Terrestrial Rabies Surveillance on Cape Cod: A Community-Based Multi-Agency Strategy to Provide Critical Information for Rabies Control

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ABSTRACT: Knowledge of the rate and extent of spread of epizootic diseases is critical to facilitate effective management. Terrestrial rabies was first detected in spring 2004 on Cape Cod Massachusetts, compromising a long-standing ORV zone established from the west side of the Cape Cod Canal to serve as a barrier to raccoon rabies spread onto the Cape. In March 2004, USDA Wildlife Services and local and state cooperators implemented a surveillance program to track the spread of rabies on Cape Cod for planning contingency action strategies aimed at containment and elimination. During 13 months of enhanced rabies surveillance, 198 (167 raccoons and 29 skunks) out of 942 specimens tested positive for rabies. We discuss management implications of these results to the Cape Cod Oral Rabies Vaccination program and to other integrated rabies control programs.

KEY WORDS: epidemiology, Massachusetts, oral rabies vaccination, rabies contingency planning, raccoon, surveillance, terrestrial rabies, trap-vaccinate-release

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BACKGROUND

USDA APHIS Wildlife Services (WS) has cooperated in the Cape Cod Oral Rabies Vaccination program (CCORV) since 2001. Cape Cod is a popular tourist destination southeast of Boston, Massachusetts, which features a 3-fold human population increase during the summer. Consequently, lessons learned from rabies control activities on Cape Cod will likely have broad applicability to future rabies control efforts in coastal, suburban, and urban areas with high human population densities.

The CCORV is a Tufts Cummings School of Veterinary Medicine, Massachusetts Department of Public Health (MADPH), Barnstable County Department of Health and the Environment, WS cooperative project designed to protect Cape Cod from terrestrial rabies. The CCORV barrier (ranging from 420-712 km^2, depending on annual funding) was first established from the Cape Cod Canal westward in 1994, shortly after raccoon (*Procyon lotor*) variant rabies was first detected in southern New England. Other cooperators include local natural resource, animal control, police, and health departments; Centers for Disease Control and Prevention; the Senior Environment Corps/Elder Services; the United States Coast Guard; the National Park Service; the Massachusetts State Police; Humane Society of the U.S. Cape Wildlife Center; nuisance wildlife control operators; and a private courier service.

In early 2004, the raccoon variant of the rabies virus was first detected on the ocean side of the Cape Cod Canal, representing a compromise of the CCORV barrier. As a result, the CCORV program conducted contingency actions including a 13-day trap-vaccinate-release (481 raccoons and 20 skunks) and oral rabies vaccination (101,898 ORV baits in 2004) program that resulted in treatment of more than 700 km^2, based in part on the Ontario Point Infection Control program (Rosatte 2000) in an attempt to stop the spread of rabies. Subsequent CCORV rabies control efforts have been conducted exclusively on the ocean side of the Canal, with the goals of 1) stopping the spread of raccoon variant rabies across Cape Cod, and 2) eliminating the variant from Cape Cod through continued ORV baiting and hand-vaccination of raccoons and striped skunks (*Mephitis mephitis*).

Knowledge of the rate and extent of spread of infectious disease is critical to the development of management strategies. Municipal and other officials receive numerous calls from their constituents requesting investigation of or assistance with sick, strange-acting, or nuisance wildlife. Call volumes frequently increase during epizootic events, especially when featured by media outlets, and can overwhelm under-staffed and under-funded municipal governments. Consequently, responses to requests for assistance frequently focus on situations for which an immediate threat to human health and safety is imminent. While this approach has the potential for providing adequate public health responses, it is often not sufficiently sensitive for characterizing and monitoring rabies epizootics.

Enhanced rabies surveillance is specifically directed at detecting the presence of rabies beyond those cases involving rabies exposures to humans or their companion mammals. Samples include sick or strange-acting animals, roadkills, animals found dead, and animals removed for wildlife damage control purposes. A primary goal of the CCORV program during this time was to level the surveillance effort among Cape Cod municipalities, as the considerable variance in available resources between towns was assumed to result in uneven surveillance effort intensity.

