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# Anatomy of the Cape Cod Oral Rabies Vaccination Program

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**ABSTRACT:** Rabies remains a globally significant zoonotic disease, but rabies control is achievable under certain circumstances. Canine rabies has been eliminated from the U.S.; however, approximately 55,000 humans die annually worldwide from the disease. In the U.S., economic losses continue to be substantial and the risk to humans and domestic animals has not been eliminated. As an example of the complexity of rabies management, we describe a local rabies control program and efforts to restore Cape Cod, MA to terrestrial rabies-free status, after a 2004 oral rabies vaccination (ORV) barrier breach following 10 years of rabies-free status. The emergence of raccoon rabies in southeastern New England in 1992 prompted the U.S. Centers for Disease Control and Prevention, the Tufts Cummings School of Veterinary Medicine, and the Massachusetts Department of Public Health to begin an ORV program to reduce the occurrence of carnivore rabies in an area directly adjacent to the Cape Cod Canal. In 2001, USDA APHIS Wildlife Services began full-time collaboration on the Cape Cod Oral Rabies Vaccination Program (CCORVP) as part of national wildlife rabies control efforts. The primary objective of the CCORVP was to use ORV in tandem with the physical barrier created by the Canal to prevent the spread of rabies to peninsular Cape Cod, a heavily-populated tourist destination southeast of Boston. After an increase in rabies cases within the traditional Cape Cod ORV zone, ORV bait distribution efforts were modified to reduce the risk of rabies spread onto the Cape. In spite of these modifications, raccoon rabies was detected for the first time on peninsular Cape Cod in March 2004. A trap-vaccinate-release campaign, removal of suspect raccoons and skunks, and expanded ORV efforts were unsuccessful in preventing the spread of the virus. Rabies surveillance became the priority of the Cape Cod Rabies Task Force. In 2006, rabies was finally detected at the eastern extremity of the peninsula. In this paper, we summarize ORV efforts, explore possible causes for the spread of raccoon rabies onto the Cape, summarize several small-scale Cape Cod rabies research projects, and suggest a 5-year plan for future Cape Cod rabies controls efforts.

**KEY WORDS:** bait, Cape Cod, disease, oral rabies vaccination, ORV, *Procyon lotor*, rabies, Rabies Task Force, raccoon, surveillance, trap-vaccinate-release

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## INTRODUCTION

Rabies has plagued human and animal populations for millennia and remains a significant public and animal health problem. The virus has a long and storied history, as evidenced by appearances in the writings of Democritus in 500 B.C., and Aristotle in the 4<sup>th</sup> Century (Baer 1991). The first documented large-scale rabies outbreak occurred in Franconia in 1271, where at least 30 humans died during a rabies epizootic among wolves, while the first reference to rabies in the Americas was from a Spanish missionary in Mexico in 1703 (Baer 1991). Despite advances in vaccines and other rabies control measures, the virus occurs today in all but a few locations world-wide. Under certain circumstances, rabies control in domestic, feral domestic, and wild animal populations is achievable. However, success is dependent upon adequate responses by concerned agencies and beneficial medical, veterinary, and techno-

logical advances. We present a brief overview of rabies ecology and control world-wide and specific information on an effort to control the spread of a terrestrial variant of rabies virus on a northeastern coastal peninsula.

## Global Public Health Impacts from Rabies

Worldwide, rabies infections result in approximately 55,000 human deaths annually (WHO 2006) and more than 10 million human exposures in need of prophylaxis, as well as considerable fear and suffering. The economic costs of rabies prevention and control are estimated at over \$300 million for the United States alone (CDC 2007a). Furthermore, rabies management in much of the developing world is hampered by inadequate rabies surveillance, which likely underestimates the occurrence of the virus and reduces the perceived importance of the problem among top-level administrators of human and an-

imal health programs (WHO 2006). Many of the human deaths from rabies in developing nations are a direct result of infrastructure inadequacies. Sub-standard vaccines; a lack of resources and facilities for purchasing, storing and administering pre- and post-exposure rabies vaccinations; and insufficient education all play a role (WHO 2006). Overabundant and frequently unvaccinated domestic animal reservoirs perpetuate this serious ongoing public health problem.

