Parasitology and Denning Ecology of Raccoons, *Procyon lotor*, in Black Rock Forest, New York

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ABSTRACT

Raccoons, *Procyon lotor*, which are abundant and widespread across North America, carry numerous parasites and diseases that are transmissible to many other species, including humans. Varying patterns of movement and denning in raccoons can affect the dynamics of parasites and disease by altering rates of contact among individuals. This study evaluated such patterns in a population of raccoons in Black Rock Forest, New York with radiotelemetry data for the winter of 1999 and summer of 2000. The shift from several instances of communal denning in the winter to none in the summer suggests that raccoons are communally denning in winter for thermoregulation.

This study also used sugar and zinc sulfate fecal flotation techniques to identify ova of enteric parasites in raccoons in Black Rock Forest. Ova of eleven species of enteric parasites were found in 36 fecal samples collected from the summer of 1999 through the winter of 2000. No *Baylisascaris procyonis* or *Giardia* were found in any raccoons in Black Rock Forest.

Trends in ectoparasites (lice, fleas, and ticks) were evaluated using hair samples and tick assays of the ears and back of trapped raccoons. Raccoons of greater weight were found to carry more ticks. All abundances of ectoparasites were correlated with the date and month of hair sample collection except for lice. There was a significant relationship between the presence of one ectoparasite and another for lice and fleas, lice per mg and fleas per mg, and lice per mg and ticks, fleas and ticks, and fleas per mg and ticks. There was also a significant relationship between sex and lice, with males having more lice and lice per mg on average than females.

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INTRODUCTION

Understanding the roles of parasitism and disease in regulating mammal populations is vital to the conservation and management of wild and domestic species, and it is only in the last few decades that these factors have been integrated with studies of the ecology and behavior of mammals. Epidemiology and parasitology are integral to the conservation of small and endangered populations which may suffer decline or extirpation in the face of introduced or increased pathogens. Studying diseases and parasites in larger or more stable populations is also important, because these populations may act as reservoirs for pathogens which can spread into other wild and domestic populations. In one such case in Kruger National Park, a buffalo population suffered an outbreak of bovine tuberculosis, which may have then spread into and caused a decline in the sympatric lion population (Keet et al., 1996; Weyer et al., 1999). Many mammal populations in the United States act as reservoirs for hantavirus and Lyme disease, which can spill into and devastate other populations and cause severe illness and death in humans (WDA, 2000). While disease is a serious concern for any mammal population, it becomes an even greater public concern when it affects domestic populations of livestock, pets, or humans.

Rabies, plague, and bovine tuberculosis have been studied at length because of the serious impacts they have on humans and economically important livestock. However, most pathogens are not as well studied, especially in terms of their interactions with their host species' life history and social structure. Therefore, a greater understanding of the behavioral ecology of both hosts and parasites and their interactions is needed. Manipulative experiments that investigate how parasites and disease move among

individuals in populations with varying social structures are integral to this effort. Raccoons, *Procyon lotor,* provide a unique model system to study such relationships, because they are widespread and abundant and because they exhibit flexibility in their social behavior. Furthermore, raccoons can carry rabies virus, *Giardia*, canine distemper virus, and the roundworm *Baylisascaris procyonis*, which can cause fatal disease in many other species, including humans.

Behavioral Ecology in Relation to Parasitology and Epidemiology

Many behavioral and ecological factors, such as population size, density, distribution, and social structure, determine the nature and rates of contact among individuals. Therefore, the behavior and ecology of a species are important determinants of parasite and disease dynamics. Different pressures acting on a population may alter transmission patterns or increase susceptibility of individuals to parasitism and disease. Such pressures may include climatic variability, demographic stochasticity, or human disturbances such as decreased or altered habitat and food resources.

Frequency and patterns of movement in mammal populations can affect or be affected by parasitism. For example, yellow baboons (*Papio cynocephalus*) alternate stays of a few nights at one sleeping grove, where soils contain ova and larvae of intestinal parasites, with longer periods of avoidance of that grove (Hausfater & Meade, 1982). In this case movement may decrease transmission of parasites when used strategically to avoid areas with high infestation potential. Conversely, movement may increase exposure to parasites by increasing contact rates among individuals.

The formation of social groups may increase parasite and disease transmittance by increasing contact rates among individuals, but these social groups may also act as

barriers to transmittance to other social groups that are avoided. Within a social group, there may be similar rates in infection or infestation of individuals, as in the mara (*Dolichotis patagonum*), a rodent from southern Argentina (here studied in England) that displays monogamy and communal denning with a couple and its young. In one population, family membership was shown to have a highly significant effect on the intensity of strongyloid egg shedding in feces and on the prevalence of infection (Porteous & Pankhurst, 1998). Homogeneity of infection was greater within than between families and adult pairs, showing the impact that social structure can have on parasite transmittance in mammals.

Understanding the behavior and ecology of a species and their effects on parasite and disease dynamics is important to the human management and manipulation of mammal populations. One example which demonstrates the necessity of these studies is the culling of fox populations in Europe that was performed to prevent the spread of the rabies (Bogel & Moegle, 1980). It was later suggested that this management decision may have actually aided in the transmittance of rabies by increasing contact rates among individuals and increasing the number of young individuals in the population who are more susceptible to disease (MacDonald, 1980). Rabies is an important management concern worldwide because almost all mammals, including raccoons and humans, are susceptible to various strains of this fatal disease.

