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Authors: Olson, Cathy A., and Werner, Patricia A.

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ORAL RABIES VACCINE CONTACT BY RACCOONS AND NONTARGET SPECIES IN A FIELD TRIAL IN FLORIDA

Cathy A. Olson[1,2,3] **and Patricia A. Werner**[1]

[1] University of Florida, Department of Wildlife Ecology and Conservation, 303 Newins-Ziegler Hall, P.O. Box 110430, Gainesville, Florida 32611-0430 USA

[2] Current address: Charlotte County Natural Resources Section, 18500 Murdock Circle, Port Charlotte, Florida 33948 USA

[3] Author to whom requests for reprints should be sent

ABSTRACT: Rabies is enzootic in raccoons (*Procyon lotor*) in the eastern United States. Oral vaccination of free-ranging raccoons against rabies has the potential to control the disease in a principal reservoir and reduce the risk of rabies exposure among domestic animals and humans. Free-ranging animal contact with baits containing a vaccinia virus recombinant vaccine expressing the rabies glycoprotein gene (V-RG) was monitored in Pinellas County (Florida, USA) from February through May 1997. Bait contact was assessed with 423 tracking plate nights; conducted in four land use zones: single residential, multiple residential, industrial-commercial, and undeveloped. The undeveloped land use zone was further described by six vegetation communities: mangrove swamp, red maple swamp, beach dune, pine forest, mixed oak hammock, and cabbage palm hammock. Seven animal taxa contacted the baited tracking plates across the four land use zones: raccoons, opossums (*Didelphis virginiana*), cats (*Felis catus*), dogs (*Canis familiaris*), rabbits (*Sylvilagus* sp.), unidentified rodents, and birds. A total of 252/413 (61%) of the baits was contacted by animals; 95 (38%) of these were specifically by the raccoon, the target species. Overall bait contact by all animals was significantly different among the four land use zones, being highest in the undeveloped zone (82%) and lowest in the industrial-commercial zone (34%). Bait contact by raccoons also was significantly different among the undeveloped and pooled urban zones. Among the six vegetation communities, bait contact by all animals was significantly different ranging from 95% in the mangrove to 50% in the cabbage palm hammock. Among the four vegetation communities tested, bait contact by raccoons also was significantly different.

Key words: Field trial, oral vaccination, *Procyon lotor,* rabies, raccoon, vaccinia recombinant virus.

INTRODUCTION

Rabies is enzootic in raccoons (*Procyon lotor*) in the eastern United States from Florida to Maine. Oral vaccination of raccoons against rabies has the potential to control the disease in a principal reservoir and reduce the risk of rabies exposure among domestic animals and humans. An oral rabies vaccine, consisting of a vaccinia virus recombinant containing the rabies virus glycoprotein gene (V-RG), has proven to be an effective oral immunogen in raccoons (Rupprecht and Kieny, 1988) and is incapable of causing rabies in any of the species tested (Rupprecht et al., 1992). The first North American release of this V-RG vaccine occurred on Parramore Island (Virginia, USA) in 1990 (Hanlon et al., 1998). Currently, the V-RG vaccine is being tested as a rabies control measure in several parts of the United States (Krebs et al., 1997; Fearneyhough et al., 1998; Roscoe et al., 1998; Robbins et al., 1998).

Successful wildlife vaccination programs require effective baits and baiting strategies for self-delivery of the vaccine to the target species. This requires the monitoring of individual vaccine-laden baits to determine the animals that come in contact with them. Animals that come in contact with the bait must be identified in order to determine which species compete with the target species for the bait. Potentially, baiting strategies may then be tailored according to the fate of baits in different habitats so that the proportion of baits contacted by the target species is maximized. Once nontarget species have been identified, the bait can be reformulated, if necessary, to decrease the attractiveness of the bait to various nontarget species.

