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TRAP-VACCINATE-RELEASE AND ORAL VACCINATION FOR RABIES CONTROL IN URBAN SKUNKS, RACCOONS AND FOXES

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ABSTRACT: Two rabies control tactics, trap-vaccinate-release (T-V-R) and oral vaccination were used for the control of rabies in skunks (*Mephitis mephitis*), raccoons (*Procyon lotor*), and foxes (*Vulpes vulpes*) in metropolitan Toronto, Canada. Using T-V-R, a mean of 45% to 72% (95% confidence limits of 40% to 81%) of the skunks and a mean of 17% to 68% (95% confidence limits of 14% to 76%) of the raccoons in a 60 km² area of Toronto were vaccinated against rabies between 1987 and 1991. The area has been free of skunk rabies from May 1989 to April 1992. Forty-five rabies cases were diagnosed during 1980 to 1986. In contrast, only three skunk cases have been reported since the vaccination program began in July 1987. The T-V-R area also remained rabies free during an epizootic of skunk rabies in metropolitan Toronto during 1991.

Following distribution of rabies vaccine-baits throughout the ravines of metropolitan Toronto, June 1989 to December 1991, 46% to 80% of the Toronto fox population was immunized during 1989, 1990 and 1991. Only one case of fox rabies was reported in metropolitan Toronto since vaccination began, compared to 80 cases reported between 1982 and 1988. The area has been free of reported fox rabies from October 1990 to April 1992.

Key words: Control, foxes, rabies, raccoons, skunks, urban, vaccination.

INTRODUCTION

Rabies has existed at enzootic levels in Ontario, Canada, for the last three decades. Between 1954 and 1990 about 55,000 cases were reported in wild and domestic animals, both in rural and urban areas of Ontario (MacInnes, 1988; Rosatte et al., 1990a). The red fox (*Vulpes vulpes*) has accounted for approximately 45% of the total diagnoses in Ontario, whereas striped skunks (*Mephitis mephitis*) represented about 20% of the reported rabies cases (Rosatte, 1988). As a consequence, most research has been focused on producing efficient vaccine and delivery systems for these two species.

One feasible system for control of rabies in foxes involves aerially dropping baits containing vaccine over rural southern Ontario (Johnston and Voigt, 1982; MacInnes, 1987; Johnston et al., 1988; Bachmann et al., 1990). However, distribution of baits by aircraft is not accurate enough to target small pockets of fox habitat in cities. Therefore, to combat an increase of fox rabies in metropolitan Toronto, Ontario (Fig. 1), staff of the Ontario Ministry

of Natural Resources distributed rabies vaccine-baits by hand-placement throughout the ravines of metropolitan Toronto during 1989, 1990 and 1991.

Skunk rabies also has been prevalent in metropolitan Toronto since the early 1960's (Fig. 1). Unfortunately, the vaccine developed for foxes does not immunize skunks (Lawson et al., 1987, 1989). However, a recombinant vaccine in a bait is still probably the most feasible approach for the control of skunk rabies in Ontario (Tolson et al., 1987, 1988). Development and testing of such a vaccine will require at least 3 to 5 years. Rather than wait for licensing of the recombinant rabies vaccine, the Ontario Ministry of Natural Resources implemented a trap-vaccinate-release (T-V-R) program for the control of rabies in skunks. The vaccine used is inactivated (Imrab®-Mérieux, MTC Pharmaceuticals, Mississauga, Ontario, Canada) and produces immunity when injected intramuscularly (Rosatte et al., 1987, 1990b).

Development of the T-V-R system was initiated in metropolitan Toronto in 1984 (Rosatte et al., 1987). During 1987 to 1991,

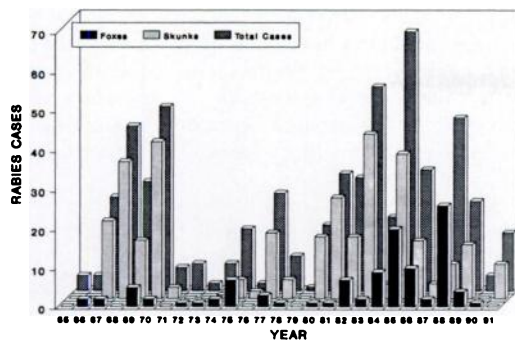


FIGURE 1. Rabies cases in metropolitan Toronto, Ontario, 1965 to 1991.

we used T-V-R to control skunk rabies in a portion of metropolitan Toronto. Data also were collected on raccoons (*Procyon lotor*) in the event that rabies control in that species might become necessary in the future. An epizootic of raccoon rabies which originated in the mid-Atlantic U.S. (Jenkins and Winkler, 1987) was about 80 km from the Ontario border in December 1991. Our objectives were to determine the feasibility of trap-vaccinate-release and oral immunization for the control of rabies in skunks, raccoons and foxes in cities.