## **Rabies Epizootiology**

### ***Domestic Rabies Reservoirs***

Rabies reservoirs over most of the world remain primarily domestic and feral dogs (*Canis familiaris*), which are implicated in most human rabies deaths (WHO 2006). Although numerous attempts at canine rabies prevention and control have been undertaken in various locations, complete elimination has been achieved under only limited circumstances, such as where aggressive parenteral vaccination occurs. Despite the use of efficacious parenteral vaccines and oral rabies vaccination (ORV), which led to canine rabies virus variant-free status for the United States in 2007, canine rabies continues to pose a risk by translocation from its territories, possessions, or from foreign countries.

### ***Wildlife Rabies Reservoirs***

In North America, wildlife species surpass domestic species in terms of rabies occurrence. For example, 92% of all U.S. animal rabies cases were among wild animals in 2006 (CDC 2007b). Several rabies virus variants circulate in wildlife, threaten human and domestic animal health and safety, and are the focus of considerable research and management attention.

## **Rabies Management**

### ***Domestic and Feral Domestic Rabies Management***

Control of rabies in domestic animals (primarily dogs) can be achieved under certain circumstances (e.g., aggressive rabies vaccination has led to the elimination of canine rabies in the U.S.). However, other forms of rabies control such as population reduction have been less effective at combating the disease. For example, rabies remains a serious public health problem on Flores Island (Indonesia), where more than 295,569 dogs (~70% of all dogs there) were killed in an unsuccessful attempt to arrest the spread of the virus during 1998 - 2000 after a dog translocation event brought it to that previously rabies-free island (Windiyaniingsih et al. 2004).

### ***Wildlife Rabies Management***

Wildlife rabies management is complex and exigent. Traditional tools such as population reduction generally fail to achieve desired results. Further complicating matters, the transmission of rabies across political boundaries necessitates coordinated surveillance and control efforts that overlap borders and require cooperation and procedural standardization among governments at the local and international levels. While traditional rabies control cooperators are normally government entities (e.g., federal, state, and local public health, wildlife, and agriculture agencies), interaction with universities, pharmaceutical

companies, air service vendors, and others brings additional complexity.

Establishing sufficient population ("herd") immunity to stop the spread of rabies in wildlife with the parenteral vaccination used in domestic animals is problematic, due to budgetary constraints and the cryptic nature of wild rabies reservoir species. However, relatively new schemes for the oral rabies vaccination (ORV) of wildlife have met with some success. Success may be enhanced where ORV programs are designed to take advantage of substandard raccoon (*Procyon lotor*) habitats and landscape features that are physical barriers to the movement of the virus as ORV zone anchor points. However, ORV area integrity and success are frequently threatened by intentional or accidental animal translocation events. Examples include 1) Massachusetts, where wildlife rehabilitators are permitted to release animals at locations other than their original capture site under certain circumstances; and, 2) Florida, from which the translocation of raccoons northward in the late 1970s (Nettles et al. 1979) moved the then-novel raccoon variant of rabies hundreds of miles northward, leading to the current rabies epizootic in the northeastern U.S. that now threatens Canada and the mid-western United States.

