

## Evaluating the Success of the Oral Rabies Vaccine (ORV) Program in New York State

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### Abstract

Rabies has been a significant economic and public health burden on New York State (NYS) for many years. As a response to this problem, NYS and the US Department of Agriculture's National Rabies Management Program (NRMP) has an oral rabies vaccine (ORV) distribution program implemented to reduce the prevalence of rabies in raccoon populations, the primary species that spread rabies on the Eastern Coast of the U.S. The purpose of this project was to evaluate the current ORV program in place, identify areas of potential improvement, and evaluate the success of new ORV, called Ontario Rabies Vaccine Bait (ONRAB). This was done using public data from the NYS Department of Health, and the NRMP. Annual ORV distribution and the prevalence of rabid raccoons from 2009–2015 were analyzed. The prevalence of rabid raccoons in NYS decreased by 50%, there was no significant decline in other rabid terrestrial species from 2009–2015. Maps constructed with Arc Geographic Information System (ArcGIS) revealed that more than ten raccoons consistently tested positive in the more populated counties, some of which distribute baits and some that do not. The analysis revealed that a significant decline in the rabid raccoons in NYS was observed after the addition of ONRAB in 2012. The ORV program in NYS appears to be a successful mode to reduce the prevalence of rabies and should be continued. This analysis supports other studies that have shown that ONRAB is a more effective mode to reduce the prevalence raccoon rabies in comparison to the first ORV, RABORAL V-RG.

**Keywords:** Rabies prevention and control, zoonotic diseases, rabies vaccines, wildlife, rabies epidemiology, rabies prevention/economics

### Background

Rabies is one the most significant zoonotic diseases globally because of the worldwide distribution, public health impact, and lethality in both humans and animals.<sup>1</sup> In North America, the disease is currently endemic only in wildlife species, including raccoons, skunks, foxes, and bats, and these wildlife species are responsible for human exposures each year. The variant of raccoon rabies virus has grown each year in prevalence and geographic distribution and has been the target of wildlife rabies control methods since the early 2000s. New York State (NYS) has been a location for control of wildlife rabies for many years for reasons including the proximity to the Canadian border, where rabies in wildlife is almost eliminated, in conjunction with the high human and raccoon populations across the state. According to the Centers for Disease Control and Prevention (CDC), rabies is an expensive annual economic burden for NYS; recent estimates of the cost of post-exposure prophylaxis to individuals that have a suspected rabies exposure is \$3,800 per individual, which NYS is required to cover by law.<sup>3</sup> Due to the costly nature of rabies prevention in humans, a successful rabies control program would be both economically beneficial and promote the health of NYS humans and animals.

Multiple methods have been utilized to control rabies in the wildlife populations of NYS, but the most commonly used method is aerial and ground bait distribution containing oral rabies vaccine (ORV). This method has proven to be economically feasible and effective in producing immunity among wildlife populations over large geographic areas. NYS works with the US Department of Agriculture, Animal and Plant Health Inspection Service (USDA APHIS) and their National Rabies Management Program (NRMP) to distribute rabies baits across the state.<sup>12,13</sup> The ORV vaccine distributed in NYS specifically targets the raccoon rabies variant. The ORV is administered through an edible bait package, which includes the ORV coated in fishmeal or palatable flavors. The fishmeal and flavors encourage raccoons to eat the bait, which when bitten deposits the vaccine into the mouth of the animal and is subsequently swallowed. According to a certified wildlife biologist with the NRMP, locations and densities of bait distributions each year are dependent on a multitude of factors, including rabies surveillance data, serology data from prior years, high-risk areas (such as along the Canadian border), natural geographic barriers that may prevent the spread of rabies (such as bodies of water or mountain ranges), contingency action baiting in response to outbreaks, and political and budgetary considerations of particular areas.