In New Zealand, a study of brushtail possums (*Trichosurus vulpecula*) found that reducing population density by culling lowered the probability of den-sharing and was estimated to eliminate the behavior altogether at a 60% population reduction (Caley et al., 1998). Because these possums are reservoir hosts of bovine tuberculosis and can spread

the disease to cattle (Morris & Pfeiffer, 1995), population control has been suggested as a mechanism for preventing domestic outbreak of the disease. If the probability of shared denning is similarly density-dependent in disease-carrying North American mammals such as raccoons, then population control may reduce the spread of disease by reducing contact rates among individuals. Investigating other options of disease prevention is worthwhile however, in light of the possible benefits which communal denning provides some mammal species and the unknown effectiveness of culling in disease control.

Movement and Denning Behavior in Wild Mammals

In my study, patterns of movement and denning are investigated, as well as the relationships between these factors and parasite diversity and abundance in raccoons in Black Rock Forest, New York. In order to study the manner in which disease and parasites move through raccoon populations, it is first necessary to review and collect more information on their movement and denning behavior throughout their range. In Texas, male raccoons were found to have larger home ranges than females than would be predicted by their greater weight in all seasons (Ghert & Fritzell, 1997). As in other mammal species, this study showed that female raccoon home ranges are determined by resource distribution, while male home ranges are determined by the distribution of females.

A study of den selection in a population of Tennessee raccoons found a very low occurrence of communal denning (15 out of 1838 radiotelemetry locations), but those instances of shared denning were not limited to male-female groups or to a particular season (Endres & Smith, 1993). The instances of communal denning were not limited to one type of habitat, but occurred in rock dens, tree cavities, and a ground burrow.

Communal denning has been reported among raccoons during winter elsewhere in North America (Twitchell & Dill, 1949; Mech et al., 1966), with a larger group reaching eight individuals (Whitney & Underwood, 1952). However, in one unusual instance, twenty-three raccoons were found denning together in one winter den that was the cellar of an abandoned house (Mech & Turkowski, 1996)

Den selection in raccoons may vary among seasons, with more insulated and sheltered den types being chosen in winters with inclement weather. In North Dakota, one study found that raccoons used rock dens more often than tree cavities during winter (Endres & Smith, 1993). Females used tree cavities more often than males in all seasons, especially during summer when rearing their young, which may better protect these individuals from predation. Ground burrows were consistently used more frequently by juveniles, which may be due to their inability to obtain and secure the better den sites.

For mammals living in colder climates with harsh winters, communal denning may provide a thermoregulatory function, especially during winter hibernation. Alpine marmots (*Marmota marmota*) live in large groups of up to 20 individuals, frequently due to delayed dispersal of offspring (Arnold & Lichtenstein 1993). These groups hibernate together in one burrow throughout the winter, saving individuals energy (Arnold, 1998; Arnold, 1990b). Social thermoregulation may also be present in the closely related yellow-bellied marmot (*Marmota flaviventris*) present in North America. Though some individuals live alone, those that are more social may den and hibernate communally, especially in the cases of mother and offspring during their first winter and of closely pairs of such groups (Lenihan &Van Vuren, 1996a; Van Vuren, 1996).

In Arnold's 1990 study of joint hibernation in Alpine marmots, groups with no infants experienced decreased mass loss per individual as group size increased. In groups with infants, winter survival was higher in groups with adults other than the territorial pair, even if the oldest subordinates were only yearlings. Mass loss of subordinates increased with group size when infants were present. Infant mortality was lower in groups where most subordinate animals were potentially their full siblings. Studies on Alpine marmots suggest that communal denning in similar mammals may decrease the energetic costs and mass loss per individual of staying warm throughout winter hibernation or any bought or harsh weather. Additionally, species with shared-denning and hibernation behaviors may have group sizes, age structures, and degrees of relatedness that yield maximum reproductive fitness. In Alpine marmots, groups with infants experience lower energetic costs per individual as group size increases. Survival of infants seems to be linked to the degree of relatedness of subordinates in a group, indicating that subordinates may be warming their infant siblings more effectively than unrelated individuals. Therefore, in managing any population of communal denning mammals, it is important to understand how the age structure affects the costs of hibernation. In species where adults other than the reproductive pair are needed to help warm infants, preservation of shared denning behaviors is integral for their continued reproductive success and survival.

In Alpine marmots, harsh weather in the form of a later thaw negatively impacts den-sharing by limiting the social structure which dens can support. Arnold's study (1990b) found that poor habitats (those with a later Spring thaw) did not support any groups with infants and older subordinates who were not offspring of the territorial pair,

whereas better habitats did. It is thus suggested that hard weather may impact the social structure and number of individuals in den-sharing groups of mammals.