METHODS

Starting in March 2004, WS and cooperators implemented an ongoing enhanced rabies surveillance program to track the rabies epizootic on Cape Cod for a) planning, b) collecting epizootiological data, and c) reduction of municipal infrastructure-based variation in rabies surveillance specimen submissions. Primary activities of the CCORV rabies surveillance program were the collection, preparation, and transportation of sick, strange-acting, or nuisance specimens acquired from or through municipal officials and roadkill surveys. Rabies specimens were tested by the Massachusetts Department of Public Health Laboratory Institute via the direct florescent rabies antibody method. Test results were communicated to WS and other cooperators via telephone and mail, and they were confirmed through database exchanges at the end of operational periods. Rabies specimen data and test results were entered into the CCORV rabies database, and categorized based on source types (Table 1). In most cases, rabies surveillance specimen source analyses were performed only on data from animals collected directly by WS during March 2004 to March 2005.

Specimen Acquisition

Cooperators in the CCORV program developed a network and decision model for enhancing rabies surveillance on Cape Cod (Figure 1). Development of and adherence to a decision scheme was to a) reduce the potential for confusion over specimen acquisition duties, and b) separate specimens submitted for public health reasons from enhanced rabies surveillance specimens.

Sick or Strange-Acting Rabies Suspect Animals

Rabies surveillance specimens were collected from residences, businesses, and other locations by municipal officials or WS based on reports from the public or other cooperators. Sick and strange-acting animals were euthanized primarily by town officials. Specimens collected by municipal officials were made available to WS either at the location first reported, or in cold storage. WS or HSUS Cape Wildlife Center prepared and submitted specimens via courier service to the MADPH Laboratory Institute for rabies testing as described below. Specimen locations were provided by town officials, and entered into a surveillance database for conversion to latitude/ longitude data via geocoding in ArcGIS™.

Table 1. Prevalence of rabies among surveillance specimens (all species) collected by WS on Cape Cod during March 2004 - March 2005[1].

Source Type	*n*	Rabies-positive (%)	Unsuitable for testing (%)[2]
Residential Complaint-based	128	27 (21)	12 (9)
Roadkill	45	2 (4)	23 (51)
Commercial/Business	8	1 (13)	0
Trapped (deemed sick after capture)	7	2 (29)	0
Other (forested, recreational area)	4	1 (25)	0
Unknown	21	3 (14)	0
Total	**213**	**36 (17)**	**35 (16)**

[1]does not include specimens submitted directly by municipal governments.
[2]specimens deemed unsuitable for testing in the field by WS or in the lab by MADPH Laboratory Institute

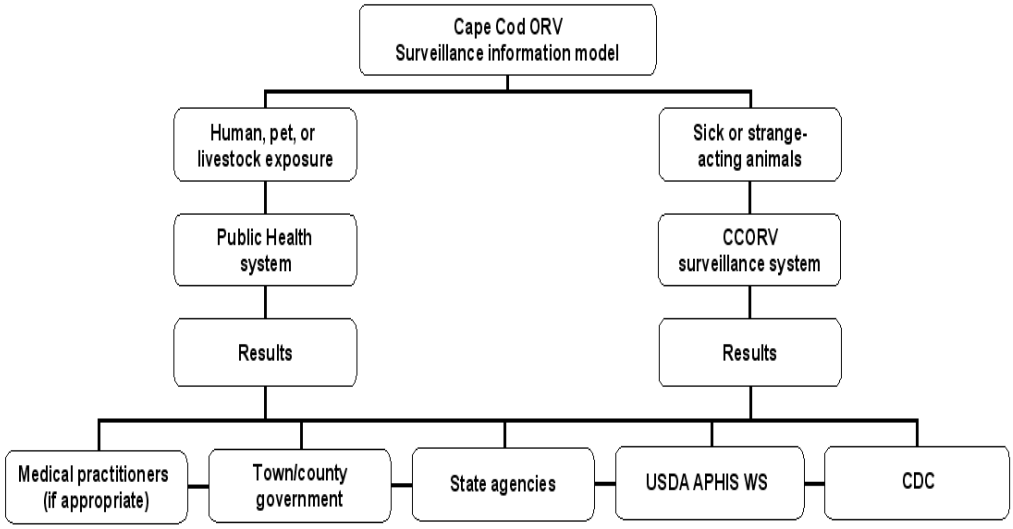


Figure 1. Cape Cod ORV surveillance information model.