## Current bait types

Two ORV types have been distributed in NYS. The first type of ORV developed is called RABORAL V-RG. Seroconversion tests in target species have revealed that RABORAL V-RG is successful in providing vulnerable wildlife populations with some level of rabies immunity. However, because of the challenging nature of collecting samples from wild animals and the dynamic nature of wild animal populations, it is hard to truly measure the effectiveness of RABORAL V-RG providing wildlife populations with rabies immunity.<sup>9</sup> Studies have shown varying seroconversion rates in animals captured in bait zones in the weeks following bait distribution campaigns. This may be partly attributed to the fact that antibody levels in the blood peak 4–8 weeks following inoculation and then drop steadily. Therefore, these studies may not reflect the true efficacy of the vaccine in the field. In addition to challenges in measuring seroconversion rates, getting true estimates of the prevalence of wildlife rabies is challenging because prevalence data are usually collected by passive surveillance (from nuisance cases handled by animal control departments).<sup>9</sup> However, large field trials in the United States have revealed that RABORAL V-RG produces seroconversion rates in raccoons from around 29% (+/ 14%) to 37% (+/ 17%).<sup>10</sup> RABORAL V-RG has proven to be effective at creating disease boundaries through vaccinated populations in targeted wildlife populations to stop the spread of rabies during outbreak situations and prevent spillover of the disease to other species or geographic locations. RABORAL V-RG has also proven to be effective at greatly reducing the incidence of rabid wildlife cases in areas with previously high prevalence of rabies across Europe and North America.<sup>10</sup>

While RABORAL V-RG has proven to be effective in raccoon and fox populations, it lacks efficacy in skunk populations. An efficacy trial of RABORAL V-RG in skunk populations revealed that this was most likely due to different foraging and eating behaviors of skunks than that of raccoons, causing most of the vaccine to be spilled and not ingested by the skunks when attempting to eat the bait.<sup>10</sup> Hence, ONRAB was developed as an effective skunk–raccoon ORV.<sup>8</sup> Developed and tested in Canada, ONRAB has been used for years and has contributed to the great reduction in the prevalence of wildlife rabies in Ontario. ONRAB has shown to induce high rates of immunity in target species in both controlled trials and in the field. One controlled trial of wild-caught raccoons revealed a 77% seroconversion rate, and 75% of the raccoons that received an ONRAB dose and challenged with a live rabies virus survived.<sup>2</sup> Other trials produced similar results, with survival rates of 73% in a Spring trial and 91% in a Fall trial in the study group that was challenged with a live rabies virus.<sup>6</sup> These survival rates were higher than the seroconversion and survival rates elicited by RABORAL V-RG in trials. Currently, ONRAB is not licensed in the United States, but since 2011 has been distributed in the NRMP bait campaigns as part of the trial phase for licensing in the United States.

## Project Justification and Hypothesis

The purpose of this project was to evaluate the success of the NYS ORV program in reducing the prevalence of raccoon rabies within the state. This was done through the comparison of rabies