MATERIALS AND METHODS

Skunk and raccoon rabies control

The T-V-R study area was a 60 km² section of metropolitan Toronto, Ontario (43°42'N, 79°25'W) (Fig. 2). The population density in this area is approximately 4,200 people/km². Toronto is a mosaic of residential, field, forested park, groomed grass (cemetery, golf course, playground), industrial and commercial areas (Rosatte et al., 1987).

The study area was divided into sixty 1-km² cells. Tomahawk live-traps #105, #106, #108 (Tomahawk Live-trap Company, Tomahawk, Wisconsin, USA) and Havahart #1079 (Havahart Live Trap Company, Niagara Falls, Ontario, Canada) baited with sardines were placed at densities of 50 per km² during 1987 and 1988, and at 75 per km² during 1989 to 1991. Each 1-km² cell was trapped for four consecutive nights. Traps were set wherever signs such as dens, scats or runways were evident. Trapping commenced during the first week of July and continued until October or November of each year. During 1988, only the outer perimeter of the study area, approximately 38% of the total area, was trapped due to a funding shortage.

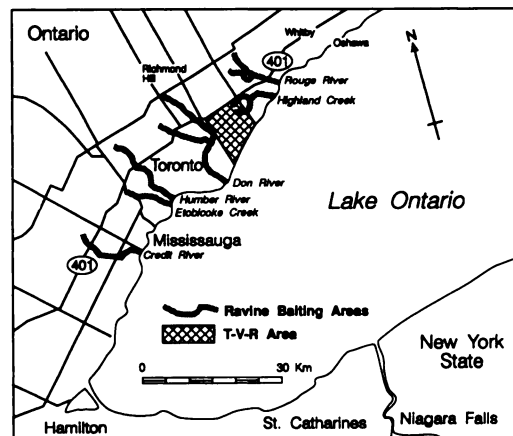


FIGURE 2. Location of the trap-vaccinate-release (T-V-R) and ravine baiting areas in metropolitan Toronto.

All captured skunks and raccoons were tagged with numbered size 1 and 3 ear tags (National Band and Tag Company, Newport, Kentucky, USA), hand vaccinated with a 1-ml intramuscular injection of Imrab® inactivated rabies vaccine and released at the point of capture (Rosatte et al., 1990a).

Twenty to 75 traps were placed in each 1 km² cell that had been trapped 1 wk to 3 mo previously to obtain an estimate of the skunk and raccoon population. A modified Petersen model was used to estimate the abundance of skunks and raccoons using the numbers of marked and unmarked animals that were captured (Begon, 1979). Because the entire T-V-R area was not trapped during 1988, an estimate of the skunk and raccoon population for that year was calculated using the ratio of different animals and ratio of capture success for the area trapped between 1987 and 1988 (Skalski et al., 1983). The proportions of skunks and raccoons captured and vaccinated was determined by dividing the number of each species captured during the initial trapping period by the estimated population size. A range of the percent captured was calculated by dividing the actual number of animals captured by the upper and lower population estimates (95% confidence interval). A simple linear correlation analysis was used to detect any relationship between the number of vaccine-baits contacted by foxes and the level of rabies neutralizing antibody present in blood serum samples (Zar, 1974).

Fox rabies control

We informed the public of the Ministry's urban fox rabies control program by issuing a news release to the Toronto area media during May

1989, 1990 and 1991. We requested that the public report fox sightings and locations of active fox pup-rearing dens. Ministry personnel then verified the sightings by observation as well as by track and scat identification.

During June 1989, 1990 and 1991, baits containing Evelyn-Rokitnicki-Abelseth (ERA) rabies vaccine (Bachmann et al., 1990; Lawson et al., 1989) were distributed at fox pup-rearing dens in metropolitan Toronto. Twenty baits were placed in a 2-m radius around each den site. Baits and vaccine were manufactured by Connaught Laboratories Limited, Willowdale, Ontario and Langford Laboratories, Guelph, Ontario. Ingredients for the bait-matrix included 59% tallow (Minor Meats Limited, Lowbank, Ontario), 32% microbond wax (International Wax Limited, Agincourt, Ontario), 8% mineral oil (Daminco Incorporated, Mississauga, Ontario) with 1% chicken essence (International Flavours and Fragrances, Concord, Ontario) as an attractant (Bachmann et al., 1990). Tetracycline (100 mg/bait) (Novapharm Limited, Toronto, Ontario) was added to the bait as a biomarker (Johnston et al., 1987) to indicate whether a fox had eaten a bait. Each bait contained an identifying label and telephone number. A labelled blister-pack (Novapharm Limited, Toronto, Ontario), was incorporated in the bait and contained 2 ml (liquid) of a modified live-virus rabies vaccine ERA strain propagated in the BHK-21 cell line (Lawson et al., 1989); the vaccine titer was about $10^{7.3}$ Fluorescent Antibody Test (FAT)/ml.