Several studies have evaluated potential baits and baiting strategies for delivering oral rabies vaccines to raccoons in the United States. However, most of the published studies have been conducted on undeveloped barrier islands or in non-urbanized mainland areas that lacked the complete mainland faunal assemblages (Hadidian et al., 1989; Hanlon et al., 1989; Perry et al., 1989; Hable et al., 1992; Linhart et al., 1994). Only one published study has been conducted in a highly urbanized mainland area (Hadidian et al., 1989). No bait contact studies have been conducted on the mainland south of Virginia or in highly urbanized landscapes. This study was specifically designed to assess which animal species contacted V-RG vaccine-laden baits and to determine whether there were differences in contact among four land use zones and among six vegetation communities in a highly urbanized county in west-central Florida.

MATERIALS AND METHODS

Study site description

Pinellas County is a 54.4 km long peninsula located on the west-central coast of Florida (USA; 27°50′N; 82°45′W). It has the highest population density (1,158.3 people per km^2) in the state and includes the city of St. Petersburg. By 1990, 81% of the county's 800 km^2 had been developed. An additional 65.3 km^2 were slated for development, leaving only 86.7 km^2 of undeveloped land, mainly consisting of environmentally sensitive areas or nature preserves (Pinellas County Planning Department, 1995).

Land use zones and vegetation communities

Four land use zones were designated according to the dominant land use: single residential (SR), multiple residential (MR), industrial-commercial (IC), and undeveloped (UN). The SR zone consisted of areas that were primarily single family homes, excluding mobile home parks. The MR zone consisted of apartment complexes and mobile home parks. IC zones were business districts where houses were uncommon. UN zones consisted of parks, reserves, and other minimally developed land. The three urban zones (SR, MR, and IC) consisted of both county and privately owned land located throughout the county wherein 11, seven, and 17 different sites were selected, respectively, for monitoring. The UN zone consisted of eight sites selected for monitoring including seven parks or reserves and other undeveloped land.

Within the UN areas, six vegetation communities were designated, including mangrove swamp, red maple swamp, beach dune, pine forest, mixed oak hammock, and cabbage palm hammock. Vegetation communities follow the descriptions of Myers and Ewel (1990) except for the pine forest, which is a combination of their pine flatwoods and sand pine scrub. The dominant species in mangrove swamps were red mangrove (*Rhizophora mangle*) and black mangrove (*Avicennia germinans*). Red maple swamps were dominated by red maples (*Acer rubrum*), but water oak (*Quercus nigra*), Carolina willow (*Salix caroliniana*), dahoon holly (*Ilex cassine*), elderberry (*Sambucus canadensis*), and red bay (*Persea borbonia*) were common. Dominant plants along the beach dunes included beach elder (*Iva imbicata*), salt grass (*Distichlis spicata*), sea oats (*Uniola paniculata*), and an unidentified member of the goosefoot family, Chenopodiaceae. Pine forests were dominated by slash pine (*Pinus elliottii*) with an understory primarily of saw palmetto (*Serenoa repens*). Sand pine scrub, a habitat type within the pine forest category, was dominated by sand pine (*P. clausa*) with sand live oak (*Q. geminata*), and myrtle oak (*Q. myrtifolia*). Mixed oak hammocks included live oaks (*Q. virginiana*), water oaks, laurel oaks (*Q. hemisphaerica*), slash pine, and cabbage palms (*Sabal palmetto*). Cabbage palm hammocks were dominated by cabbage palms, with an understory of saw palmetto and grasses.

Vaccine-laden baits

The V-RG rabies vaccine is contained in a plastic sachet embedded within a rectangular fishmeal polymer bait. Each sachet contains 2 ml live Vaccinia vector rabies vaccine, (Merial Limited; formerly Rhone Merieux, Inc., Athens, Georgia, USA). The fishmeal polymer bait (Bait-tek Inc., Beaumont, Texas, USA) contains a tetracycline HCl biomarker.