Thermoregulation has also been suggested as a cause or benefit of communal denning in porcupines (*Erethizon dorsatum*) and raccoons (*Procyon lotor*) in North America (Wolfe, 1990; Mech & Turkowski, 1996). However, one population of porcupines in Massachusetts displayed less den-sharing in harder winters and a higher percentage of den-sharing among individuals in the area of high-den density relative to that of lower (70% v. 45%) (Greisemer, Fuller, DeGraaf, 1996). In this study den-sharing was not limited to male-female pairs, nor was it limited to the mating season. Some pairs denned together through seasons and years, and some individuals and pairs displayed den-fidelity. Greisemer speculates that the weather in harder winters may have reduced movement between dens, which thereby lead to reduced den-sharing. The study did find that den sharing in porcupines must occur for reasons other than mating, since it is not limited to mating pairs or mating seasons. However, replication of this study with a larger sample size is needed to clarify the effects, if any, of population density, den-site availability, and weather on den-sharing in porcupines. The effects of weather on den-sharing in raccoons in Black Rock Forest can be investigated in the coming years. However, population density and den-site availability are probably not important factors affecting den-sharing in this population, as there is a very abundant supply of rock dens and trees in this habitat.

Ectoparasitism and Fitness in Wild Mammals

Ecoparasites can affect the fitness of an individual by causing anemia, damaging skin and tissue, and transmitting disease (Van Vuren, 1996). Furthermore, ectoparasites

such as mites, ticks, and lice can increase the amount of time an individual spends grooming itself thereby decreasing the amount of time available for foraging and other activities (Hoogland, 1978). Growth rate and reproduction of mammals can be adversely affected by ectoparasitsm, as Van Vuren's study (1996) of yellow-bellied marmots in Colorado demonstrated. In this marmot population, the probability of winter survival was significantly lower in individuals with a greater number of fleas. Growth rate in marmot yearlings was negatively correlated with amount of fleas per individual. Females who did not produce litters had significantly more fleas than those females who successfully reproduced. Another study utilizing field and experimental enclosures showed that the presence of the tick *Eimeria arizonensis* was found to be negatively related to recruitment, overwinter survival, and change in body mass in deer mice, *Peromyscus maniculatus* (Fuller & Blaustein, 1996). These fitness losses and those found in yellow-bellied marmots demonstrate the vulnerability of mammals to ectoparasitism, which may be more prevalent in social species.

A study of Alpine marmots showed that mass loss during hibernation was greater and probability of winter survival was lower for individuals with higher loads of the mite *Echinonyssus blanchardi* (Arnold & Lichtenstein, 1993). Not only was there a higher winter mortality of infants with high ectoparasite loads, but litters of females with high mite loads were weaned later and therefore had a lower chance of surviving the next winter hibernation. Surprisingly, neither the number of individuals (of any or all age classes) per group or per unit area of land correlated with the number of mites in Alpine marmots. Ectoparasitism is a substantial fitness cost for Alpine marmots, but apparently is not a cost of their sociality. Similarly, average numbers of fleas (*Oropsylla stanfordi*),

lice (*Linognathoides marmotae*) and mites (family Dermanyssidae) were not significantly different in a study comparing colonial and non-colonial yellow-bellied marmots (Van Vuren, 1996). These studies on two species of marmots fail to find a correlation bewteen sociality and ectoparasite loads, which is surprising given the high rates of contact and increased opportunity for spread of ectoparasites. Therefore, more research needs to be done to see if there exists a relationship between high rates of contact in communal denning and levels of ectoparasitism in other species such as raccoons.

Important Parasites and Diseases Carried by Raccoons

While there are many potential ectoparasites of raccoons, my study focuses on the broad categories of lice, fleas, and ticks. Raccoons, as well as other mammal and bird species, can serve as reservoirs of *Borrelia burgdorferi*, the spirochetal agent of Lyme disease by carrying the tick vector *Ixodes dammini* (Fish & Daniels, 1990). *Ixodes dammini* comprised 99% of all ticks collected and identified in one study at Armonk in Westchester County, NY, less than 30 miles from my study site (Fish & Dowler, 1989). Five species of ticks (*Amblyomoma americanum*, *Dermacentor variablis*, *Ixodes texanus*, *Ixodes scapularis*, *Ixodes cookei*) were found on 351(78%) of 449 raccoons in North Carolina (Quellete et al. 1997). Species identification of ticks was not performed in my study because removing ticks from the raccoons would have compromised other aspects and later stages of the study. In one study which assessed the importance of mammal species as hosts of immature deer ticks, it was recommended that future studies should include holding animals for several days and collecting replete ticks rather than relying upon exams for attached ticks at capture (Donahue et al., 1987). However, such exhaustive methods were not feasible in the context of my field studies, and on site tick

checks on the face and ears were used instead. In a study where most (59%) ticks on raccoons were found attached to the head and neck in areas where the fur was thin, it was demonstrated that tick checks on these spots can be used as an estimate of overall tick abundance (Quellete et al., 1997).

While the infection rate of *Borrelia burgdorferi* in *Ixodes damminii* ticks attached to raccoons has been shown to be lower than that of white-footed mice *Peromyscus leucopus*, the abundance of ticks on raccoons could be great enough to make them significant vectors of Lymne disease (Donahue et al., 1987). Therefore, studying how different movement and social behaviors affect tick abundances among raccoons may be important for understanding and managing Lymne disease in the northeastern US.