Because 1989 was the first time that we placed baits containing live-virus rabies vaccine in an urban environment, an effort was made to reduce human and companion animal contact. Baits were covered with debris. A conspicuous sign noting that the site was a baiting area for fox rabies control was posted at each station. A telephone number also was listed for information on the program. Baits were placed during the early evening and collected the next morning. Any missing or partially eaten baits were replaced the following evening so that 20 baits per night were available for foxes at each station during each baiting night, for five consecutive nights.

During June 1990 and 1991, 20 baits were placed at each den site and were not retrieved. The den sites were searched one week after baiting for uneaten baits and discarded blister packs containing the vaccine.

During October and November 1989 and June and October or November, 1990 and 1991, vaccine-baits were distributed along the major ravine systems of metropolitan Toronto: Credit River, Etobicoke Creek, Humber River, Don River, Highland Creek and the Rouge River

(Fig. 2). Baits were placed at approximately 50 m intervals along both sides of the waterway in each ravine system. Some areas received more baits than others because of the mosaic characteristic of the urban landscape; thus, forested parks were baited more heavily than commercial property.

To determine if foxes had eaten baits, a first premolar tooth was extracted from foxes immobilized with 25 mg/kg ketamine hydrochloride (Ketaset) (Rogar/STB Inc., London, Ontario). The foxes were live-captured using Novak foot snares (Ontario Trappers' Association, North Bay, Ontario) during a radio-telemetry program. Canine teeth were extracted from road-killed foxes. Teeth were sectioned and examined for tetracycline fluorescence according to Johnston et al. (1987). Blood was collected from live-captured foxes from the jugular vein. Blood samples from road-killed foxes were collected directly from the heart using a 10 ml syringe. Blood samples were centrifuged and the sera stored in 2-ml serum pro-vials (Dynatech Laboratories, Chantilly, Virginia, USA) at -20°C . Sera were tested for rabies antibody using a fluorescent focus inhibition test (FIMT) (Zalan et al., 1979) and by the enzyme-linked immunosorbent assay (ELISA) (Barton and Campbell, 1988).

RESULTS

Skunk and raccoon rabies control

During 1987 to 1991, 9,181 animals were captured in the 60 km² study area over 91,405 trap-nights. Of those captures, 955 different skunks were taken on 1,702 occasions and 2,266 different raccoons were captured 3,736 times (Table 1). Other captures (3,743) included 2,365 cats (*Felis catus*), 604 woodchucks (*Marmota monax*), 377 rats (*Rattus norvegicus*), 184 grey squirrels (*Sciurus carolinensis*), 157 cottontail rabbits (*Sylvilagus floridanus*), 10 red foxes, 2 muskrats (*Ondatra zibethica*), 41 miscellaneous birds, one dog (*Canis familiaris*), one chipmunk (*Tamias striatus*) and one European hare (*Lepus europaeus*).

We estimate that we captured and vaccinated a mean of 52% to 72% (95% confidence limits = 47% to 81%) of the skunk population within the 60 km² study area during 1987, 1989, 1990, and 1991 (Fig.

TABLE 1. Capture success in the metropolitan Toronto, Ontario, T-V-R area, 1987 to 1991.

Year	Trap-nights	Total captures (all species)	Skunks T (D)*	Raccoons T (D)*
1987	14,119	1,432	195 (123)	606 (378)
1988	5,902	700	214 (114)	174 (128)
1989	22,316	2,048	447 (252)	885 (543)
1990	24,774	2,326	438 (216)	854 (487)
1991	24,294	2,675	408 (250)	1,217 (730)
Total	91,405	9,181	1,702 (955)	3,736 (2,266)

* T, total number of animals captured; D, number of different animals captured.

3). Since we only trapped 38% of the study area during 1988, the percent captured estimate was much lower (45%) for that year (Fig. 3). In the year following vaccination, only 10% to 18% of all vaccinated individuals were captured in the study area (Table 2). This occurred because most captures were juveniles not present for vaccination the previous year. However, an estimated 27% to 58% of the adults captured during any given year had been vaccinated during a previous year (Table 2). During 1987, 1989, 1990, and 1991, we captured an estimated mean of 61% to 68% (95% confidence limits = 60% to 76%) of the estimated raccoon population (Fig. 4). The 1988 percent captured estimate was very low (17%) because we only trapped part of the area and also were concentrating on trapping skunks (Fig. 4). As with skunks, few (11% to 23%) vaccinated raccoons were found one year post-vaccination due to the high prevalence of juveniles in the population (Table 2). However, 28% to 63% of the adults had been vaccinated previously (Table 2).