Tracking plates

Bait contact was monitored indirectly, using 423 tracking plate nights. Each tracking plate night was the period from when the tracking plate was set and baited to the following morning when the tracking plate was monitored for disturbance. Each tracking plate consisted of a 1 m^2 sheet of aluminum with a 30 cm^2 sheet of white paper secured to the center of the tracking plate with duct tape. Wooden frames, made of 2.5 cm pine, were attached to the bottom of the plate with sheet metal screws. Equal parts of black printer's ink (Sharp Electronics Corporation, Mahwah, New Jersey, USA) or black powder tempera paint (Dixon Ticonderoga Company, Maitland, Florida, USA) and vegetable oil (Kash n' Karry Food Stores Inc., Tampa, Florida, USA) were used as a tracking medium (Justice, 1961; Lord et al., 1970). The tracking medium was applied with a squeeze bottle and spread on the exposed aluminum with a paint roller. The vaccine-laden bait was placed on the center of the paper. Animal tracks remained on the paper after the animal walked through the tracking medium.

Individual tracking plates were placed along trails, habitat edges, or in yards spaced at least 50 m apart, to minimize repeated contacts by the same individual. Plates were set between 3 and 6 P.M. and were evaluated between 7 and 10 A.M. the following morning for the presence of bait, the condition of bait, and species tracks. Tracking plates were reused after securing a new piece of paper and reapplying the tracking medium. Each station was monitored daily for two days following the initial baiting. Baits were monitored only for a two-night period so that a greater variety of areas could be sampled. All baited tracking plates were monitored between February and May 1997.

Baits were considered to have been "contacted" if the bait had been disturbed (missing or partially eaten bait). Baits were considered to have been visited if the bait had not been contacted, but there were animal tracks on the paper. If the bait was contacted after the first night, it was replaced with a new bait for the second night. Baits that remained intact after the first night were left in place for the second night. Only those tracks left directly on the paper were included in the analyses. To reduce tracking plate losses, individual tracking plates that were destroyed or removed by humans were not repeated, but data from successful nights were included in the analyses.

All tracks made by animals other than raccoons were considered nontarget species. When there were tracks of more than one species, a multiple species category was used, with all species noted. All multiple species contacts, even those that included a raccoon, were considered nontarget for analyses purposes, since it was impossible to determine which animal took the bait. This method provided a conservative estimate of raccoon contact. When baits were contacted but no discernable prints were left on the tracking paper, an undetermined category was used; this category was considered nontarget for analyses.

An approximate 3 m area surrounding the tracking plate was searched for bait remains when disturbance occurred. If remnants of baits that were contacted were found, the condition was noted. Contacted baits were classified as either partially or completely consumed, and sachets were classified as either punctured or intact. The bait was assumed to have been consumed if the sachet was found, but the fishmeal bait was missing. No distinction was made for contacts where the bait was consumed, but the vaccine chamber was rejected. A sachet was assumed to have been punctured if there was a vaccine stain on the paper, regardless of whether the sachet was located. When an animal contacted a baited tracking plate, but no trace of the bait was found, the bait was counted in a "not found" category.

Nontarget species

The opossum (*Didelphis virginiana*), mink (*Mustela vison*), river otter (*Lutra canadensis*), striped skunk (*Mephitis mephitis*), spotted skunk (*Spilogale putorius*), coyote (*Canis latrans*), red fox (*Vulpes vulpes*), gray fox (*Urocyon cinereoargenteus*), domestic dog (*Canis familiaris*), bobcat (*Lynx rufus*), domestic cat (*Felis catus*), feral pig (*Sus scrofa*), and armadillo (*Dasypus novemcinctus*) were identified as nontarget mesomammals that could potentially contact the vaccine-laden bait. In addition to the mesomammals, small mammals, such as rodents, particularly the black rat (*Rattus rattus*) and the rice rat (*Oryzomys palustris*), were identified as nontarget species that could potentially contact the bait. Avifauna that could potentially contact the bait included the black vulture (*Coragyps atratus*), turkey vulture (*Cathartes aura*), fish crow (*Corvus ossifragus*), American crow (*C. brachyrhynchos*), and gulls (Laridae). Reptiles and amphibians also were included as potential nontarget species; however this was unlikely because of the large size of the bait. Insects, especially ants (Hymenoptera) and beetles (Colepotera) have the potential to destroy the baits and were considered nontarget species.