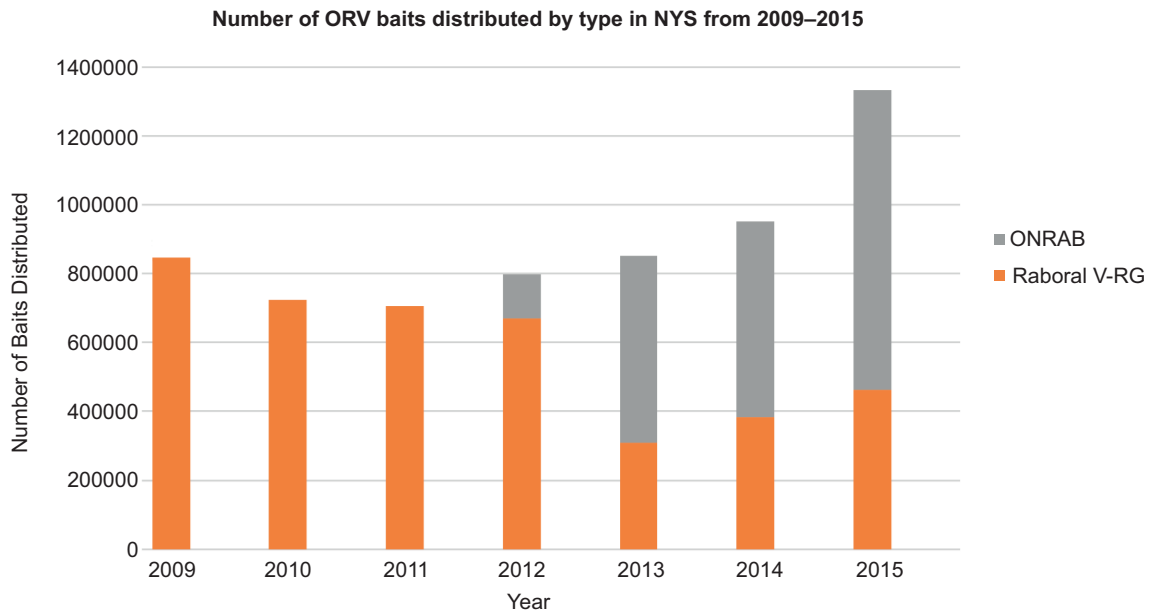
surveillance data from the NYS Department of Health and ORV distribution data from the USDA APHIS National Rabies Management Program.<sup>12,13</sup> This analysis offers a better understanding of the current strengths and weaknesses of the NYS ORV program and offers insight to potential improvements or changes that need to be made to make the program more effective. Data from the years 2009–2015 were compared in order to evaluate the success of ONRAB in reducing the prevalence of raccoon rabies, which was added to the program in 2012. Prior to 2012, RABORAL V-RG were the only ORV distributed. The primary hypothesis for this analysis is that there is an observable decline in the annual prevalence of rabid raccoons in NYS because of the ORV program, especially after the addition of ONRAB in 2012, due to the evidence that ONRAB generates higher seroprevalence rates of rabies antibodies in wildlife populations than RABORAL V-RG. A secondary hypothesis for this analysis is that a decline in the prevalence of rabid raccoons would lead to a decline in the prevalence of rabies in other mammals, since raccoons are the reservoir species in NYS. The results of this analysis offer insight into the success of ONRAB in reducing the prevalence of rabies and provide the USDA with more information in preparation of ONRAB licensing for use in the United States.

## Methods

All data used in this project were public data. The rabies surveillance data came from the NYS' Department of Health, Wadsworth Center, which is the laboratory that tests animal specimens for rabies. Each year the Wadsworth Center publishes an annual report summarizing the number of animals tested for rabies by species and county, and whether the test was positive or negative. Surveillance data from the annual reports from 2009–2015 were used in this analysis. The shape files used in this analysis containing the locations of bait distribution zones, along with the bait distribution information such as the locations, density, and type of baits distributed, were obtained from the USDA APHIS NRMP website.<sup>12,13</sup> The bait reports and shape files from 2009–2015 were used in this analysis. The software used in this analysis included Microsoft Excel and Arc Geographic Information System (ArcGIS). The analysis performed was descriptive in nature and included the following: distribution of ORV baits, incidence of raccoon and terrestrial animal rabies, and maps of raccoon rabies prevalence by county with corresponding locations of bait distribution.

## Results

The annual number of ORV distributed from 2009–2012 remained steady until ONRAB was introduced into the ORV program in 2012. From 2012 to 2015, there was a steady increase in the amount of bait distributed, with an increasing amount of ONRAB distributed each year as part of the ONRAB field trials in the United States (Figure 1). The number of raccoons infected with rabies in NYS was found to steadily decline from 2009–2015 while rabies in other terrestrial mammals such as dogs, cats, cattle, skunks, fox, rodent lagomorphs, and other domestic and wild animals displayed no clear pattern of increasing or decreasing (Table 1). The county-wide bait distribution locations did not change much, if at all, from 2009 to 2015 (Figure 2).



**Figure 1.** Number of ONRAB and RABORAL V-RG ORV baits distributed from 2009–2015.

**Table 1.** Year-wise summary of the incident cases of rabies in raccoons and other terrestrial animals in NYS from 2009 to 2015.

