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CONTACT RATES OF RACCOONS (*PROCYON LOTOR*) AT A COMMUNAL FEEDING SITE IN RURAL EASTERN ONTARIO

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ABSTRACT: Intra- and interspecific contact rates of 12 adult (five females, seven males) raccoons (*Procyon lotor*) were recorded while these animals fed at a rural garbage dump 40 km north of Kingston, Ontario, Canada from 15 June to 5 September 1995. While raccoons were being observed, they bit, and were bitten, by their conspecifics an average of 0.99 ($\pm$0.21) and 1.28 ($\pm$0.21) times per hour, respectively, while feeding. Based on mean nightly contact rates (which included time when raccoons were not observed), raccoons bit one of their conspecifics once every 3 nights while feeding. The mean rate of bites made and received per hour for males was not significantly different from lactating females. There was no detectable difference between the mean rate of bites made and received per hour for raccoons which regularly versus occasionally fed at the dump. No interspecific contacts were observed, though raccoons and striped skunks (*Mephitis mephitis*) often fed at the dump concurrently. The contact rates in this study are the first to be calculated for raccoons directly from field data and will be useful as a point of reference for modeling rabies spread in raccoons in areas with similar site characteristics.

Key words: Communal feeding, contact rate, disease transmission, field study, *Procyon lotor*, rabies, raccoon, social behavior.

INTRODUCTION

Exposure to rabid wild animals poses a potential health threat to humans, livestock, other wildlife, and pets (Rosatte, 1988; MacInnes, 1988). One tactic used to control rabies in wildlife vectors such as red foxes (*Vulpes vulpes*) and raccoons (*Procyon lotor*) in Ontario (Canada) is to distribute from aircraft baits containing oral rabies vaccine (MacInnes, 1988; Bachmann et al., 1990; Rosatte et al., 2001). Effectiveness of this procedure can be enhanced when disease models are used to plan the timing and placement of aerial bait drops (Voigt et al., 1985; Broadfoot et al., 2001). One of the most important parameters in rabies models is the transmission rate, or the number of susceptible animals infected by a diseased animal per unit time (White et al., 1995).

Coyne et al. (1989) designed a model to evaluate strategies for controlling the raccoon strain of rabies which is currently enzootic in the eastern United States and was first reported in Canada during July, 1999 (Jenkins and Winkler, 1987; Wandeler and Salsberg, 1999; Rosatte et al., 1997, 2001). Although most of the model parameters were calculated directly from field data, transmission rate had to be estimated indirectly because no study quantifying intra- or interspecific rabies transmission rates of free-ranging raccoons had been published. This is probably because the nocturnal, secretive nature of wild raccoons makes direct observation of their social interactions difficult (Sharp and Sharp, 1956). Rabies transmission rate can be estimated directly by calculating the contact rate of healthy animals such as foxes (White et al., 1995). However, to our knowledge, no data currently exist in the literature noting contact rates for raccoons.

Because of their omnivorous and opportunistic feeding habits, raccoons quickly learn to exploit new, concentrated food sources such as feeding stations (Seidensticker et al., 1988). This behavior is most apparent in summer and early fall when raccoons are building up fat stores in preparation for winter dormancy (Mech et al., 1968; Rosatte, 2000). A heightened potential exists for both intra- and interspecific contacts and, hence, rabies transmission to occur at concentrated food sources because large numbers of raccoons as well as other mammals may be attracted to them (Seidensticker et al., 1988). In addition, common feeding areas offer a unique opportunity for observing, unobtrusively, the social interactions of wild raccoons (Sharp and Sharp, 1956).

The objectives of this study were to determine (1) the rate of intraspecific contacts relevant to the spread of rabies in raccoons with regard to the sex of the animal and frequency of visits to the dump, (2) the interspecies contact rates of raccoons at the dump with species to which they may transmit the raccoon rabies strain and from which they may contract the Arctic fox (*Alopex lagopus*) rabies strain, the only terrestrial rabies strain endemic in southern Ontario at the time of this study (MacInnes, 1988), and (3) the number of raccoons using the dump area, since population size may also affect the contact rate (Allen and Cormier, 1996).