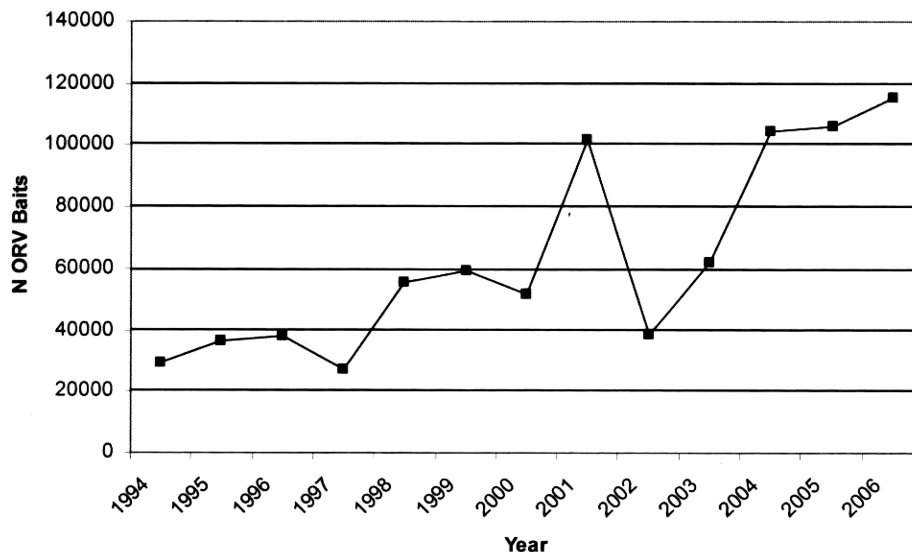
However, rabies control by ORV remains elusive, given the inadequacy of currently-available vaccines to sufficiently immunize an array of terrestrial rabies reservoirs, and the lack of durable and attractive baits capable of enticing target animals to consume those vaccines. Furthermore, shifting political will, an unstable economy, and the rising costs of ORV baits and fuel all have the potential to reduce the number of ORV doses that can be distributed, and thereby reduce program effectiveness.

## **THE CAPE COD EXAMPLE**

Upon the emergence of raccoon rabies in southeastern New England, the U.S. Centers for Disease Control and Prevention (CDC), the Tufts Cummings School of Veterinary Medicine, and the Massachusetts Department of Public Health began an ORV program designed to reduce the occurrence of carnivore rabies in an area directly adjacent to the Cape Cod Canal (1994 - present) (Robbins et al. 1998). In 2001, USDA APHIS Wildlife Services began full-time collaboration on the Cape Cod Oral Rabies Vaccination Program (CCORVP) as part of national wildlife rabies control efforts. The primary objective of the CCORVP was to use ORV in tandem with the physical barrier created by the Canal to prevent the spread of terrestrial rabies to peninsular Cape Cod, MA, a 1,067-km<sup>2</sup> (412-mi<sup>2</sup>) heavily-populated tourist destination southeast of Boston.

The spatial-temporal distribution and placement of ORV baits in relation to raccoon populations may influence bait uptake and associated levels of population immunity. Ground-based ORV efforts, over a relatively large geographical area of southeast Massachusetts adjacent to the Cape Cod Canal, may have been insufficient because of limited roadway access (e.g., large patches of forest or wetlands). Resulting ORV-coverage gaps represent potential foci or corridors through which raccoon rabies may spread and compromised larger rabies control efforts. Although target bait densities were generally met,





**Figure 1. Southeast Massachusetts ORV baits distributed, 1994 - 2006.**

and the variable treatment area tracked variations in bait numbers resulting from fluctuating budgets (Figure 1), the effectively baited proportions of the treated areas were frequently less than the area treated (i.e., bait distribution patterns could not be altered to cover habitats not easily reached from roadways, thus leaving un-baited gaps). Consequently, despite increasing bait numbers some years, bait distribution efforts may have been inadequate to overcoming this apparent limitation. In addition to potential gaps in bait distribution, other possible reasons for the rapid spread of rabies onto Cape Cod include intentional or unintentional translocation of incubating or rabid wildlife, and the dynamic nature of project funding.

Furthermore, because animal capture to assess program effectiveness is conducted within the same narrow corridors (roadsides) as ground-based ORV baiting, estimates of vaccination rates may be higher than in the actual raccoon population at risk and could result in misleading conclusions regarding program effectiveness. A larger-scope post-bait monitoring program may be required to ensure that estimates of antibody-prevalence from sampled animals on Cape Cod are representative of those of the population.