	2009	2010	2011	2012	2013	2014	2015
Raccoons	266	250	162	186	147	166	133
Other terrestrial mammals	134	181	144	125	106	108	130

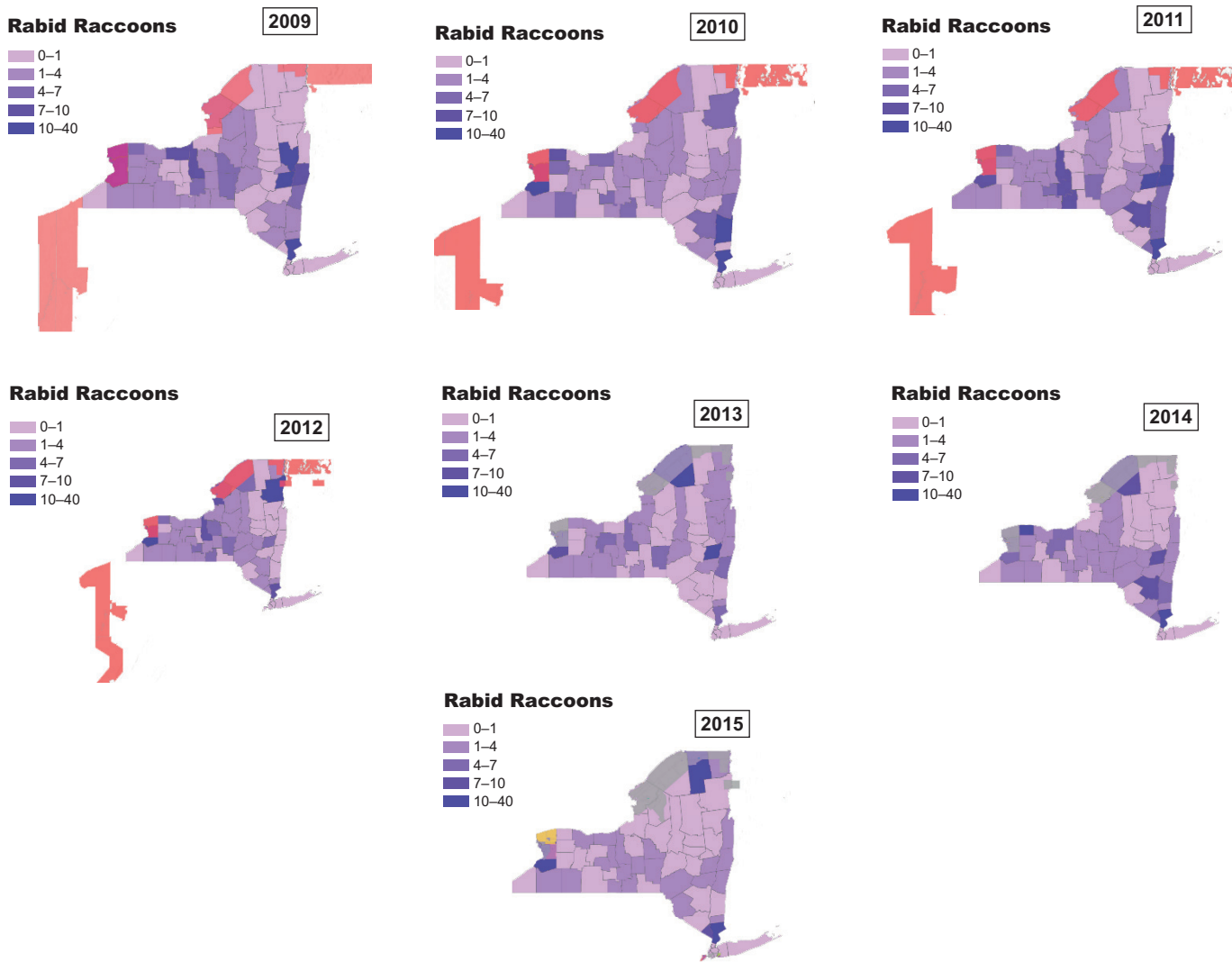
The baits were distributed along the Canadian border in Northern New York and in Erie and Niagara counties, and some baiting occurred around the New York City area. Most counties throughout the state have no more than 1–4 raccoons testing positive each year. Notably, there were almost consistently ten or more raccoons testing positive for rabies in Erie County, where baiting occurred each year, and Westchester County, where no baiting took place. A few counties in the eastern side of the state, where baiting did not occur, including Albany and Saratoga Counties, had multiple years of ten or more raccoons testing positive for rabies. From 2009–2015, the number of rabid raccoons in NYS declined by 50%, from 266 in 2009 to 133 in 2015 (Figure 3). There was steady decline in the number of raccoons testing positive for rabies, except for a small increase in 2012 and 2014. There was no observable decline in the total number of rabid terrestrial animals in NYS from 2009–2015 (Figure 4).