MATERIALS AND METHODS

In this study, visual observations of raccoons feeding at a rural garbage dump in eastern Ontario were recorded from 15 June to 5 September 1995 as a preliminary attempt to quantify contact rates in raccoons. Trapping and behavioral observation took place 40 km north of Kingston, Ontario, at a private garbage dump (44°34′N, 76°20′W). This site was chosen because it was off limits to the general public, attracted many raccoons, and because of its proximity to the St. Lawrence River, one of the regions where raccoon rabies was most likely to enter Ontario from New York (USA)(Rosatte et al., 1997, 2001). The study area was a 2.3 ha clearing bisected by a 20 × 10 m band of garbage, and bound to the north by a disused Canadian National railway, to the south by a two-lane county road, to the west by a marsh, and to the east by a gravel road. Surrounding land consisted of farm land used for livestock, cottages, forest, and wetlands. Fresh garbage was deposited at the dump daily between 13:00 and 14:00 and often again between 18:00 and 19:00.

Raccoons were captured using Tomahawk #106 (Tomahawk Live-trap Company, Tomahawk, Wisconsin, USA), and Havahart #1079 (Havahart Live Trap Company, Niagara Falls, Ontario) live-traps baited with peanut butter and/or marshmallows. All raccoons trapped were tagged with two serial-numbered size three metal ear tags (National Band and Tag Company, Newport, Kentucky, USA); vaccinated, via intramuscular injection, against rabies (Imrab® inactivated rabies vaccine, Rhone, Merieux, Inc., Athens, Georgia, USA) and canine distemper (Fromm D®, modified live virus, SOLVAY Animal Health, Inc., Mendota Heights, Minnesota, USA); and released at their point of capture. Trapping to estimate the raccoon population size took place from 28 August to 19 September 1995; at this time of year juveniles are larger and easier to trap and handle than they are earlier in the summer (Seidensticker et al., 1988). The number of raccoons in the study area was estimated using a modified Petersen Index and mark-recapture data (Begon, 1979).

Thirteen adult raccoons (six females, seven males) were trapped and marked between 30 May and 27 June 1995 for behavioral observation. Each of the raccoons was weighed, sexed (checked for lactation if female), immobilized by intramuscular injection of ketamine hydrochloride (Rogar/STB Inc., London, Ontario) and xylazine hydrochloride (Bayvet, Rexdale, Ontario) (30 mg/kg body weight ketamine, 10:1 ratio ketamine : xylazine), and a first premolar tooth extracted for age determination by cementum analysis (Johnston et al., 1987).

Each animal was fitted with an adjustable radio-collar (151–152 Mhz, Lotek Engineering Inc., Newmarket, Ontario). Each collar was color coded using reflective tape adhered with contact cement and double sealed with fibreglass resin for waterproofing. Identification of study animals was subsequently made by recognition of the animals' facial and body markings and confirmed using a 4-element Yagi antenna connected to a programmable hand-held telemetry receiver (Lotek model SRX-400, Lotek Engineering Inc.). Visual aids used included binoculars (7 mm × 35 mm), a night scope (Infrascan, Toronto, Ontario), hand-held flashlights, and a large, four-cell flashlight with a fluorescent bulb which was left on continuously throughout the observation period.

From 21 May to 14 June 1995, researchers periodically sat at the dump site about 10 m from the most recently deposited pile of garbage without recording contact rates in order to allow the raccoons to adjust to their pres-

TABLE 1. Sex, age, dump visit frequency, hours observed, and contact rates of raccoons feeding at a garbage dump 40 km north of Kingston, Ontario, Canada from June to September 1995.

Raccoon[a]	Age[b] (years)	Dump visit frequency (%)	Hours observed	Contacts made (per hr)	Contacts received (per hr)
F3 (L)	5 or 6	51	5.58	0.36	0.54
F4	1	49	5.25	0.76	1.33
F5 (L)	5 or 6	57	3.50	2.00	1.71
F7 (L)	4	49	1.90	2.63	1.05
F8 (L)	3	68	3.93	0.50	1.27
M1	2	71	7.90	1.14	2.30
M2	2	85	9.80	0.61	1.43
M3	2	60	9.62	1.14	1.14
M4	6	37	1.08	0	2.77
M5	2	57	3.80	1.32	1.05
M6	2	11	1.43	0.70	0
M7	1	35	1.23	0.81	0.81

[a] F = female; M = male; L = lactating.
[b] Age determined by counting cementum layers in the premolar teeth.

ence. Initially, two researchers made recordings until both agreed on what constituted a relevant contact. After about 2 wk only one observer made recordings. Raccoons were grouped into regular (>51% of nights at the dump) and occasional (≤51% of nights at the dump) dump visitors.