Statistical analysis

Bait contact was statistically analyzed for all animals combined as well as for raccoons alone. Comparisons were made among the four land use zones and among the six vegetation communities using Chi-square goodness-of-fit and Bonferroni 95% confidence intervals (Byers et al., 1984; Mills et al., 1991). Since there were fewer than five raccoon contacts in each of the three urban zones (SR, MR, and IC), they were pooled together so that the Chi-square goodness-of-fit test would be valid to test bait contact by raccoons in these land use zones. Similarly, two vegetation zones (mixed oak and cab-

TABLE 1. Animal contact with baits containing an oral rabies vaccine in four land use zones in Pinellas County, Florida.

Land use zone	Number of baits	Total number of baits contacted	Raccoon	Opossum	Cat	Dog	Rodent	Undetermined	Multiple species
Single Residential	91	46 (51)	4 (9)[a]	17 (37)	5 (11)	3 (7)	1 (2)	7 (15)	9 (19)[b]
Multiple Residential	52	26 (50)	2 (8)	14 (54)	2 (8)	—	2 (8)	3 (11)	3 (11)[c]
Industrial-Commercial	87	30 (34)	2 (7)	6 (20)	6 (20)	—	1 (3)	10 (33)	5 (17)[d]
Undeveloped	183	150 (82)	87 (58)	38 (25)	1 (<1)	—	—	2 (1)	22 (15)[e]
Total	413	252 (61)	95 (38)	75 (30)	14 (6)	3 (1)	4 (2)	22 (9)	39 (15)

[a] (n) = %; Percentages associated with the species are based on the number of baits contacted.
[b] Four of the multiple species contacts included a raccoon.
[c] Two of the multiple species contacts included a raccoon.
[d] Three of the multiple species contacts included a raccoon.
[e] Twenty-two of the multiple species contacts included a raccoon.

bage palm hammocks) were omitted from the Chi-square goodness of fit test so that it would be valid to test raccoons within the six vegetation communities. Bonferroni expected values for bait contact in each land use zone or vegetation community were computed by multiplying the percent of baits contacted over all four land use zones (252/413, 61%) by the number of baits placed in each zone or vegetation community. Bonferroni expected values for raccoon contact were computed by multiplying the percent of baits contacted by raccoons over all four land use zones (95/252, 38%) by the number of baits that were contacted in each land use zone or vegetation community. All four land use zones and six vegetation communities were used for all Bonferroni Confidence intervals. Statistical significance was determined at $P \leq 0.05$.

RESULTS

Ten of the 423 tracking plates were destroyed, mostly by humans, and were omitted from analyses. Of the 413 successful tracking plate nights, 61% (252) of the baits were contacted by raccoons, nontarget animals, or a combination of the two (Table 1, 2). Baits were contacted by raccoons, opossums, cats, dogs, rodents, birds, and rabbits (*Sylvilagus* sp.). Raccoons contacted 23% (95/413) of the available baits and 38% (95/252) of the baits that were contacted. Nontarget species contacted 38% (157/413) of the available baits and 62% (157/252) of the baits that were contacted.

Bait contact, by all animals combined, was significantly different among the four land use zones ($\chi^2 = 66.36$, 3 df, $P < 0.001$). Bonferroni 95% confidence intervals reveal bait contacts by all animals occurred in the undeveloped zone (UN)

TABLE 2. Animal contact with baits containing an oral rabies vaccine in six vegetation communities of the undeveloped land use zone, in Pinellas County, Florida.

Vegetation community	Number of baits	Total number of baits contacted	Raccoon	Opossum	Cat	Undetermined	Multiple species[a]
Mangrove Swamp	42	40 (95)	35 (88)[b]	1 (2)	—	—	4 (10)
Red Maple Swamp	39	31 (79)	11 (35)	14 (45)	1 (3)	—	5 (16)
Beach Dunes	26	24 (92)	24 (100)	—	—	—	—
Pine Forest	50	38 (76)	14 (37)	15 (39)	—	2 (5)	7 (18)
Mixed Oak Hammock	12	10 (83)	—	5 (50)	—	—	5 (50)
Cabbage Palm Hammock	14	7 (50)	3 (43)	3 (43)	—	—	1 (14)
Total	183	150 (82)	87 (58)	38 (25)	1 (<1)	2 (1)	22 (15)

[a] All of the multiple species contacts included a raccoon.
[b] (n) = %; Percentages associated with the species are based on the number of baits contacted.

more often than expected by chance and less often than expected by chance in the industrial-commercial zone (IC). Overall, bait contact by all animals was highest in the UN zone and lowest in the IC zone.

