCR/year
2005							$197,216	$19,446	$216,662	$216,662	0.00	0.00
2006							$465,670	$30,574	$496,244	$712,905	0.00	0.00
2007							$536,384	$60,579	$596,963	$1,309,868	0.00	0.00
2008							$560,006	$116,768	$676,774	$1,986,642	0.00	0.00
2009							$495,040	$29,187	$524,227	$2,510,869	0.00	0.00
2010	110	$462,330	487	$235,221	$697,551	$697,551	$382,200	$22,310	$404,510	$2,915,379	0.24	1.72
2011	220	$924,660	974	$470,442	$1,395,102	$2,092,653					0.48	
2012	330	$1,386,990	1461	$705,663	$2,092,653	$4,185,306					0.72	
2013	440	$1,849,320	1948	$940,884	$2,790,204	$6,975,510					0.96	
2014	550	$2,311,650	2435	$1,176,105	$3,487,755	$10,463,265					1.20	
2015	660	$2,773,980	2922	$1,411,326	$4,185,306	$14,648,571					1.44	
2016	770	$3,236,310	3409	$1,646,547	$4,882,857	$19,531,428					1.67	
2017	880	$3,698,640	3896	$1,881,768	$5,580,408	$25,111,836					1.91	
2018	990	$4,160,970	4383	$2,116,989	$6,277,959	$31,389,795					2.15	
2019	1100	$4,623,300	4870	$2,352,210	$6,975,510	$38,365,305					2.39	

Net benefits are the total benefits minus the total costs. As of 2014, benefits for New York exceeded $10 million. Benefits through 2019 exceeded $38 million while costs were approximately three million dollars, returning a net benefit of the ORV program exceeding $35 million. Comparing the benefits with the costs of the program for each year gives the benefit-cost ratios (BCRs). The cumulative BCR (benefit each year divided by the total cost) reached 2.39 indicating every dollar spent on the ORV program saves $2.39 in costs.

Regional economic modeling predicted employment growth of 106 jobs and a Gross Domestic Product (GDP) increase of $9.2 million through 2019 due to increased consumer spending resulting from avoided PEPs and ATs (Table 2). This takes into account the spending offset in the medical sector by including only saved costs that would have gone out of state (vaccines) and the avoided costs of lost wages, for which there is no offset.

Table 2. REMI results indicating the macroeconomic impacts of the ORV program to New York State (GDP in thousands of dollars).

	2010	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**Total**
Jobs	4	5	6	8	12	12	12	12	18	17	106
GDP	128	384	512	640	1,024	896	1,408	1,024	1,536	1,664	9,216

Discussion

This study provided a retrospective examination of the benefits and costs of an aggressive wildlife rabies elimination program on Long Island that incorporated, for the first time, the macroeconomic impacts of reduced rabies burden to the New York State economy. Other studies examining the benefits and costs of successful elimination of rabies from an area have been conducted but have never estimated the broader macroeconomic implications (7, 12). The domestic dog/coyote variant of rabies was eliminated from Texas by moving a zone of immunity south to the Mexican border and maintaining the zone at the U.S.-Mexico border to prevent reintroduction. In Quebec, a variety of techniques including ORV and point-infection control were used to successfully eliminate an outbreak of raccoon rabies. While both of these studies provided a benefit-cost analysis of the elimination program, an examination of impacts to those not directly impacted by rabies exposure was absent.

Regional economic modeling was used to estimate the macroeconomic effects of the ORV program on the New York economy in terms of employment and GDP (income). As the ORV program protected individuals in Suffolk and Nassau counties, fewer individuals had to receive PEP. Avoided expenditures on PEP were reflected as increased consumer spending. While some of the gain to individuals was offset by a loss to medical sector, the REMI model predicted positive impacts on jobs and income in New York as a result of the program. Estimating the impact on employment and state GDP of controlling a primarily wildlife-based disease is largely absent in the literature. This is the first estimation of the broader implication of rabies to the macroeconomy. This type of analysis is important because it links the impacts of the disease control (ORV) program to individuals who were otherwise not involved in the program through tangible concepts such as changes in employment and income. These individuals may have been aware that a program was being conducted in their area, but may not have been able to discern any personal benefit.

A challenge of this study was determining the hypothetical annual frequencies of public health interventions (PEP and AT) that would have existed in the absence of a raccoon rabies control program. These data were needed to calculate damages avoided in the economic analysis. Because rabies control tactics were initiated within days of identification of the first terrestrial case in 2004, the estimated frequencies were based on information from previous raccoon rabies epizootics occurring in New Brunswick, New Jersey and New York. The use of these average and adjusted frequencies reduces uncertainty of the monetary value of damages avoided.