Imrab was almost 100% effective in stimulating antibody response in sampled skunks and raccoons (Rosatte et al., 1990b). Therefore, the prevalence of rabies immunity in both populations should have been equivalent to the percent of the skunk and raccoon populations that were captured and vaccinated (Figs. 3, 4).

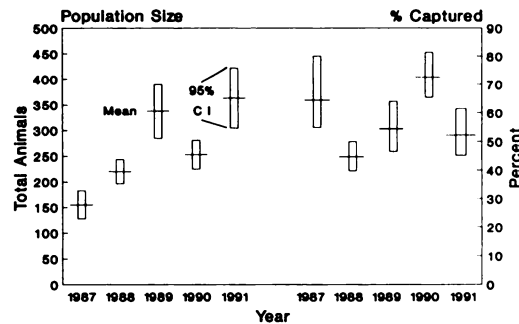


FIGURE 3. Skunk population and percent captured estimates for the 60 km² trap-vaccinate-release study area, 1987 to 1991. CI is confidence interval.

Fox rabies control

During 1989, 1990, and 1991, 66,168 vaccine baits were placed at fox dens and along 190 km of ravine systems in metropolitan Toronto at a mean density of 61 baits/km of ravine (Fig. 2, Table 3). Of the 1,170 baits placed at 28 fox pup-rearing dens during June 1989, at least 10 baits were removed by animals from each of 18 of the baiting stations. At one week post-baiting we found only 517 baits. Of these retrieved baits, 69% were not contacted by any species; 21% were chewed by carnivores (fox, skunk, raccoon); 5% by sciurids (woodchucks, squirrels, chipmunks); and 5% by cricetids (mice, rats or voles) as indicated by tooth impressions on the baits. We retrieved 164 blister-packs (vaccine containers without bait-matrix) following an intensive ground search. Of these, 90%

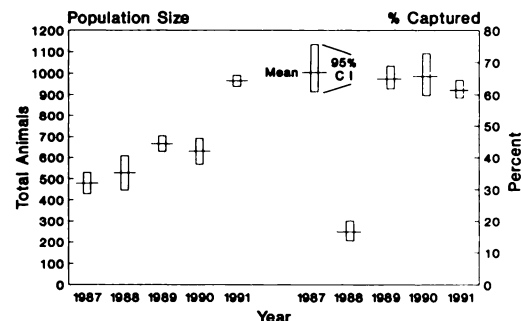


FIGURE 4. Raccoon population and percent captured estimates for the 60 km² trap-vaccinate-release study area, 1987 to 1991. CI is the confidence interval.

TABLE 2. Proportions of the skunk and raccoon population captured in metropolitan Toronto, Ontario, 1988 to 1991, that had been vaccinated during a previous year.*

Year	Skunks		Raccoons	
	Adults and juveniles	Adults only	Adults and juveniles	Adults only
1988	18/98 (18) ^b	18/31 (58)	20/87 (23)	20/32 (63)
1989	9/79 (11)	9/34 (27)	27/236 (11)	27/95 (28)
1990	29/202 (14)	29/82 (35)	84/471 (18)	84/223 (38)
1991	25/250 (10)	12/44 (27)	163/730 (22)	118/247 (48)

* Sample taken from skunks and raccoons captured during July, August, and September to reduce bias due to dispersing animals.

^b Number of animals vaccinated in a previous year and captured this year ÷ total number of animals captured this year (percent of animals captured this year vaccinated in a previous year).

(147) were well chewed and had no vaccine remaining. Of the chewed blisters, 93% (136/147) were due to foxes as indicated by tracks and visual observations in the area of the baiting station. Six percent (9/147) of the blister-packs were chewed by raccoons and 1% (1/147) by skunks as identified by tracks.

Following the June 1990 vaccine-bait distribution campaign, we found 78 blister-packs. All but one were well chewed and had no vaccine remaining. Most (86%) were chewed by foxes as indicated by tooth impressions. Seven blister-packs had been pierced by birds and four pierced by mice.

Of the foxes sampled between the summer of 1989 and the fall of 1991 baiting campaigns, 55% to 80% of the tooth sections contained tetracycline (Table 4). Rabies antibody was detected in 74% to 100% of the sera collected from foxes positive

for tetracycline (Table 4). Immunity for the sampled foxes was 46% to 80% during 1989–91 (Table 4). No foxes (0/18) collected outside of the baited areas were positive for tetracycline; however, three of 18 were positive for rabies antibody.

Of the foxes that ate baits during 1989 to 1991, 75% (33/44) had more than one tetracycline line in their tooth sections suggesting they had eaten baits on more than one day. Also, 52% (23/44) of the foxes had four or more tetracycline positive lines, meaning they had consumed a considerable number of baits over several days (Fig. 5). We detected no correlation between the number of tetracycline lines and titer for rabies antibody ($P > 0.50$) (Fig. 6).