Similarly, bait contact by raccoons, the target species, was significantly different among the three pooled urban zones (SR, MR, and IC) and the UN zone (χ^2 = 66.39, 1 df, $P < 0.001$). Bonferroni 95% confidence intervals reveal that raccoon contacts occurred less often than by chance in the single residential (SR), multiple residential (MR), and IC zones. Contact by raccoons was highest in UN areas, regardless of how it was calculated. Raccoons contacted 48% (87/183) of the available baits in the UN and 58% (87/150) of the baits that were contacted in the UN zone.

Among the six vegetation communities in the UN zone, bait contact by all animals combined was significantly different (χ^2 = 17.95, 5 df, $P < 0.003$). Bonferroni 95% confidence intervals reveal that bait contacts by all animals combined did not occur more often than by chance among the six vegetation zones. However, within the six vegetation communities, bait contact by all animals combined, occurred most often in the mangrove swamp (95%) and least often in the cabbage palm hammock (50%).

Among the four vegetation communities (mixed oak and palm hammocks omitted), bait contact by raccoons was significantly different (χ^2 = 45.70, 3 df, $P < 0.001$). Bonferroni 95% confidence intervals reveal that raccoon contacts occurred more often than expected by chance in the mangrove swamp. Raccoon bait contact in the mangrove swamp was 88% (35/40).

Bait contact by raccoons was low in the three urban zones. If the number of multiple species contacts with raccoons are added to the raccoon-only contacts, the number of baits potentially contacted by raccoons doubles within the three urban zones to 17% (8/46), 15% (4/26), and 17% (5/30) in the SR, MR, and IC zones, respectively. Raccoon contacts increase by 22 in the UN zone resulting in 73% (109/150) of the contacts. The number of baits contacted by the pooling of raccoons and these multiple species combinations increases from 23% (95/413) to 28% (117/413) of the total baits over all four land use zones.

Bait visits

At the majority of tracking plates with animal tracks, baits were actually contacted (the baits were at least partially eaten). On four occasions tracking plates were visited, but the baits were not contacted (no part of the bait was eaten). The visits included one raccoon in the mangrove swamp, one opossum in the red maple swamp, one cat in the MR zone, and one rabbit in the IC zone. None of the sachets was punctured in any of these visits.

Bait remnants

No remnants were located for the majority of the baits that were contacted (82%, 207/252) and were categorized as "not found". In contrast, bait remnants were located for 45 of the 252 (18%) contacted baits. Thirty-three baits had evidence of being contacted solely by raccoons. Of these 33, 16 (48%), were completely eaten and only the punctured sachets were found, seven (21%) were completely eaten but the sachets were intact, three (9%) were partially eaten with punctured sachets, and seven (21%) were partially eaten with intact sachets. The remaining 12 bait remnants were contacted by nontarget species, which included opossums (3), cats (5), a raccoon-nontarget species combination (2), multiple nontarget species combinations (1), and undetermined (1). Further details of bait remnants contacted by nontarget species can be found in Olson (1998).

Bait contact rate

The length of time for baits to be contacted was assessed over a two-night period using a subsample of 207 baits from all four land use zones. A total of 123/207 (59%) baits was contacted on the first night. Of the 84 remaining baits, an additional 29 (34%) baits were contacted by the second night. A total of 152 (73%) baits was contacted over the two-night period. A total of 55/152 (36%) baits was contacted by the same species on consecutive nights and was contacted by different species on 97/152 (64%) occasions. Details of the bait contact rate can be found in Olson (1998).