Since 1990, the raccoon-associated variant of the lethal rabies virus has spread to all of New York except for a few counties (CDC, 2000). In 1998, the Center for Disease Control reported that New York had 1096 laboratory-confirmed rabies cases in animals; this marked the eighth consecutive year with greater than 1000 cases. This epizootic has been associated with raccoon rabies in domestic and wild animals, including one black bear and 31 white-tailed deer. Though there is not a great danger to humans of contracting rabies in the United States, postexposure propylaxis and prevention can result in great economic costs (Rupprecht & Smith, 1994; Fishbein & Arcangeli, 1987). Oral rabies vacine (ORV) programs, which set up immune barriers and prevent epizootic spread of wildlife rabies in several states, and human postexposure treatments, which have increased where epizootics of raccoon rabies have occurred, are both costly strategies (CDC, 1997; Meltzer & Rupprecht, 1998). While this project does not directly address rabies transmittance in Black Rock Forest, the baseline information on parasite

transmittance and behavior collected can indirectly give insight into how transmittance of diseases such as raccoon rabies may be affected by movement and social structure.

Protozoan *Giardia spp.* can be carried by raccoons and are the most commonly diagnosed intestinal parasite in human public health laboratories in the United States (Kappus et al., 1994; Kappus et al., 1991). Giardiasis occurs in humans when cysts are ingested through person to person transmission or ingestion of fecally contaminated food or water. Though infection in humans may be asymptomiatic, an estimated 4,600 hospitalizations per year in the United States resulted from severe giardiasis and its complications from 1979 through 1988 (Lengerich et al., 1994). *Giardia spp.* can be carried by many mammal species and is therefore of concern to wildlife management, especially in commensals such as raccoons.

Baylisascaris procyonis (Ascaridae), the raccoon roundworm, is the most commonly recognized cause of clinical larva migrans in animals, having produced fatal or severe neurological disease in over 50 species of mammals and 20 species of birds (Kazacos, 1997; Evans & Tangredi, 1985). *Baylisascaris* is common in the Northeast and midwestern US, and has also been reported in south coastal Texas (Kerr et al., 1997). There is no effective therapy for *Baylisascaris* larva migrans disease in humans, and there are several reports of children's death due to this disease (Fox et al., 1985; Cunningham et al., 1993). In less severe cases or in earlier stages of the disease, ocular larva migrans cause blindness in animals including humans (Kazacos et al., 1985). Raccoons themselves are not subject to larva migrans disease, though they rarely become sick and die from *Baylisascaris* worms due to intestinal obstruction (Stone, 1983). Animals with high infection of *Baylisascaris* (74 to 226 worms) have been found to have obstructed,

enlarged intestines with increased liquid content (Ching et al., 2000). Raccoon roundworm is a serious management concern because of the major impacts it has on many other populations including the declining Alleghany woodrat, which is potentially threatened by this pathogen (Balcom & Yahner, 1996).

In one study, three raccoons with 15 adult female *Baylisascaris procyonis* worms were reported to contaminate their enclosure with 1.7x10^6 eggs (Kazacos, 1982). *Baylisascaris* eggs are distributed nonrandomly in raccoon habitat and are associated with raccoon latrines which may build up from feces of one or several individuals (Cooney, 1989). At established latrines, large quantities of raccoon feces can accumulate and increase the potential for transmittance of *Baylisascaris* among raccoons or to other birds and mammals (Page et al., 1999). In particular, some granivores (oppossums, white-footed mice, chipmunks, squirrels, birds) may come to recognize raccoon latrines as food sources and return to them, thereby increasing their risk of infection. In examining active foraging for undigested seeds in raccoon feces, it has been found that seeds are removed at a greater rate from feces at established latrines than at non-latrines of raccoons (Page et al., 1999).

In the scientific literature, 55 species of enteric raccoon parasites have been documented in the United States and Canada (see Appendix 1). Varying trends have been reported for prevalence and abundance of different species of endoparasites in raccoon populations in North America. Ching et al. (2000) found no difference in prevalence or abundance of intestinal parasites between adult and young raccoons among 34 females and 40 males in British Columbia. Hamir and Snyder (1999) found a higher prevalence of *Capillaria spp.* in male than in female raccoons (55% versus 41%),

whereas Hamir and Rupprechtt (1998) found no significant difference between prevalence of *Capillaria spp.* in male and female raccoons. This discrepancy may be due to differences among raccoon populations or to the grouping of three *Capillaria* species which cannot be supported by their poorly known life cycles. However, Butterworth and Beverly-Burton (1981) did find a significant difference in prevalence of one species *Capillaria procyonis* in male and female raccoons in Ontario. Cole and Shoop (1987) found that two species of gastrointestinal helminths, *Baylisascaris procyonis* and *Trichinella spiralis* had higher prevalences in male than in female raccoons in Kentucky. Kidder et al. (1989) did not find significant differences of prevalence between males and females, but found that juvenile raccoons in Ithaca, NY had higher prevalence of *Baylisascaris procyonis* than did adults during fall. Ermer and Fodge (1986) and Snyder and Fitzgerald (1985b) also found higher prevalences of *Baylisascaris* in juveniles than in adults.