#### **Southeastern Massachusetts Rabies Surveillance**

Prior to the inception of the current enhanced rabies surveillance program on peninsular Cape Cod (in response to the 2004 emergency), rabies surveillance was public health-based, or focused on the mainland ORV zone (with the exception of portions of the towns of Bourne and Sandwich, which straddle the Canal). As is the case in many states, public health-based rabies surveillance for terrestrial rabies in Massachusetts is designed to provide a) information for medical decisions, and b) baseline knowledge of the distribution of rabies. All animals involved in human or animal exposure events that are available are tested. In addition, non-exposure-related rabies suspect specimens are tested until no more than 2 test positive for a terrestrial variant of rabies. Upon detection of a second case of terrestrial rabies, the town is declared rabies endemic and no further non-exposure-related rabies surveillance testing

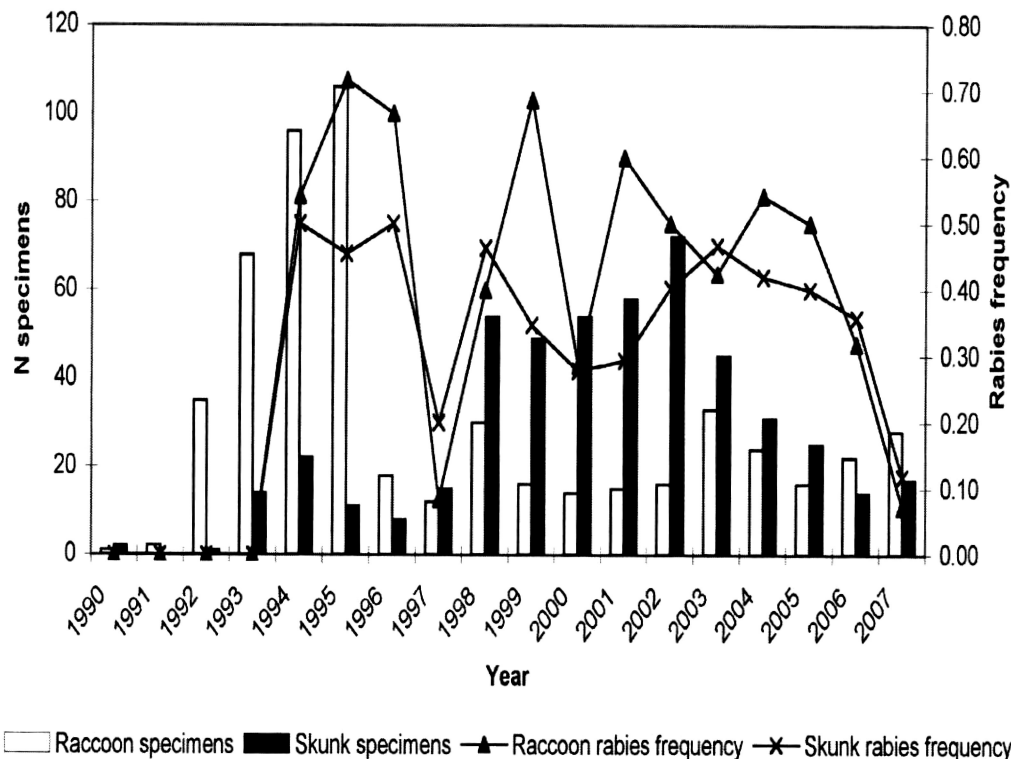
is normally conducted. As a consequence, public health-based rabies surveillance is often not spatial-temporally sensitive for formulating wildlife rabies control strategies. During 1994 - 2007, Plymouth County rabies surveillance resulted in median annual specimen submission and rabies frequency values of 20 and 0.41 for raccoons, and 19.5 and 0.35 for skunks (Figure 2).

#### **The Cape Cod Rabies Emergency**

Despite modifications to the ORV zone, raccoon rabies was detected for the first time on peninsular Cape Cod in March 2004. Enhanced surveillance, a trap-vaccinate-release (TVR) campaign, and ORV baiting was implemented for the remainder of peninsular Cape Cod within a few weeks of index case detection. In response to the presence of raccoon rabies in the northeastern United States, and to complement the statewide interagency co-operation already occurring through the Massachusetts Rabies Advisory Committee, the Cape Cod Rabies Task Force was formed in 1994. In 2004 it increased its meeting frequency and communications to help member towns and agencies keep abreast of rabies-related developments, and to encourage enhanced surveillance efforts and continued volunteer participation in ORV bait distribution.