DISCUSSION

Raccoon contact

In this study, conducted on the mainland across a wide array of land use zones and vegetation communities, overall bait contact by raccoons was much less than that reported in previous field trials. In previous studies on barrier islands, raccoons contacted 89% of the available baits on Parramore Island, 100% on North Island (Virginia) (Hanlon et al., 1989), and 92% on Murphy Island (South Carolina, USA) (Hable et al., 1992). Raccoons contacted 72% of the baits that were contacted on Sapelo Island (Georgia, USA) and 45% of the baits that were contacted on the Chesapeake and Delaware Canal (Maryland and Delaware, USA) (Linhart et al., 1994). In contrast, raccoons alone contacted only 23% (95/413) of the available baits, and 38% (95/252) of the baits that were contacted in this study.

In Pinellas County, raccoon bait contact was similar to previous studies only along the beach dunes (100% of those that were contacted) of a barrier island park and in the mangrove swamps (88% of those that were contacted). Differences between bait contact by raccoons in this study and previous studies are likely due to differences in the degree of urbanization and/or relative extent and type of vegetation communities. Also, differences in bait type, species or density differences of nontarget competitors, the barrier island versus mainland status, and/or the time that the vaccine-laden baits were monitored may have played some role.

Differences in bait contact among the vegetation communities correspond with the preferred habitat types of raccoons. It is widely accepted that raccoons prefer wetlands to drier upland sites, especially upland southern pine forests (Leberg and Kennedy, 1988). Raccoon bait contact in Pinellas County was highest in the wetlands, including the beach dunes, mangrove swamps, and red maple swamps, and lower in the uplands, including pine forests, cabbage palm hammocks, and oak hammocks. Raccoon contact may have been even lower in the pine forest if areas adjacent to lakes and ponds had not been sampled.

Bait contact by raccoons was low in the three urban zones. Nearly half of the baits in the three urban areas were not contacted by raccoons. This observation does not appear to be a result of bait competition with nontarget species. Although raccoon contact within each of the three urban zones was less than 5% of the total available baits, almost half the baits were not contacted by any species. Bait contact by raccoons is still low even when multiple species contacts involving raccoons are pooled with raccoon contacts.

Quantifiable data regarding raccoon contacts in relation to vegetation density and distance to nearest water were not collected. However, habitat elements such as vegetation density, vegetation type, and permanent water may be useful predictors for bait contact by raccoons in urban zones. Stuewer (1943) claimed that the three essential habitat elements for raccoons are permanent water, tree dens, and available food. All raccoon contacts within the urban zones were in areas that had both mature trees and water. Four of the areas had both mature trees and water, three had only mature trees, and one site had sparse vegetation and water.

Raccoon abundance and density were not addressed within this study; however areas that showed high raccoon activity, based on tracks and scat, had more baits contacted than areas with fewer raccoon signs. The three urban zones appear to have lower raccoon activity than the parks in the undeveloped zone. Observations of raccoons in other urban-suburban zones show a preference for woodlots and parks over residential, commercial, or industrial zones (Rosatte and MacInnes, 1987; Hadidian et al., 1991).

Clearly, under the conditions present in our study area, what works well in the undeveloped setting, is not as effective in the urban areas. Many of the baits were either wasted on nontarget species or were not contacted at all in the three urban zones. Habitat factors that are favorable to urban raccoons must be identified and baiting should be concentrated in areas with these factors. Factors such as vegetation density and distance to water should be investigated as predictors for raccoon abundance. Once described, areas that have good predictors of raccoon use could be baited more heavily than mediocre or poor areas.

The easily removable vaccine chamber may present a problem in vaccinating the dexterous raccoon. The number of raccoons that actually came in contact with the vaccine is lower than the number of raccoon contacts reported. Fourteen of the 33 (42%) bait remnants that were contacted by raccoons had unpunctured vaccine chambers.

Nontarget contact

Nontarget animals contacted 62% (157/252) of all the baits that were contacted. The opossum is the leading competitor with the raccoon for baits in Pinellas County. Opossums took 30% of the baits that were contacted across the four land use zones and when multiple species combinations that included opossums are considered, nearly 44% of the baits could have been contacted by opossums. Opossum contact will be hard to control with bait placement or bait formulation because raccoons and opossums are both opportunistic omnivores that occupy similar habitats (Kissell and Kennedy, 1992).