Observations of contacts were recorded from 15 June to 5 September. Total observation time spent at the dump was 115.3 hr. Contact rates were recorded three to four times per wk, beginning before dusk and ending when no collared animals had been visible at the dump for at least 20 min.

Only collared raccoons were used for estimating contact rates because the sex and age of those animals was known. Behavior of collared raccoons was recorded using a modified version of focal animal sampling (Altmann, 1974). When using this technique, if more than one collared animal was present, the most readily visible one was selected for observation and type and placement of contacts with other raccoons were recorded. If the focal animal left the dump, another study animal was selected for observation from the remaining collared animals. Duration of sampling for each observed animal was not predetermined but dependent, instead, upon how long the animal selected for observation was visible. Such behavior-determined selection was used because it decreased the amount of time in which no contacts were being recorded while maximizing the data collected for each observed animal.

Rabies is transmitted primarily by biting; non-bite exposures rarely result in infection (Fishbein, 1991). For the purposes of this paper, a bite and a contact were considered to be synonymous as only bites were used in the analysis. A bite was defined as a quick closure of the attacker's mouth on some part of the recipient's body. All bites were assumed to be of equal severity, but due to the distance of the observer from the animals, it was not possible to assess whether or not every bite penetrated the skin. The date, time, and animal(s) involved in each biting incident (biter and bitten) were recorded.

Independent 2-tailed t-tests (Zar, 1996) were performed to detect differences in intraspecific contact rates between males and females and regular versus occasional dump visitors.

RESULTS

The Petersen estimate of the number of raccoons using the dump was 19, with upper and lower 95% confidence limits of 35 and 12 respectively. A social hierarchy among the raccoons at the dump existed as evidenced by aggressive and submissive behavior of individuals; however, no specific hierarchy was determined during this study. Contact data were recorded for 12 of the 13 raccoons fitted with radio-collars (Table 1). One raccoon was removed from the study after being hit by a car on 18 June 1995. The mean (±SE) rate of bites made and received (per hr) for males (0.82 ± 0.17 and 1.36 ± 0.35) compared to lactating females (1.37 ± 0.56 and 1.14 ± 0.24) was not significantly different. The mean (±SE) rate of bites made and received (per hour) for males versus all females (1.25 ± 0.45 and 1.18 ± 0.19) was also not significantly different.

Because there was no significant difference in contact rates or bites between males and females, rates for both sexes were pooled for comparison of contact rates of regular versus occasional dump users. The mean (±SE) rate of bites made and received (per hour) for regular dump visitors (1.12 ± 0.22 and 1.49±0.19) versus occasional dump visitors (0.87 ± 0.37 and 1.08 ± 0.38) was not significantly different. Because no apparent significant difference was found between males versus females, nor between regular versus occasional dump visitors, contact rates for the dump raccoons were pooled to compute mean overall contact rates for all study animals. Collared raccoons bit and were bitten an average of 0.99 (±0.21) and 1.28 (±0.21) times per hour, respectively, while they fed at the garbage dump.

Because of the way the data were recorded, the amount of time each collared animal spent at the dump could not be determined. However, hourly contact rates were converted into nightly contact rates by dividing the total number of contacts made during periods of observation by the total number of nights that the animal was observed. These rates, however, would be underestimates of actual contact rates as any given animal was not necessarily observed during its entire stay at the dump. Nightly average contact rates revealed that, at a minimum, raccoons bit their conspecifics an average of 0.33 times per night and were bitten an average of 0.41 times per night. Skunks were observed feeding at the dump site concurrently with raccoons. However, no physical contact between a raccoon and a skunk was observed. Raccoons tended to remain at least 2–3 m from any skunks present.

DISCUSSION

In rabies simulation models, one of the key parameters, the transmission rate, is estimated by using another parameter, threshold density, or the minimum population density of the vector species required for rabies to persist (Anderson et al., 1981). Accuracy of model predictions may be enhanced if contact rates of healthy wild vectors, measured in the field, are used to refine estimates of transmission rate (Anderson et al., 1981). Contact rates of rabid animals are assumed to be higher than those of healthy animals because of aggressive tendencies of rabid animals (Anderson et al., 1981). Although use of contact rates of healthy animals may be an underestimate of rabid animal contact rates, they can be used to predict actual transmission rates in infected populations (White et al., 1995). Indeed, in the Anderson et al. (1981) fox rabies model, the transmission rate estimated from the threshold density was very close to contact rates of wild healthy foxes.