Road-Killed Animals

Road-killed raccoons and skunks were collected and prepared by WS and submitted via HSUS Cape Wildlife and a private courier service for submission to MADPH Laboratory Institute for rabies testing. Latitude and longitude data were recorded for each specimen.

Other Animals

Seven raccoons captured as part of rabies bait-uptake analysis trapping displayed potential signs of rabies. These were humanely euthanized and submitted to the MADPH Laboratory Institute for rabies testing.

Specimen Preparation

Morphological data were collected from all potential rabies surveillance specimens including weight, sex, age (tooth/mandible extracted), and reproductive condition. These data will be reported elsewhere. Specimens were screened for viability as rabies test specimens based on decomposition and cranial condition. Those considered suitable for submission were decapitated, refrigerated or frozen (depending on anticipated submission timetable), and submitted to the MADPH Laboratory Institute via private courier service.

RESULTS

Enhanced rabies surveillance on Cape Cod began in March 2004. Specimen submission rates varied considerably (n = 33 in June 2004, to n = 144 in March 2005) (Figure 2), based on the availability of personnel, season effects on raccoon and skunk behavior, and the likely effects of rabies and other disease conditions on population size. Variation in the rabies surveillance effort between towns was related principally to differences in municipal-level infrastructure and budgets (Figure 3).

Rabies Test Results

The CCORV enhanced rabies surveillance program submitted 942 specimens for rabies testing on Cape Cod from March 2004 - March 2005, with 198 (21%) testing positive for rabies. Among raccoons submitted (n = 682), 24% were rabies-positive; of skunks submitted (n = 163), 29 (18%) were rabies-positive; and of the 97 specimens of other species submitted, 2% (1 coyote, *Canis latrans*; and 1 bat, *Myotis* spp.) tested positive for rabies (Figure 4).