DISCUSSION

Skunk and raccoon rabies control—trap-vaccinate-release

There was a rapid population turnover in our study area. Juvenile skunks and raccoons accounted for 55% to 70% of the annual fall populations between 1987 and 1990 (Rosatte et al., 1991). Also, only 10% to 23% of the 1988 to 1991 skunk and raccoon captures (both juveniles and adults) had been vaccinated during a previous year (Table 2). The low percentage of adults vaccinated during a previous year suggests dilution of the vaccinated population through immigration of animals from outside the vaccination area, or a high mortality among vaccinated adults (estimated to be 34% to 60%, Rosatte et al., 1991). The percent vaccinated estimates for

TABLE 3. Summary of rabies vaccine-baits distributed in metropolitan Toronto, Ontario, 1989 to 1991.

Baiting campaign	Total baits	Mean baits/km of ravine (SE) ^a
Fall 1989 ^b	10,262	49.3 (13.9)
Summer 1990	16,015	68.9 (17.8)
Fall 1990	11,520	60.5 (19.7)
Summer 1991	15,110	65.2 (19.9)
Fall 1991	13,261	61.3 (32.5)
Total	66,168	61.1 (22.7)

^a Baits placed at fox den, golf courses and park areas not part of the ravine systems were not included in the calculation of baits/km of ravine system; SE = standard error.

^b Includes 1,170 baits that were placed at fox dens in June, 1989.

TABLE 4. Sampled foxes in metropolitan Toronto, Ontario, positive for tetracycline and rabies antibody, 1989 to 1991.

Baiting campaign	Tetracycline ^a positive n (%)	Vaccine efficiency ^b n (%)	Immunity ^c n (%)
Summer 1989	6/11 (55%)	5/6 (83%)	5/11 (46%)
Fall 1989	7/10 (70%)	5/6 (83%) ^d	5/9 (56%) ^d
Summer 1990	21/27 (78%)	14/19 (74%) ^{e,f}	15/25 (60%) ^{e,f}
Fall 1990	4/5 (80%)	3/4 (75%)	4/5 (80%) ^g
Summer 1991	12/16 (75%)	11/12 (92%)	11/16 (69%)
Fall 1991	2/3 (67%)	2/2 (100%)	2/3 (67%)

^a Number of foxes that had contacted a bait and were positive for tetracycline ÷ number of sampled foxes (percent positive).

^b Number of animals seroconverting ÷ number of animals that had contacted a vaccine-bait (percent positive).

^c Number of animals seroconverting that had or had not contacted a vaccine-bait ÷ number of animals sampled (percent positive).

^d Blood sample was not available for one fox.

^e Blood samples were only available for 19 of the 21 tetracycline positive foxes.

^f Three of the blood samples were chest fluids from road-killed foxes and were partially hemolyzed; two of those were antibody negative and tetracycline positive.

^g One fox was antibody positive but tetracycline negative.

skunks and raccoons with recapture intervals of 2 to 3 mo post-initial capture were 10% to 24% lower than those with recapture intervals of 1 wk. Thus, more dilution may have occurred over time due to immigration (Rosatte, unpubl. data). For dilution of the vaccinated populations to occur, one might assume that the immigrating animals were fairly mobile. However, based on our telemetry and live-trapping program data, skunks and raccoons in the T-V-R area are fairly sedentary (mean annual movement <1 km) and exist at high densities (mean = 2 to 16/km²) (Rosatte et al., 1987, 1990a, 1991, 1992). Skunks and raccoons immigrating even small distances (<1 km) along the three

sides of the T-V-R area could easily account for the dilution of the vaccinated populations as the perimeter in question is 28 km in length (Fig. 2).

When using live-traps in a large metropolitan environment, one has to consider the amount of human interference encountered. Only 7% to 13% of our traps were disturbed on an annual basis. Most of that was due to animals digging under the trap to reach the bait. The key to success was communication of the program objectives to the public.

Trap-vaccinate-release is a very labor

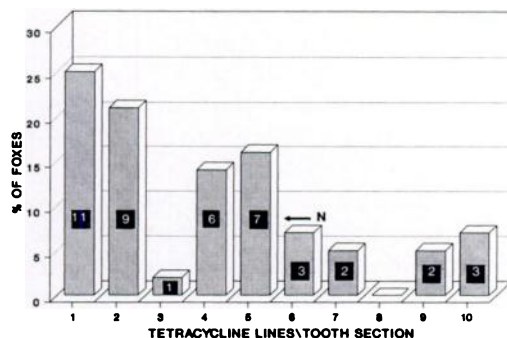


FIGURE 5. Frequency of tetracycline in tooth sections from Toronto foxes (N = 44), 1989 to 1991. N = sample size.