In contrast, the transmission rate estimated in the Coyne et al. (1989) model does not correspond to the contact rates of raccoons in our study. In that model, one rabid raccoon infects one susceptible raccoon approximately every 11 days. In our study, nightly average contact rates indicate that one raccoon bites a conspecific once every 3 days while feeding at the dump. However, the transmission rate estimated by Coyne et al. (1989) was based on a threshold density (three raccoons/km^2) which was itself an estimate made to reflect conditions in the mid-Atlantic states. The density of raccoons at our study site was high due to the concentrated food source at the dump. Therefore the contact rates in our study may be higher than in areas where raccoon densities are lower.

Data from our study indicate that, in a population of approximately 19 individuals feeding at a concentrated, common food source available during the summer in rural eastern Ontario, raccoons bite and are bitten an average of 0.99 and 1.28 times per hour, respectively. These intraspecific contact rates are the first to be calculated for raccoons directly from field data and will be useful as a benchmark for modeling rabies spread in areas with similar site characteristics. However, the data should be used with caution, as there were biases in the study. These rates are minimal contact rates for our study area because raccoons were only observed for a small portion of each observation night. Also, we could not determine if the severity of the bite or contact was sufficient to facilitate transmission of rabies. Although we did not find evidence of sex and age differences in contact rate, our sample sizes were small; larger sample sizes may have yielded different results. Other biases such as raccoon tolerance of humans may also have existed and affected the availability of raccoons for observation and determination of contact rate.

Population density has a major impact on contact probabilities in foxes (White et al., 1995). The population size estimate for our study was made at the end of summer after young of the year entered the population. Contact rates at the dump were probably at a maximum at this time. Contact rates where raccoon density is higher or lower may be different from contact rates observed in this study.

Although no contacts between raccoons and other species were observed during this study, opportunities for such contacts could have occurred outside the dump area. It is possible that the presence of the researchers caused other mammalian species to avoid the dump. It is also possible that interspecific contacts are more likely to occur only when one or both animals involved is infected with rabies because of disease-induced behavioral changes (White et al., 1995). Although skunks did spray periodically in the presence of the raccoons, this was not considered a potential contact because the rabies virus is generally not shed in significant quantities in the musk of infected skunks (Beauregard and Casey, 1973). However, contact between species such as raccoons and skunks must occur as skunks have been reported with the raccoon strain of rabies in the United States and Canada where the raccoon is the primary vector of the disease (Rosatte, unpubl. data).

Results of this study indicate that areas such as common feeding sites are potential foci for the spread of rabies in raccoons. In urban and suburban areas where concentrated sources of food are available throughout the year and where densities of raccoons tend to be higher than in rural habitats (Hoffmann and Gottschang, 1977; Rosatte et al. 1991, 1992; Rosatte, 2000), intraspecies contact rates are probably even greater than those observed in our study. In support of this, >40 raccoons have been observed at one residential feeding site in Toronto, Ontario (Rosatte, unpubl. data). In fact, in some Toronto habitats, raccoon density was >100 raccoons/km^2 (Rosatte, 2000). Such conditions may be highly conducive to rabies spread.

The Ontario Ministry of Natural Resources (OMNR) currently employs trap-vaccinate-release (TVR) and oral rabies vaccination (ORV) programs to vaccinate raccoons against rabies (Rosatte and Lawson, 2001; Rosatte et al., 1997, 1998, 2001). Oral rabies vaccination involves aerial distribution of rabies vaccine impregnated baits to vaccinate raccoons over large tracts of rural habitats in Ontario (Rosatte et al., 2001). However, bait distribution from aircraft is not accurate enough to target small pockets of habitat within urban areas (Rosatte et al., 1992). In some urban areas, it may be practical to immunize raccoons against rabies by placing baits at artificially created feeding stations; raccoons have been known to change their movements and home ranges to include new concentrated sources of food (Seidensticker et al., 1988). However, research is needed to determine the effective range of urban baiting stations and the number of baiting stations required per unit area to immunize a significant portion of an urban raccoon population. Research is needed on raccoon contact rates in urban areas as well, including data on juvenile raccoons, which would help improve the predictive power of raccoon rabies models and the planning of urban baiting stations.

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