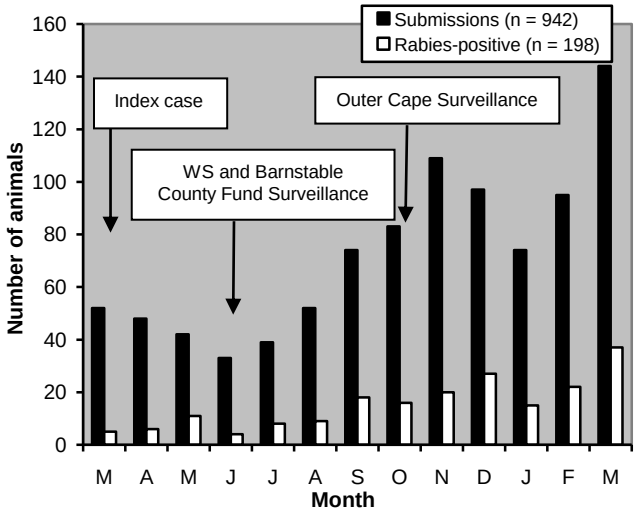
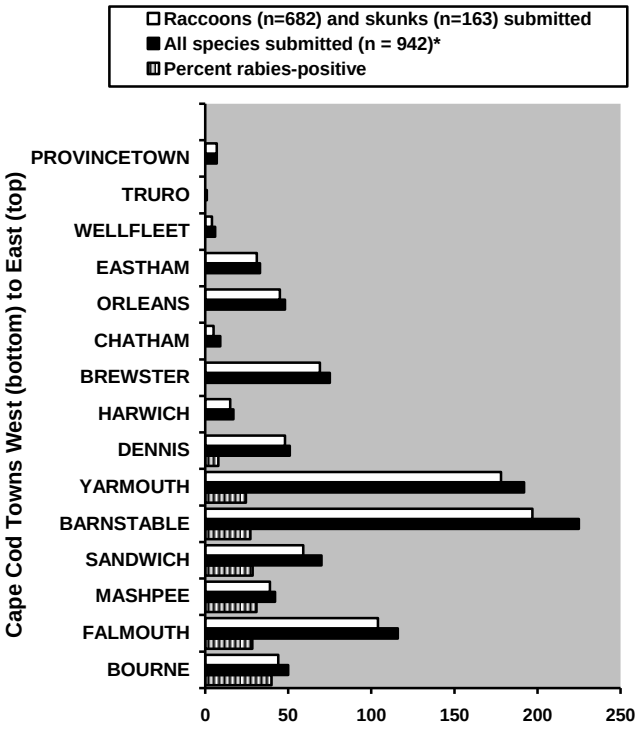
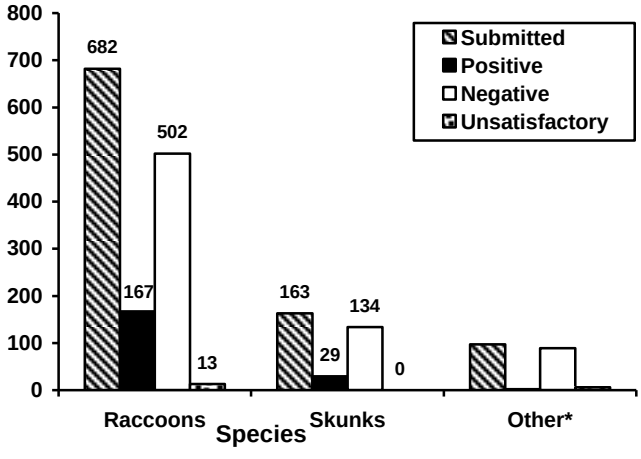


Figure 2. CCORV rabies surveillance, March 2004 - March 2005.



*Other species include bat (19/1), fox (11/0), cat (26/0), dog (17/0), squirrel (8/0), coyote (2/1), rabbit (2/0), mouse (1/0), muskrat (2/0), woodchuck (1/0), shrew (1/0), opossum (7/0).

Figure 3. Cape Cod rabies prevalence by town, March 2004 - March 2005.



*Other species include: bat (19/1), fox (11/0), cat (26/0), dog (17/0), squirrel (8/0), coyote (2/1), rabbit (2/0), mouse (1/0), muskrat (2/0), woodchuck (1/0), shrew (1/0), opossum (7/0).

Figure 4. Cape Cod rabies prevalence by species, March 2004 - March 2005.

Rabies Specimen Sources

Considerable variation in positivity and suitability for testing was noted for specimens obtained by WS from different specimen source categories. The greatest number of specimens (n = 128), and the third highest positivity rate (21%) of all types was noted for specimens from the "Residential Complaint-based" category. Categories with high positivity and low submission rates included "Trapped" and "Other." The source categories "Unknown" and "Commercial" had low numbers collected and low positivity, while the "Roadkill" category provided a larger sample but very low positivity (Table 1).

Rabies Specimen Age and Sex Data

Age (adult:juvenile) and sex (M:F) ratios of 5.9:1 (n = 138) and 1.4:1 (n = 115) were observed among raccoons, and of 44:1 (n = 45) and 1.1:1 (n = 40) among skunks. Age (n = 26) and sex (n = 54) were not determined for badly damaged or decomposed specimens. Adult raccoons collected for rabies surveillance (n = 118) exhibited a 24% positivity, while 15% of the juvenile raccoons (n = 20) tested positive. Of the raccoons tested for rabies, 14% of the males (n = 67) and 15% of the females (n = 48) were positive. Of the 45 skunks collected by WS, just 1 adult female tested positive for rabies (Table 2).

Table 2. Age and sex of rabies surveillance specimens (% positive) collected by WS on Cape Cod during March 2004 - March 2005[1].