#### **Enhanced Rabies Surveillance**

Rabies surveillance in Barnstable County during 1990 - 2003 (except for the towns of Bourne and Sandwich) was primarily public health-based. Median annual rabies specimen submissions and rabies frequencies from that county were 10 and 0, and 4 and 0 per year for raccoons and skunks, respectively (except from a small area of Barnstable County, which is on the mainland portion of Cape Cod). However, once enhanced surveillance (based on the removal and rabies diagnosis of suspect raccoons and skunks, road kills, and specimens submitted by private nuisance wildlife control operators) began on peninsular Cape Cod (2004 -present), median specimen submission rates increased (raccoons = 245, skunks = 56.5). Median rabies frequencies were lower (raccoons = 0.29, skunks = 0.20) in Barnstable County than for neighboring enzo-



**Figure 2. Plymouth County, Massachusetts wildlife rabies surveillance, 1990 - 2007.**

otic Plymouth County, possibly reflecting a population vaccination effect, a frequency dampening effect from increased and variable sampling, or both, as part of enhanced surveillance (Figure 3). We continue enhanced surveillance on Cape Cod to assess the distribution and frequency of raccoon rabies there, and to increase our understanding of the virus in raccoons as well as in skunks, since the relationship between raccoon rabies and skunks is poorly understood (Guerra 2003).

#### **Trap, Vaccinate, Release**

During April 14-27, 2004, 481 unique raccoons and 20 unique skunks (*Mephitis mephitis*) were captured over 3,800 trap-nights in the towns of Bourne, Sandwich, Mashpee, and Falmouth. All captured raccoons and skunks were injected with 1 cc of Imrab™ (donated by Merial, Duluth, GA); sampled for rabies virus neutralizing antibodies, age, ORV bait uptake, sex, weight, and reproductive condition; ear-tagged; and released at the point of capture. Despite this effort, raccoon rabies was detected beyond the initial control area and continued to spread eastward, due at least in part to insufficient enhanced surveillance to direct the focus of TVR efforts. In addition, the implementation of TVR as a strategy in tandem with ground (and minor amounts of aerial) ORV baiting, in the face of a major rabies epizootic, may have been inadequate in scale and scope to stop the spread of rabies on Cape Cod.

#### **ORV**

Expanded ORV efforts were also unsuccessful in preventing the initial spread of the virus. In 2004 alone, 101,898 ORV baits were distributed aerially and from the ground in an unsuccessful attempt to halt the spread of the virus (Figure 4). Subsequent control efforts with primarily

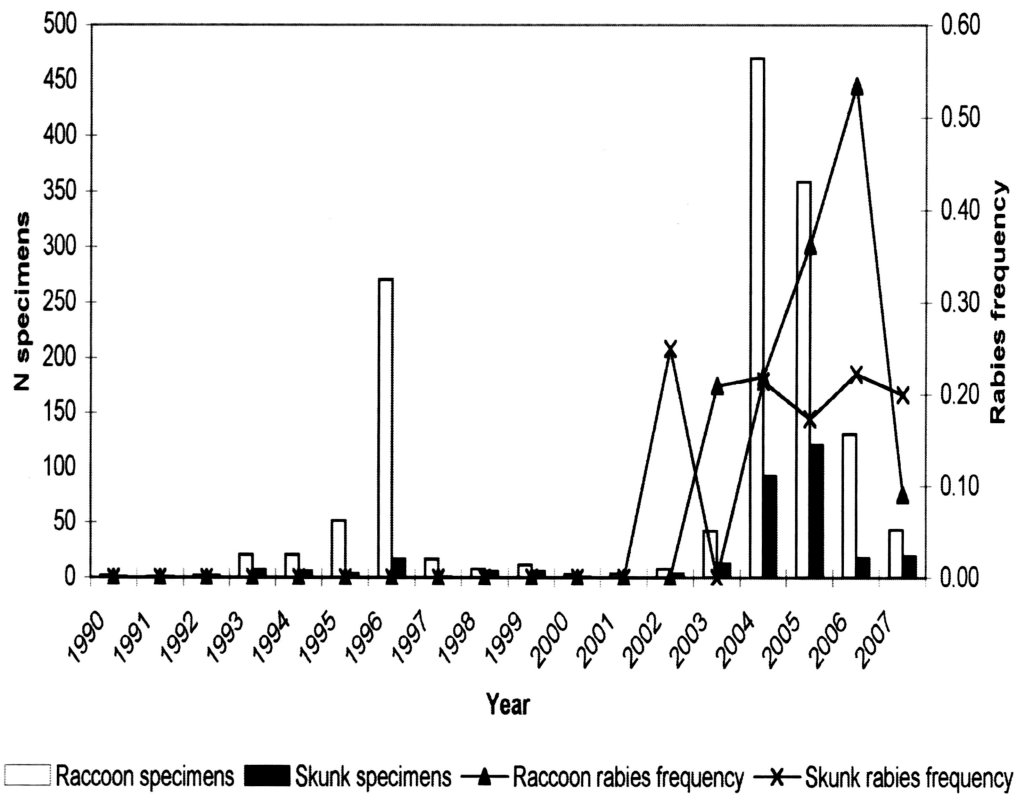
ground-based ORV and opportunistic TVR were unable to prevent rabies from eventually spreading across Cape Cod. ORV baiting continues there today in an effort to reduce rabies and begin the process of rabies elimination from the outer Cape (Figure 5).