Studies report that the majority of raccoons in wild populations carry some or many species of gastrointestinal parasite. Robel et al. (1989) found enteric helminths in all individuals of one raccoon population and 96% of individuals in another population in Kansas. Similarly, Snyder and Fitzgerald (1985) found enteric helminths in 244 of 245 raccoons in Illinois. However, Jacobson et al. (1982) found that gastrointestinal helminth prevalence was greater in raccoons from a rural population where there were humans, some residences, traffic, trapping, and farming than raccoons from a military post where there was little human activity and traffic and none of the other activities. These differences may have been due to differences in exploitation or trapping among the

populations or the other factors mentioned which differed in the urban and rural popualtions.

Prevalences of different endoparasitic species can vary greatly among raccoon populations and prevalence of worms or ova shed through feces may vary among seasons. *Baylisascaris procyonis* was found in 20.2% of fecal samples collected from 243 raccoons in Ithaca, New York, though this rate of prevalence increased to 42.4% when only considering the months of September, October, and November (Kidder et al., 1989). Cole and Shoop (1987) found *B. procyonis* in 31% of raccoons in one population, though 81% of all infected individuals occurred in one smaller sample area.

Project Summary

Parasitism and disease in raccoons which are widespread and abundant is of concern because of the detrimental effects they have on raccoons and other populations including humans which frequently come into contact with them. Studying the diversity, abundance, prevalence, and transmittance of internal and external parasites in relation to the social structure and movement of raccoons can give insight into how parasites and disease move through populations of raccoons and other mammals. My project will provide a parasitological survey and baseline information on movement, denning, and parasite diveristy and abundances in relation to weight, sex, and age class in raccoons in Black Rock Forest, New York. In future research, the social structures of these two populations will be altered by augmenting food resources, and the baseline information and trends found in my research will be compared to those in the manipulated populations to examine how sociality affects the abundance and transmittance of parasites. Genetic analysis of relatedness among individuals will be used to examine its

role in determining the social structure and dynamics of disease and parasites in these raccoon populations. Particularly in the case of raccoons, which are known to carry diseases transmittable to numerous populations including humans, we need an understanding of how parasites and disease are affected by such human disturbances as reductions in natural food resources and increases in clumped food resources such as garbage dumpsters. More generally, this research will contribute to the poorly understood interactions of behavior and ecology with parasitology and disease in mammals.

METHODOLOGY

Study Area

My studies were conducted in Black Rock Forest, New York, a 1500 hectare preserve dedicated to scientific research, education, and conservation. The forest lies in the Hudson Highlands on the west bank of the Hudson River, 80km north of New York City, neighboring the town of Cornwall and West Point Military Academy (BRF, 2001). The land is bordered by highway 9-W and a golf course and forest area owned by West Point. Historically, the forest was cut and largely cleared in the 18th and 19th century for agriculture and timber. Dr. Ernest Stillman established Black Rock Forest as a research and demonstration forest early in 1928, and the forest has been preserved for science and education since then. Due to burns and cutting of selected parts of the forest, tree stands range from 20 up to 120 years old (BRF, 2001).

Schist, granite, and gneiss lay the geological foundation of the land, and rock outcroppings visibly jut out from the soils in Black Rock Forest. Due to the rockiness of the land and variable topography ranging from 1000 to 1400 ft elevation within my study

area, there appears to be an abundance of rocky den sites for raccoons. The predominant vegetation is oak, mixed hardwoods, hemlock, mountain laurel, rododendron, and blueberry.

My two study sites were "Glycerine Hollow" in the eastern part of the forest and "Jim's Pond" in the southern part of the forest. Each area is approximately 3 km^2, which is estimated as the approximate range of all animals caught in the trapline at each site. The two sites are separated by about one kilometer and the two water bodies of Arthur's Pond and Bog Meadow Pond. Because of this geographical isolation and no observed movement of raccoons from one site to the other during the course of this study, these two sites are considered relatively independent subpopulations.

The Glycerine Hollow site encompasses the geographical feature Glycerine Hollow as well as some of the surrounding area. Cascade Brook runs through the center of the bowl-shaped hollow, and there are small ponds and marshy areas throughout the site. The Jim's Pond site encompassed the area around Jim's Pond as well as the area around Sutherland Pond and Wetlands (see Appendix 2). Major water features include the aforementioned ponds as well as several swamp areas, one of which extends from the east side of Sutherland Pond. Sutherland Pond is the only natural pond in Black Rock Forest; the others are artificially dammed. The abundance of water features in both study sites suggests that water is not a restricting resource for raccoons therein, unlike the role of restricted water sources for shaping home range and sociality in other raccoon populations in west Texas (Gehrt & Fritzell, 1998). One section of the Jim's Pond site underwent a large accidental burn which spread over from West Point land in 1999. In

this part of the study site, there is noticeable damage and lack of live vegetation, except in the riparian areas.