It is unlikely that cats, dogs, rodents, rabbits, and birds were important competitors for baits in Pinellas County. However, some of the undetermined contacts were probably dog or bird contacts. Medium to large sized dogs can easily reach the bait without stepping on the tracking plate or paper. Most of the undetermined contacts were in residential areas where dogs are most common. Birds, especially crows, are also likely to have contacted baits in these areas. Crows contacted baits in placebo trials conducted by Perry et al. (1989) and Linhart et al. (1994).

Ten of the potential nontarget mesomammals, including gray and red foxes, coyotes, spotted and striped skunks, bobcats, feral pigs, armadillos, river otters, and mink, did not make contact with, nor visit, the baited tracking plates. With the exception of the armadillo, these species are rare throughout most of the county. Neither species of vulture, nor any member of the family Laridae, nor members of the classes Amphibia or Reptilia made contact with baits, nor visited, the tracking plates.

The bait contact rate according to individual species suggest that animals did not learn to associate the tracking plates with feeding stations over a two-night period. It is unlikely that an animal followed a line of tracking plates since consecutive tracking plates were rarely contacted by the same species. Consecutive tracking plates that were contacted by the same species were usually contacted by different individuals, based on the size of the tracks. Further, individual animals that contacted a baited tracking plate on the first night did not usually contact the bait on the second night.

Results indicate differences in the density and diversity of species among the land use zones and vegetation communities. Baits in the three urban zones, red maple swamps, pine forests, and cabbage palm hammocks were contacted by different species more often than by the same species, in contrast to baits placed in the beach, mangrove swamps, and oak hammock, which were usually contacted by the same species on the second night. Bait contacts on the beach and mangrove swamps were made almost exclusively by raccoons, while bait contact in the oak hammock was primarily by opossums. Based on raccoon contacts throughout the rest of the study areas, it is unlikely that the same individual raccoon contacted baits at the same tracking station on consecutive nights. Based on the abundance of raccoon tracks and scats, it is more likely that bait contact was high in these areas due to high population densities.

In order to develop the most effective and economical baiting strategies, future research should include the ecology of urban raccoons and the fate of individual baits within the urban zones in the eastern United States. Parks and woodlots in urban landscapes generally have high raccoon densities (Hoffmann and Gottschang, 1977) and bait contact by raccoons will most likely be high, as shown in this study. Factors affecting habitat use and bait contact by raccoons in the most developed zones must be identified, if baits are to be used most effectively. Future studies addressing raccoon population densities, home ranges, denning sites, and zone usage need to be conducted. The population densities and home ranges of competitors, like opossums should also be investigated.

One potential baiting regime in the urban landscape is cluster baiting (Hadidian et al., 1989), where known feeding sites, such as restaurant dumpsters, could be baited heavily. This baiting method can potentially vaccinate a high proportion of raccoons that are living in exceptionally high densities. This method may also be most important in targeting animals that have a high likelihood of coming into contact with humans. This cluster baiting should be compared with the more standard method of baiting areas with set bait densities.

A more intensive investigation into the fate of individual baits should be conducted. The vaccine chambers in roughly one-third of the recovered bait remnants, contacted by all animals, were not punctured. If this is representative of the majority of the baits that were not recovered, the baits may have to be reconfigured, so that the vaccine chamber is not so easily discarded. Animal visits, where no bait contact occurred, were low throughout this study, showing that the bait itself was highly attractive, to both raccoons and select non-target species.

The number of baits that were destroyed by ants was not quantified in this study. Ant contact with the baits did not occur on the tracking plates since the ink and oil mixture served as a barrier for ants. However, baits or portions of baits, that were knocked off of the tracking plates were often covered with fire ants (*Solenopsis invicta*) and probably inaccessible to raccoons. In areas where fire ants and Argentine ants (*Iridomyrmex humilis*) occur, bait destruction by these species may greatly alter the practical application of oral vaccination programs.

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