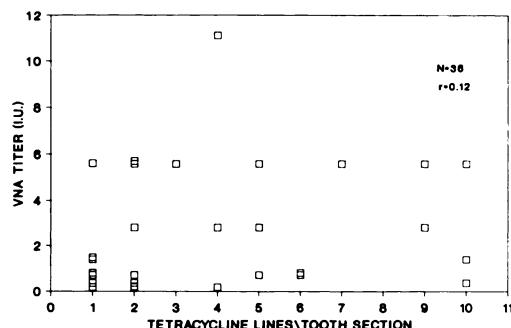


FIGURE 6. Number of tetracycline lines/tooth section and levels of serum virus neutralizing antibody in Toronto foxes, 1989 to 1991. VNA = rabies virus neutralizing antibody; I.U. = International Units; N = fox sample size; r = correlation coefficient. Striped boxes denote multiple samples (N = 3 to 7).

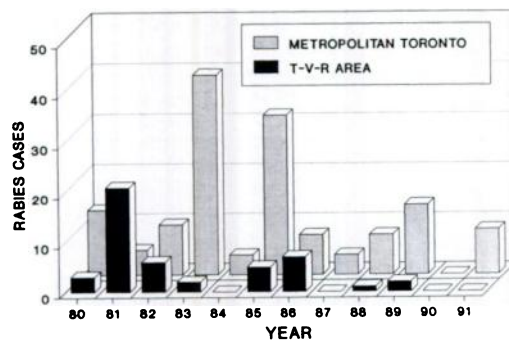


FIGURE 7. Skunk rabies cases in the trap-vaccinate-release (T-V-R) study area and in the remainder of metropolitan Toronto (excluding the T-V-R area), 1980 to 1991.

intensive and costly tactic for the control of rabies. Annual costs for T-V-R were between \$450 and \$1,150/km² (Canadian). This is the total program cost per year divided by the study area size. The cost was high because it included salaries for research staff as well as labor to retrap all areas to obtain an estimate of the population and the percent vaccinated. For conducting control only, the cost is less. The City of Windsor, Ontario, used T-V-R during 1990 to combat an outbreak of skunk rabies; the cost was about \$15,000 or about \$150/km².

Although use of T-V-R for rabies control appears expensive, T-V-R targeted for urban areas is cost-effective because the areas treated are not extensive and the cost of human exposure can be high. For example, more than 200 people per year in metropolitan Toronto receive treatment for exposure to rabid animals at a cost in excess of \$100,000 annually (Rosatte et al., 1990a).

It is postulated that 60% to 70% of a rabies vector population must be immunized to eradicate or control rabies (Steck et al., 1982; Voigt et al., 1985; MacInnes, 1988). Although our prevalence of vaccination for skunks and raccoons generally was lower, we believe that we controlled rabies in the 60 km² study area during 1987 to 1991. Based on the past prevalence of skunk rabies in the T-V-R area (Fig. 7), 30 cases were expected during the 5-yr period

(1987 to 1991). Since we initiated the T-V-R program in July 1987, only three cases of rabies in skunks have been reported and the area has been free of skunk rabies from May 1989 to April 1992 (Fig. 7). Two of the three skunk cases were on the periphery of the vaccination zone in 1988 and may have been animals migrating into the area. We expected some cases during 1989 since only 38% of the T-V-R area was vaccinated during 1988. Skunk rabies in metropolitan Toronto outside of our T-V-R area still persists (Fig. 7). In fact, an epizootic of skunk rabies (Fig. 7) in metropolitan Toronto during April to August 1991 did not invade the T-V-R area. As densities of skunks, and rabies incidence in Toronto, and in the T-V-R area were similar in the past, the two areas provide a valid comparison to assess the effectiveness of T-V-R as a rabies control tactic (Rosatte, 1986; Rosatte and MacInnes, 1987; Rosatte et al., 1987, 1990a).

Since skunk rabies has not been predictable in metropolitan Toronto (Fig. 1), we will monitor the situation for >5 yr before being confident that skunk rabies has been controlled through vaccination. In the meantime, we believe that T-V-R is a feasible alternative to oral immunization and might be used to combat rabies outbreaks in skunks or raccoons, especially in densely populated regions. An efficient oral vaccine, however, is likely to prove to be much more cost-effective.

Fox rabies control—oral immunization

With a mean baiting density of 50 to 70 baits per kilometer of ravine, we immunized 46% to 80% of the foxes in metropolitan Toronto. There is a general consensus that if 60% to 70% of a local fox population can be immunized orally, rabies will be eradicated or at least controlled (Steck et al., 1982; Schneider et al., 1988; Voigt et al., 1985; MacInnes, 1988). We have had only one reported case of rabies in a fox in metropolitan Toronto since we initiated our oral vaccination campaign, June 1989 to April 1992 (Fig. 1). That one

case was reported from the northeast edge of the outer perimeter of metropolitan Toronto; it may have been a fox dispersing from York or Durham Region. Based on the prevalence of rabies in foxes during 1982 to 1988 (Fig. 1), one would predict >33 cases. However, prior to 1982, rabies in metropolitan Toronto existed at low levels and was sporadic. This may have been a function of the reporting system. People currently are more aware of rabies due to government publicity campaigns and as a result of this, more rabid animals perhaps are being identified. Whatever the explanation, due to the non-cyclic pattern of fox rabies in Toronto, it is premature to claim success at rabies control.