Trapping and Processing Raccoons

Trapping in Glycerine Hollow was conducted using 23 Tomahawk live-traps placed approximately fifty meters from the road on alternating sides of the road. The trapline in Jim's Pond was similarly composed of 23 traps placed fifty meters off the road. Appendix 2 shows the approximate distributions of traps in the two sites. The traps were wired open and baited with one half can of cat food both in the front and back of the trap for 3-5 days. After prebaiting, the traps were set and checked daily for 10 days to two weeks, depending on the number of new individuals captured over time. Trapping occurred in one site at a time, with prebaiting at one site overlapping the tail end of trapping in the other. Trapped animals were sedated and processed according to the following procedure.

Using PVC pipes, the animal was maneuvered and pushed against the side of the cage (photograph Appendix 3a). A 1 ml syringe with a 22 gauge needle was used to inject a mixture of Ketamine, a disassociative anesthetic (10mg per kg body weight), and Xylazine, an alpha-2 agonist sedative (0.5mg per 5kg body weight) into the muscle mass in the haunches of the animal. The animal was left alone for 3 to 5 minutes, as more stimulus increases the animal's metabolism and causes quicker processing of the drugs. If the animal was not sufficiently sedated for handling after this time period, a second dose of half the original dose of Ketamine was administered intramuscularly. Additional Xylazine was never administered, because this can be dangerous.

When sufficiently sedated, the raccoon was removed from the cage, and its eyes were immediately lubricated with Puralube Vet Ointment to prevent dessication. If the raccoon was a new individual that had not been previously captured, we shaved a portion of the outer thigh and around the neck using Oster clippers (Appendix 3e). AVM Instrument Company Transmitter type P2RLM-N model D radiocollars were put on the raccoons, leaving enough loose space for one finger under the collar and trimming all sharp edges and extra material off of the collar (Appendix 3f). On new individuals or recaptured individuals who were missing eartags, we applied Hasgo Tag Company 100S 3 model tags at the edges of both the raccoon's ears. We then cleaned the shaved area of thigh with alcohol and took a skin biopsy using Baker's 4 mm Biopsy Punch and a blade. Tissue samples were stored in 90% ethanol for future genetic analysis. The skin around the biopsy site was closed with forceps and secured using Nexaband Liquid issue glue.

For both new and recaptured individuals, we recorded the sex, approximate age judged by size and tooth wear, reproductive status, and general health of the animal (Appendix 3c). We took measurements of head to base of tail length, tail length, and neck circum and weighed the raccoon (Appendix 3g). The number of replete and nonreplete ticks on the ears and back of the animal were counted and recorded (Appendix 3d). We combed the back of the raccoon with a flea comb ten times using equal strength and duration of combing to standardize the hair samples collected for ectoparasite analysis. We emptied debris from the trap and collected and preserved any fecal sample present in 10% formalin acetate for analysis of internal parasites. After processing the raccoon, it was put back in the trap which was propped open partially, so that the animal could climb

out only after regaining sufficient coordination. We waited with the animal until it regained mobility, later making sure that the raccoon had left the trap.

Radiotelemetry

We tracked the raccoons with radiotelemetry, using an AVM LA12Q handheld receiver. We checked each radiocollar frequency daily at certain standard points throughout the site along the road at high points and other topographically significant features in the land. The frequency of each collar was checked at every point for all raccoons in its respective site and occasionally for all raccoons in both sites. The vector coordinates taken from the road were used to triangulate the approximate location of the raccoon (Appendix 3h), which was then tracked on foot using the attenuator mode of the receiver to pinpoint the den site exactly. Garmin 12XL GPS units were used to take coordinates of the den sites. When present, fecal samples at the mouth of the den site or base of the tree where the raccoon was sleeping were collected and preserved in 10% formalin at the end of the day for fecal analysis of enteric parasites.

Parasite Survey

In the laboratory of the Center for Environmental Research and Conservation, I determined the number of lice and fleas present in each raccoon hair sample under a Fisher Stereomaster dissecting microscope. I recorded these numbers on their own, as well as standardized per milligram of hair in each sample.

I processed the raccoon fecal samples using a sugar fecal flotation technique and a Leica Gallen III microscope to identify ova of many species of enteric parasites. Fecal samples were also sent out to the Diagnostic Laboratory at the Cornell Veterinary

College and processed there using both sugar and zinc sulfate flotation techniques and a *Giardia* ELISA test.

Analysis

I analyzed data collected by Amber Wright, Dr. Matthew Gompper, and myself in field studies from June through August of 2000, which included trapping and radiotelemetry. I also included radiotelemetry data collected by Dr. Matthew Gompper in December 1999 through January 2000, and data from hair and fecal samples collected by Dr. Matthew Gompper and Christine Scully in June through August of 1999 and collected by Amber Wright September through December of 2000. For endoparasite analyses, the summer months of June through August were treated as one season of fecal sample collection, and the winter months of October and December were treated as the other season (two years combined). All fecal samples analyzed were collected during these five months during 1999 and 2000.

Unpaired t-tests in SYSTAT 2000 software were used to determine if there were any significant differences in average number of lice, lice per mg of hair, fleas, fleas per mg of hair, and ticks among sexes and age classes and for age classes within each sex of raccoon.