## Discussion

This general evaluation of the success of the ORV program in NYS revealed that the ORV program appears to be contributing to a decline in the number of confirmed rabid raccoons across the state. These results

parallel a large retrospective study examining the prevalence of rabid wildlife from 2006–2017 in New York, Vermont, and New Hampshire. The study found that there was a significant overall decline in the prevalence of rabid wildlife in areas with ORV management than in areas without ORV management, suggesting that ORV is a successful way to reduce rabies in endemic areas (Gilbert et al., 2018).

This analysis also revealed that ONRAB may have been successful in contributing to the continuing decline of rabid raccoons across the state. Data from the NYS Department of Health, Wadsworth Center recently reported that the trends observed between total ORV distributed and rabid raccoons continued in 2016 and 2017. A state-low of 113 rabid raccoons were identified in 2017. Since 2012, ONRAB has been used extensively throughout the state as part of the field trials to get the vaccine licensed. Some early data from these trials have been published and results indicate that ONRAB has consistently higher seroconversion rates in the field than RABORAL V-RG. For example, 2011, the first field trial of ONRAB in the United States was conducted in West Virginia, an area that was endemic for raccoon rabies and had never been baited with ORV before. The study results indicated that prevalence of rabies antibody was 9.6% in raccoons before ONRAB distribution and increased to 49.2% after ONRAB distribution.<sup>11</sup> A 2012 study that distributed RABORAL V-RG in Maine and ONRAB across the border in New Brunswick found that 74% of tested raccoons were antibody positive in ONRAB-baited areas versus 30% of tested raccoons in RABORAL V-RG-baited areas.<sup>5</sup> Finally, a 3-year study was conducted in raccoon-endemic areas in northern New York, Vermont, and New Hampshire from 2012 to 2014. Baseline raccoon antibody seroprevalence started at 27.3% before ONRAB distribution, and after 3 years the seroprevalence averaged at 68.5% in raccoons across the study areas.<sup>7</sup> However, the current analysis being described did not