Age/Sex	Raccoon	Skunk
Adult	118 (24)	44 (2)
Juvenile	20 (15)	1 (0)
Unknown Age	20 (20)	6 (0)
Male	67 (14)	21 (0)
Female	48 (15)	19 (5)
Unknown Sex	43 (14)	11 (0)

[1]does not include specimens submitted directly by municipal governments.

DISCUSSION

Municipal-level probabilities of rabies detection on Cape Cod were affected by budget-related variation in surveillance effort among municipalities, as well as other factors such as season, habitat, and disease effects in raccoon and skunk populations. The impact of low levels of infrastructure among some outer Cape Cod municipalities was confounding to efforts to delineate the epizootic front for planning management activities, and extra efforts were made to assist these municipalities with responses to complaints and other specimen collection opportunities.

Rabies Test Results

The 24% rabies prevalence (n = 682) (Figure 4) found among raccoons from Cape Cod during March 2004-March 2005 was consistent with raccoon rabies prevalence rates reported in raccoons in Florida (3-36%; McLean 1975), Maryland (22%; Anthony *et al*. 1990), and Virginia (32%; Torrence *et al*. 1992). In contrast with these findings, Hubbard (1985) reported a 74% prevalence of rabies (n = 422) in Virginia raccoons. Although potential factors contributing to the disparity in rabies prevalence rates between Cape Cod and Virginia raccoons are unknown, a difference in adult:juvenile ratios among these (Cape Cod = 5.9:1 and Virginia = 1.9:1) is likely a contributing factor.

Rabies Specimen Sources

Consistent with previously published analyses of the impacts of human population density (Jones *et al*. 2003), and public awareness (Torrence *et al*. 1992) on raccoon rabies epizootic detection, specimen submissions from the "Residential Complaint-based" category exceeded those from all other rabies specimen submission categories on Cape Cod. However, rabies-positivity for the "Residential Complaint-based" category ranked third behind the "Trapped" and "Other" source categories (Table 1).

Although the epizootiology of raccoon and skunk variant rabies outbreaks may differ in important ways, several publications have addressed potential relationships between human demographics/public awareness campaigns and the detection of rabies in skunks. In Oklahoma, distance to laboratory and human population distributions both affected rabies detection (Lewis 1972), and in Arkansas, a public awareness campaign was reported to have likely influenced specimen submission rates (Heidt *et al*. 1982). However, analysis of these potential factors was beyond the scope of this project.

Animals that were decomposed or badly damaged were difficult to age and sex with certainty (Table 2). A high percentage of these were road-killed rabies specimens. However, roadkill specimen suitability was not compared among months or seasons, and the potential for a temperature effect should be evaluated.

Rabies Specimen Age and Sex Data

The adult:juvenile ratio for raccoons sampled between March 2004 and March 2005 on Cape Cod by WS was (5.9:1), possibly suggesting an older, inverted population age structure. A considerably higher adult to juvenile ratio (44:1) would seem to suggest a skunk population that may be in decline as well. However, both age ratios should be re-examined for a potential season-based submission rate effect.

Data collected on Cape Cod also revealed a higher number of male raccoons collected than females as part of enhanced surveillance (1.4:1); 14% of the male raccoons and 15% of the female raccoons tested positive for rabies. Hubbard's (1985) study revealed that 60% of their specimens submitted were female, 81% of which tested positive for rabies; male raccoons (40% of specimens submitted) showed 69% positivity. The slightly larger number of male raccoons collected by WS on Cape Cod during this study may reflect a maternity-based reduction in adult female activity during spring. Skunks sampled displayed a sex ratio slightly closer to 1:1, but with the same male bias. As with age ratios, the sex ratios might have been affected by season-based submission rate differences which may merit exploration.

Non-Target Rabies Surveillance Specimens

The CCORV surveillance program occasionally transported non-target specimens at the request of local

officials. While the importance of testing every potential rabies vector of concern to local officials is recognized, specimens other than raccoons, skunks, and foxes were considered relatively unimportant to the CCORV surveillance program.

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