Linear regressions were used to determine if there were any significant correlations between the date and month of hair sample collection and the number of ticks, lice, lice per mg, fleas, and fleas per mg. Pearson's chi-squared and Fisher exact tests were used to determine whether there were any relationships between the month of hair sample collection and the presence or absence of ticks, fleas, or lice.

Paired t-tests were used to determine whether the presence of lice, lice per mg, fleas, fleas per mg, or ticks was significantly affected by the presence of another category of ectoparasite. Pearson's chi-squared and Fisher exact tests were used to determine whether there was significant deviance from equal proportions of individuals carrying lice, lice per mg, fleas, fleas per mg, or ticks due to their sex, age, or carrying of any category of ectoparasites. Linear regressions were used to determine if there were any significant correlations between numbers of lice, fleas, and ticks and weight or length of individuals within each sex and within both sexes grouped.

Pearson's chi-squared and Fisher exact tests were used to determine whether there were any relationships between one of the three most common species of endoparasites (*Eimeria nutalli, Eimeria procyonis, Capillaria putorii*) or any species at all due to the following variables: individual's sex, age, study site, or status of lactation if female or the month or season of the fecal sample's collection. Unpaired t-tests were used to determine if there were any significant differences in the number of endoparasitic species among sexes, age classes, lactating and nonlactating females, study sites, and season of sample collection. Linear regressions were used to determine if there were any significant correlations between number of endoparasite species and prevalences of the three most common species and the month (two years combined).

In Microsoft Excel, linear regressions were used to determine if there were any significant relationships between numbers of lice, fleas, and ticks and weight or length of individuals within each sex and within both sexes grouped. The relationship between months and numbers of endoparasite species and prevalences of the three most common

species along with the frequency of numbers of species found in the populations were analyzed.

RESULTS

Trapping in the Glycerine Hollow and Jim's Pond site from June 1999 through August 2000 yielded 37 individuals, 24 of which were radiocollared. Nine males and eight females were trapped in Glycerine Hollow, and 13 males and seven females were trapped in Jim's Pond. Eight of the 15 females in the two sites showed signs of lactation and therefore reproduction in one or both years. The average length and weight of all females processed were 58.0 cm and 4.46 kg, whereas those of males were 64.7 cm and 5.69 kg. The two trapping sites have similar population densities of approximately 5.5-6.0 individuals/km^2 (Gompper, pers. comm.).

Movement and Denning Behavior

Raccoons in Black Rock Forest occupied both tree and rock dens during the summer of 2000, and were found several times sleeping in the forks of trees or on tree limbs. During the winter of 1999, individuals occupied rock dens only. Movement data were not sufficient to analyze relationships between ectoparasites or enteric parasites and home range size or movement patterns (see Discussion for details). Out of six individuals among both sites for which there were 5 or more confirmed den sites in the summer of 2000, three displayed some den fidelity, while three did not. Two lactating females and their offspring remained in at least two den sites for consecutive nights and returned to den sites they had previously stayed in. One male raccoon was not found to den consecutive nights in one site, but returned to two sites previously denned in during the summer of 2000. Den fidelity was also displayed by two

individuals in the winter of 1999 on the same instances that they were found communally denning. There were less than five comfirmed den sites for these individuals. Some individuals were repeatedly located on the golf course, so whether they displayed den fidelity or communal denning could not be determined.

During the winter of 1999, there were eight instances of communal denning found during tracking of raccoons when there were 7 raccoons radiocollared. Groups denning together were made up of two to four individuals and were composed of males with males or males with females, but never females with females. Raccoons were not found to den repeatedly with other specific individuals, but rather changed denning partners often. No raccoons were found communally denning during the summer of 2000 when there were 24 raccoons radiocollared, including the previous winter's seven.

Ectoparasites

In 31 total hair samples from 13 female and 18 male raccoons, SYSTAT 2000 unpaired t-tests showed significant differences in average number of lice and lice per mg of hair among male and female raccoons (P=0.025, P=0.045 using separate variances), but not for fleas, fleas per mg hair, or ticks. Females had an average of 1.091 ± 1.814 lice or 0.035 +-0.056 lice per mg, and males had an average of 3.350 ± 3.514 lice or 0.601 ± 1.180 lice per mg. There were no significant differences in lice, lice per mg, fleas, fleas per mg, or ticks between age classes and between age classes within each sex of raccoon. Paired-tests showed a significant affect of the presence of one ectoparasite on the presence of another in a raccoon for the following categories: lice and fleas, P=0.006; lice and ticks, P=0.000, ticks and fleas, P=0.000; lice per mg and fleas per mg, P=0.000; ticks and fleas per mg, P=0.000. No significant relationship was found for ticks and lice

per mg.