#### **Cape Cod-Based Research in Support of Rabies Control**

In addition to the goal of rabies elimination for Cape Cod, the CCORVP presented an unparalleled opportunity for research into rabies epizootiology, vector ecology, and control strategies. Some of these projects to date have included a) an assessment of potential raccoon activity and abundance in pitch pine/scrub oak habitat through density surveys, track station visitation (Algeo et al. 2004) and automatic camera-based indexing efforts; b) estimates of relative raccoon densities in highly developed coastal communities; c) an assessment of the utility of bait stations for ORV bait distribution to raccoons in highly developed areas; d) an investigation into the relative importance of competing raccoon food items during ORV baiting campaigns (Bjorklund et al. 2008); e) tests of the relative performance of different bait formats in terms of vehicle-based distribution characteristics; and f) enhanced rabies surveillance results, and strategy development and refinement (Bjorklund et al. 2006).

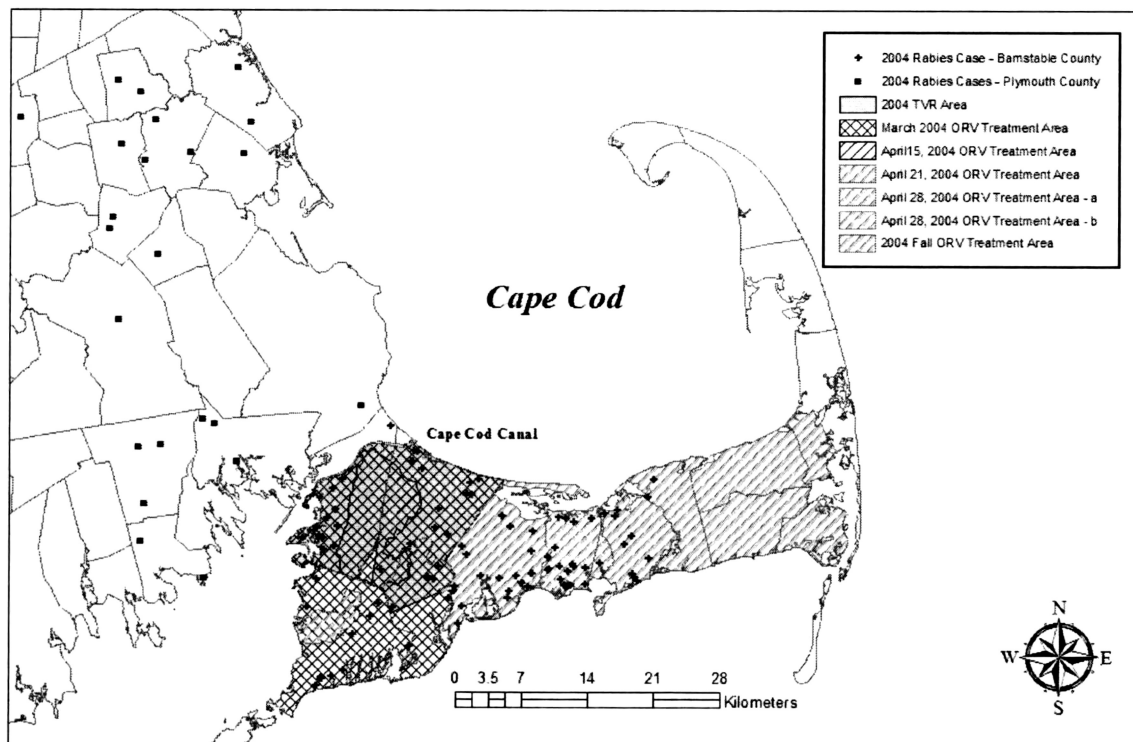
#### **A 5-Year Plan for Rabies Control on Cape Cod**