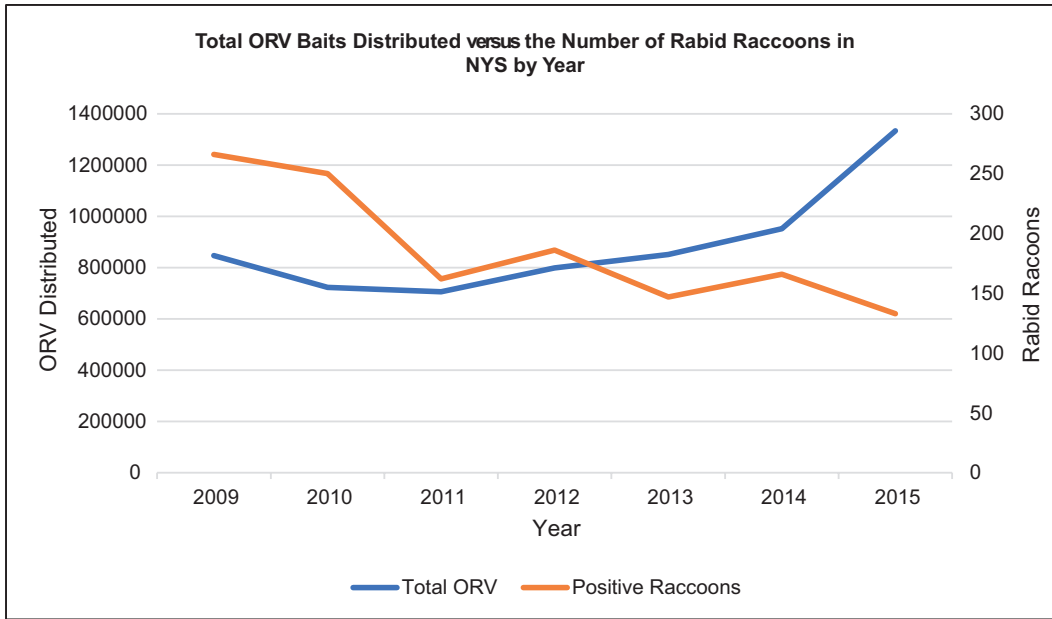


**Figure 2.** Maps of ORV distribution areas and the number of rabid raccoons by county from 2009–2015. The red, grey, yellow and pink colors indicate the areas where the vaccine baits were distributed, which could not be changed as the shapefiles were created by NRMP and downloaded from the USDA APHIS NRMP website. Starting in 2013, the NRMP created individual shapefiles for each state, rather than by the entire country, creating the color variation. There is no significance in the different colors; all indicate areas where the vaccine baits were distributed.

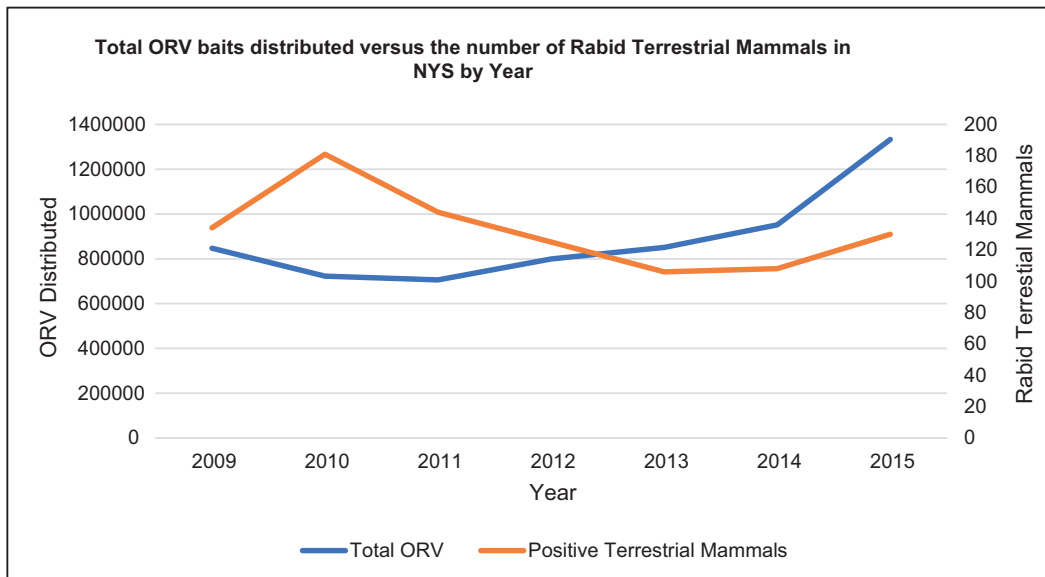
examine seroprevalence, so it cannot be used to draw conclusions on the efficacy of ONRAB in NYS raccoon populations. It is possible that the decline in the prevalence of raccoon rabies observed in this analysis is attributable to an increase in antibody seroprevalence in raccoon populations of NYS and a corresponding decline in the prevalence of rabies. Moreover, it is likely that an increase in the number of baits distributed during the observed years also played a role in the declining prevalence of rabies among raccoons. This could be confirmed by further investigating rabies antibody seroprevalence in raccoon populations.