Once an area is deemed to be rabies-free, how long should vaccination continue? If the area is geographically isolated to prevent re-infection by dispersing animals, cessation of vaccination 1 to 2 yr following the last reported cases may be appropriate. However, reinstatement of the vaccination program should occur immediately following a subsequent rabies diagnosis. Unfortunately, metropolitan Toronto is surrounded by areas enzootic for rabies in both foxes and skunks and therefore, vaccination must continue until rabies has been eradicated from those areas.

Safety considerations

The vaccine used in baits is considered safe and was approved for use by Agriculture Canada; however, we still took many safety precautions in placing a live virus vaccine in the city. Although we placed 66,168 rabies vaccine-baits throughout metropolitan Toronto, we were notified only in eleven instances that a person had encountered a bait. Of the public inquiries that we did receive, the main query was regarding the nature of our rabies control program. This is encouraging because there are more than three million people living in the baited area. As far as we can determine, there was no human contact with the vaccine, although two dogs did consume an entire bait each.

The low frequency of bait returns by the public was undoubtedly influenced by the camouflaged nature of the bait. However, the intensive communication program undertaken by the Ontario Ministry of Natural Resources, Communication Services Branch, probably played an important role by educating the public not to handle the baits. We believe education was the key to public acceptance of our program.

CONCLUSION

In our opinion, the most feasible technique for wildlife rabies control is oral vaccination with baits. Steck et al. (1982) apparently halted the spread of rabies in an area of Switzerland by immunizing 60% of the fox population using baits to deliver vaccine. Schneider et al. (1988) also reported success at rabies control in Germany, by orally immunizing 50 to 75% of the foxes in the control area. We also report success at immunizing foxes in Toronto with baits. However, an effective oral-vaccination baiting program has not been reported previously for the control of rabies in skunks or raccoons. For the immediate future, we propose the T-V-R technique for use in urban areas that combines capturing raccoons and skunks and hand-vaccinating by injection.

Although current studies support the suggestion that trap-vaccinate and oral immunization are feasible methods for rabies control, any actual claim to success at eradication or control can only be proved by a long term decrease in the numbers of rabies positive skunks and foxes in vaccinated areas.