We call upon the CCORVP to develop and implement a 5-year plan for the elimination of raccoon rabies from peninsular Cape Cod. Aggressive enhanced surveillance, combined with a TVR program and well-organized and documented ORV bait distribution campaigns, should be a critical component of this plan. In addition, we be-

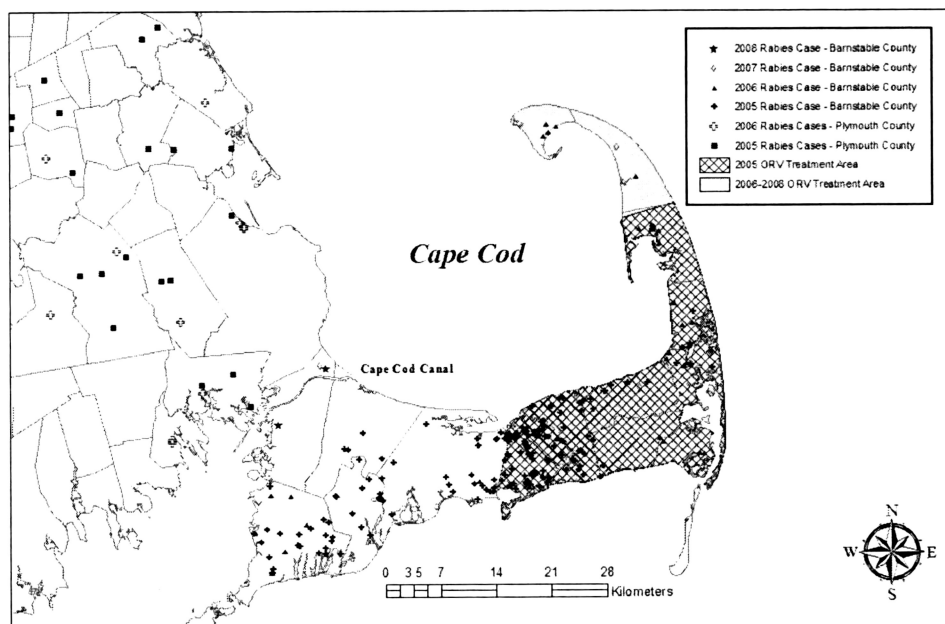


**Figure 3. Barnstable County,<sup>1</sup> Massachusetts wildlife rabies surveillance: 1990-2007.**

<sup>1</sup> The towns of Bourne and Sandwich are within Barnstable County, but straddle the Canal. Sampling occurred on both sides prior to the 2004 peninsular Cape Cod rabies epizootic, although most cases represented after 2004 were from the peninsular portion of the Cape.



**Figure 4. Rabies cases and oral rabies vaccination zones in Southeastern Massachusetts, 2004.**



**Figure 5. Rabies cases and oral rabies vaccination zones in Southeastern Massachusetts, 2005 - 2008.**

lieve ORV zones should be moved to the west, in response to 'rabies-free' status in contiguous Cape Cod towns after at least 2 years rabies-free, given adequate enhanced surveillance (WHO 2004). The ultimate goal of the Cape Cod wildlife rabies management program should be 1) the elimination of terrestrial rabies and reducing associated human and animal health risks and costs from the area, and 2) the establishment an effective ORV zone to prevent its return.

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