There was no clear decline observed in the prevalence of rabid terrestrial animals other than raccoons in this analysis. The secondary

hypothesis for this analysis was that a decline in the prevalence of rabid raccoons would lead to a decline in the prevalence of rabies in other mammals, since raccoons are the reservoir species in NYS. However, this was not observed. One explanation may be that ORV only targets raccoons, other wildlife species are not taking part in ORVs, thus there is not a decline in antibody seroprevalence rates and the rates of rabies is not steadily declining. In addition, it may be easier to capture and test other animals, especially domestic animals such as cats and dogs, thus improving the completeness of the surveillance data. Concurrently, the underreporting of raccoon rabies may be contributing to the discrepancies observed in the trends between raccoons and other terrestrial species.



**Figure 3.** Total number of rabid raccoons in New York State and the total number of Oral Rabies Vaccine baits distributed by year from 2009–2015.



**Figure 4.** The total number of rabid terrestrial animals, excluding raccoons, in New York State by year and the total number of Oral Rabies Vaccine baits distributed.

ArcGIS maps generated in this analysis revealed that there may be some gaps in the ORV distribution sites across NYS. Currently, baiting occurs in the northern and western borders of the state. Raccoon rabies is still endemic in Erie County, so continuing to bait there would be beneficial in reducing raccoon rabies in the county. In addition, ArcGIS maps generated in this analysis also revealed that

there were high incidences of rabid raccoons reported in Westchester County and the areas surrounding the city of Albany in Albany and Saratoga Counties. Those counties have high human population densities, so wildlife–human encounters are more likely to occur. Since the cost of rabies post-exposure prophylaxis is expensive it may be beneficial and cost-effective to start an ORV program in those



counties; whether it be aerial bait distribution or ground-baiting in densely populated urban areas to reduce the risk of human rabies exposures.

There are multiple strengths to this analysis. The data used in the analysis were from both USDA and NYS Wadsworth Center. Data from these two institutions had never been utilized in the same analysis, so the results of this study offer a new perspective and evaluation of the success of ORV distribution across the state. The use of ArcGIS mapping by county provided a visual analysis of the success of the ORV program in NYS and offer suggestions for new locations of bait distribution in areas that were observed to have consistently high numbers of raccoons with rabies. The analysis retrospectively observed a 7-year period, which allowed for trends in the incident of rabies to be observed and compared with the locations and types of baits being distributed. There are also some weaknesses to this analysis that need to be acknowledged. There may be some gaps in surveillance data used, which could be contributing to underreporting of the total number of rabid raccoons within the state. For example, a percentage of rabid animals may be killed each year in road accidents but not included in the NYS rabies surveillance data. In addition, the highest number of rabid raccoons are normally reported in Albany, Erie, and Saratoga Counties, and counties containing and surrounding New York City. These counties also have some of the highest human populations in the state; hence, human–wildlife encounters are more likely to occur in these counties, and as a result, more testing and reporting taking place. It may be more likely that there are more rabid raccoons in the counties containing Adirondack Park or other rural areas. However, since human density is lower in these areas, there are less occurrence of wildlife–human encounters, and as a result less testing and reporting of rabies infection. This would mean that the numbers reported in this analysis may be an underrepresentation of the actual number of rabid raccoons present in the state. However, for the purpose of this analysis, the results may not be greatly affected since the underreporting is consistently happening every year and may not bias the results of this analysis.

## Conclusion

This analysis revealed that the ORV program in NYS is reducing the prevalence of raccoon rabies across the state. It suggests that ORV is an effective mode to reduce transmission of rabies. While the results of this analysis do not show a steep decline in the prevalence of raccoon rabies infection in NYS as hypothesized, the introduction of ONRAB in 2012 resulted in a 50% decline in rabid raccoons between 2009 and 2015, suggesting that the ORV program is working well and is worth continuing. The results of analysis suggest that it may be worthwhile to expand ORV bait distribution to other counties with consistently high incidences of rabid raccoons, such as Albany and Westchester Counties. While there was a lack of an observable decline in the number of positive terrestrial mammals other than raccoons, possibly because the ORV program only targets raccoons and no other species. Overall, continued use of ORV, and more specifically ONRAB, in NYS may reduce and eventually eliminate rabies within the state. This would subsequently eliminate a large economic and public health burden to the government and residents of New York.

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