A comprehensive picture of the economic impacts resulting from elimination of wildlife diseases is crucial to understanding the benefits of control programs. Vaccination of wildlife, companion animals, and livestock against rabies is critical for elimination of the disease. The next step is choosing the most efficient and effective method available. This analysis suggests that aggressive baiting to eliminate rabies in a geographically constrained area can provide positive economic returns despite a five-year temporal delay before financial benefits start to accrue. The real and perceived risks associated with rabies exposure and PEP in small intervention areas must ultimately be compared to large-scale vaccination programs that are designed with the goal of regional rabies elimination within extensive land areas. Financial benefits to society may be negatively impacted if public and professional anxieties remain at a heightened level in narrow disease elimination zones where the threat of rabies exposure persists in close proximity. The estimated macroeconomic impacts over time demonstrate the societal value of rabies elimination in a wildlife reservoir species. Such programs are often perceived as too costly or lacking a measurable public health impact. Quantitative analyses as performed in this study are important for public health policy makers at both local and national levels. The results from this study can be used in future ORV and rabies elimination planning.

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References

1. Recuenco S, Eidson M, Kulldorff M, Johnson G, Cherry B. Spatial and temporal patterns of enzootic raccoon rabies adjusted for multiple covariates. Int J Health Geogr. 2007;6(1):14.

2. Rosatte R, Donovan D, Allan M, Howes L-A, Silver A, Bennett K, et al. Emergency response to raccoon rabies introduction into Ontario. J Wildl Dis. 2001;37(2):265-79.

3. Rupprecht CE, Briggs D, Brown CM, Franka R, Katz SL, Kerr HD, et al. Use of a reduced (4-dose) vaccine schedule for postexposure prophylaxis to prevent human rabies. MMWR Recomm Rep. 2010;59(RR-2):1-9.

4. Shwiff SA, Sterner RT, Jay MT, Parikh S, Bellomy A, Meltzer MI, et al. Direct and indirect costs of rabies exposure: a retrospective study in southern California (1998-2002). J Wildl Dis. 2007;43(2):251-7.

5. Anderson A, Shwiff S, Gebhardt K, Ramírez A, Kohler D, Lecuona L. Economic evaluation of vampire bat (*Desmodus rotundus*) rabies prevention in Mexico. Transbound Emerg Dis. 2012;61(2):140-146.

6. Diao X. Economywide impact of avian flu in Ghana: A dynamic CGE model analysis. Intl Food Policy Res Inst. 2009;15.

7. Shwiff SA, Kirkpatrick KN, Sterner RT. Economic evaluation of an oral rabies vaccination program for control of a domestic dog–coyote rabies epizootic: 1995–2006. J Am Vet Med Assoc. 2008;233(11):1736-41.

8. Shwiff SA, Sterner RT, Hale R, Jay MT, Sun B, Slate D. Benefit cost scenarios of potential oral rabies vaccination for skunks in California. J Wildl Dis. 2009;45:227-33.

9. Shwiff S, Nunan C, Kirkpatrick KN, Shwiff S. A retrospective economic analysis of the Ontario red fox oral rabies vaccination programme. Zoonoses Public Health. 2011;58(3):169-77.

10. Recuenco S, Eidson M, Cherry B, Johnson G. Risk-Based Cost Modelling of Oral Rabies Vaccine Interventions for Raccoon Rabies. Zoonoses Public Health. 2009;56(1):16-23.

11. Shwiff S, Hampson K, Anderson A. Potential economic benefits of eliminating canine rabies. Antiviral Res. 2013;98(2):352-6.

12. Shwiff S, Aenishaenslin C, Ludwig A, Berthiaume P, Bigras-Poulin M, Kirkpatrick K, et al. Bioeconomic modelling of raccoon rabies spread management impacts in Quebec, Canada. Transbound Emerg Dis. 2013;60(4):330-7.

13. Foroutan P, Meltzer MI, Smith KA. Cost of distributing oral raccoon-variant rabies vaccine in Ohio: 1997-2000. J Am Vet Med Assoc. 2002;220(1):27-32.

14. Treyz GI, Rickman DS, Shao G. The REMI economic-demographic forecasting and simulation model. Int Regl Sci Rev. 1991;14(3):221-53.

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Figure 1: Human Population at Risk (*HPR*) with and without the ORV program.