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LITERATURE CITED

- BACHMANN, P., R. N. BRAMWELL, S. J. FRASER, D. A. GILMORE, D. H. JOHNSTON, K. F. LAWSON, C. D. MACINNES, F. O. MATEJKA, H. E. MILES, M. A. PEDDE, AND D. R. VOIGT. 1990. Wild carnivore acceptance of baits for delivery of liquid rabies vaccine. *Journal of Wildlife Diseases* 26: 486-501.
- BARTON, L. D., AND J. B. CAMPBELL. 1988. Measurement of rabies-specific antibodies in carnivores by an enzyme-linked immunosorbent assay. *Journal of Wildlife Diseases* 24: 246-258.
- BEGON, M. 1979. Investigating animal abundance: Capture-recapture for biologists. University Park Press, Baltimore, Maryland. 97 pp.
- JENKINS, S. R., AND W. G. WINKLER. 1987. Descriptive epidemiology from an epizootic of raccoon rabies in the middle Atlantic States, 1982-1983. *American Journal of Epidemiology* 126: 429-437.
- JOHNSTON, D. H., AND D. R. VOIGT. 1982. A baiting system for the oral rabies vaccination of wild foxes and skunks. *Comparative Immunology Microbiology and Infectious Diseases* 5: 185-186.
- , D. G. JOACHIM, P. BACHMANN, K. V. KARDONG, R. E. STEWART, L. M. DIX, M. A. STRICKLAND, AND I. D. WATT. 1987. Aging furbearers using tooth structure and biomarkers. *In* Wild furbearer management and conservation in North America, M. Novak, J. A. Baker, M. E. Obbard, and B. Mallock (eds.). Ontario Trappers Association, North Bay, Ontario, pp. 228-243.
- , D. R. VOIGT, C. D. MACINNES, P. BACHMANN, K. F. LAWSON, AND C. E. RUPPRECHT. 1988. An aerial baiting system for the distribution of attenuated or recombinant rabies vaccines for foxes, raccoons and skunks. *Review of Infectious Diseases* 10: 660-665.
- LAWSON, K. F., J. B. BLACK, K. M. CHARLTON, D. H. JOHNSTON, AND A. J. RHODES. 1987. Safety and immunogenicity of a vaccine bait containing ERA® strain of attenuated rabies virus. *Canadian Journal of Veterinary Research* 51: 460-464.
- , R. HERTLER, K. M. CHARLTON, J. B. CAMPBELL, AND A. J. RHODES. 1989. Safety and immunogenicity of ERA® strain of rabies virus propagated in a BHK-21 cell line. *Canadian Journal of Veterinary Research* 53: 438-444.
- MACINNES, C. D. 1987. Rabies. *In* Wild furbearer management and conservation in North America. M. Novak, J. A. Baker, M. E. Obbard, and B. Mallock (eds.). Ontario Trappers Association, North Bay, Ontario, pp. 910-929.
- . 1988. Control of wildlife rabies: The Americas. *In* Rabies, J. B. Campbell and K. M. Charlton (eds.). Kluwer Academic Publishers, Boston, Massachusetts, pp. 381-406.
- ROSATTE, R. C. 1986. A strategy for urban rabies control: Social change implications. Ph.D. Dissertation. Walden University, Minneapolis, Minnesota. University Microfilms, Ann Arbor, Michigan, 311 pp.
- . 1988. Rabies in Canada—History, epidemiology, and control. *Canadian Veterinary Journal* 29: 362-365.
- , AND C. D. MACINNES. 1987. A tactic to control rabies in urban wildlife. *Transactions of the Northeast Section, The Wildlife Society* 44: 77-79.
- , P. KELLY-WARD, AND C. D. MACINNES. 1987. A strategy for controlling rabies in urban skunks and raccoons. *In* Integrating man and nature in the metropolitan environment, L. W. Adams and D. L. Leedy (eds.). The National Institute of Urban Wildlife, Columbia, Maryland, pp. 161-167.
- , M. J. POWER, C. D. MACINNES, AND K. F. LAWSON. 1990a. Rabies control for urban foxes, skunks and raccoons. *In* Proceedings of the Vertebrate Pest Conference 14: 160-167.
- , D. R. HOWARD, J. B. CAMPBELL, AND C. D. MACINNES. 1990b. Intramuscular vaccination of skunks and raccoons against rabies. *Journal of Wildlife Diseases* 26: 225-230.
- , M. J. POWER, AND C. D. MACINNES. 1991. Ecology of urban skunks, raccoons and foxes in metropolitan Toronto. *In* Wildlife conservation in metropolitan environments, L. W. Adams and D. L. Leedy (eds.). The National Institute for Urban Wildlife, Columbia, Maryland, pp. 31-38.
- , ———, AND ———. 1992. Density, dispersion, movements and habitat of skunks (*Mephitis mephitis*) and raccoons (*Procyon lotor*) in metropolitan Toronto. *In* Wildlife 2001: Populations. Elsevier Scientific Publications, New York, New York. In press.
- SCHNEIDER, L. G., J. H. COX, W. W. MULLER, AND K. P. HOHNSBEEN. 1988. Current oral rabies vaccination in Europe: An interim balance. *Review of Infectious Diseases* 10: 654-659.
- SKALSKI, J. R., D. S. ROBSON, AND M. S. SIMMONS. 1983. Comparative census procedures using single mark-capture methods. *Ecology* 64: 752-760.
- STECK, F., A. WANDELER, P. BICHSEL, S. CAPT, U. HAFLIGER, AND L. SCHNEIDER. 1982. Oral immunization of foxes against rabies: Laboratory and field studies. *Comparative Immunology Microbiology and Infectious Diseases* 5: 165-171.
- TOLSON, N. D., K. M. CHARLTON, R. B. STEWART, J. B. CAMPBELL, AND T. J. WIKTOR. 1987. Im-

- mune response in skunks to a vaccinia virus recombinant expressing the rabies virus glycoprotein. *Canadian Veterinary Journal* 51: 363–366.
- , K. M. CHARLTON, K. F. LAWSON, J. B. CAMPBELL, AND R. B. STEWART. 1988. Studies of ERA/BHK-21 rabies vaccine in skunks and mice. *Canadian Journal of Veterinary Research* 52: 58–62.
- VOIGT, D. R., R. R. TINLINE, AND L. H. BROEKHOVEN. 1985. A spatial simulation model for rabies control. *In* Population dynamics of rabies in wildlife, P. J. Bacon (ed.). Academic Press, London, United Kingdom, pp. 311–349.
- ZALAN, E., C. WILSON, AND D. PUKITIS. 1979. A microtest for the quantitation of rabies virus neutralizing antibodies. *Journal of Biological Standardization* 7: 213–220.
- ZAR, J. H. 1974. *Biostatistical analysis*. Prentice-Hall Inc., Englewood Cliffs, New Jersey, pp. 236–248.

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