Pearson's chi-squared and Fisher exact tests showed no significant deviance from equal proportions of individuals carrying lice, lice per mg, fleas, fleas per mg, or ticks due to their sex, age, or carrying of any category of ectoparasites. Linear regressions showed significant correlations between weight and ticks in females and both sexes combined (Multiple R: -0.617, Squared multiple R: 0.381, P=0.025; Multiple R: -0.431, Squared multiple R: 0.186, P=0.015), though not significantly in males (Multiple R: -0.370, Squared multiple R: 0.137, P=0.131). Linear regression showed no significant relationships between ticks and body length or lice, lice per mg, fleas, fleas per mg and weight or body length within each sex and within both sexes combined.

Linear regressions showed significant correlations between the date of hair sample collection and abundance of ticks (Multiple R: -0.514, Squared multiple R: 0.264, P=0.003), date and fleas per mg (Multiple R: 0.405, Squared multiple R: 0.164, P=0.024), date and fleas (Multiple R: 0.351, Squared multiple R: 0.123, P=0.053), date and lice per mg (Multiple R: 0.447, Squared multiple R: 0.200, P=0.012), though not between date and lice. Linear regressions showed strong correlations between month and lice per mg (Multiple R: 0.476, Squared multiple R: 0.226, P=0.008), month and fleas (Multiple R: 0.352, Squared multiple R: 0.124, P=0.057), fleas per mg (Multiple R: 0.404, Squared multiple R: 0.163, P=0.027), month and ticks (Multiple R: -0.536, Squared multiple R: 0.287, P=0.002), though not between month and lice. Peterson's chi-squared and Fisher exact tests showed a significant relationship between the month of collection and presence or absence of ticks (Pearson's chi-squared P=0.000; Fisher exact test P=0.000), though not for month and presence or absence of lice or fleas. The six samples which

contained no ticks were collected in November, while the 24 samples which contained ticks were all collected during June.

Endoparasites

Ova of 11 species of endoparasites (listed in Figure 1) were found in the feces of raccoons from Black Rock Forest collected during the summer and fall of 1999 and 2000. Thirty-six samples were collected from 31 identified individuals and five unidentified cubs. Samples from the unidentified cubs may have come from the same individual or individuals; therefore these five samples were omitted from analyses of endoparasite trends. Of the 31 samples from identified individuals, 20 contained one or more endoparasitic species. The five fecal samples from unidentified cubs contained no ova of enteric parasites. All 11 species of enteric parasites were found in raccoons in the Jim's Pond study site, while only six were found in the Glycerine Hollow site. Five species were found only in Jim's Pond, while no species were found only in Glycerine Hollow.

Figure 1. Raccoon Enteric Parasites found in Black Rock Forest, NY

Parasite	Site of infection	Number and percent of hosts carrying ova
Nematoda		
Capillaria aerophilia	JP	3 (8%)
Capilaria plica	JP	1(3%)
Capillaria putorii	GH, JP	9(25%)
Capillaria procyonis	JP	1 (3%)
Crenosoma sp.	GH, JP	2 (6%)
(Order) Digenea	GH, JP	2 (6%)
Macracanthorhynchus ingens	JP	1 (3%)
Placoconus lotoris	JP	1 (3%)
(Genus) Strongyloides	GH, JP	3 (8%)
Protozoan		
Eimeria nutalli	GH, JP	8 (22%)
Eimeria procyonis	GH, JP	11 (31%)

Peterson's chi-squared and Fisher exact tests showed a relationship between sex and *Capillaria putorii* prevalence (P=0.041, P=0.056), but not between sex and prevalences of other endoparasite species. The tests showed a relationship between season of sample collection and *Eimeria procyonis* prevalence (P=0.038, P=0.056), but not between season and prevalences of other endoparasite species. Peterson's chi-squared and Fisher exact tests showed no significant relationships between *Eimeria nutalli* and the following variables: individual's sex, age, study site, status of lactation if female, or the month or season of fecal sample collection. The tests showed no significant relationships between any endoparasite species and the following variables: age, study site, or the status of lactation in females.

Unpaired t-tests showed no significant differences in the number of endoparasitic species among sexes, age classes, lactating and nonlactating females, study sites, and season of sample collection. Linear regressions and correlations showed no significant relationships between number of endoparasite species and month or date (two years combined). A strong relationship between month and *Eimeria procyonis* prevalence was found with a correlation coefficient of 0.679. The two other endoparasite species showed very weak correlations with month and date. Linear regressions showed no significant relationships between endoparasitic species and month of sample collection.

Linear regressions showed no significant relationships between numbers of lice, fleas, and ticks and weight or length of individuals within each sex and within both sexes grouped. The relationship between months and numbers of endoparasite species and prevalences of the three most common species was described using bar graphs (Figures 2,

3, 4, 5). Figure 6, a histogram, shows the frequency of numbers of species found in the Black Rock Forest raccoon population.

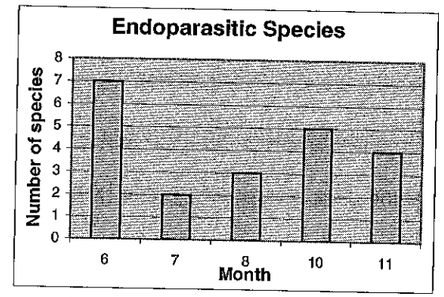

Figure 2. Number of endoparasitic species per month in fecal samples from raccooons in Black Rock Forest.

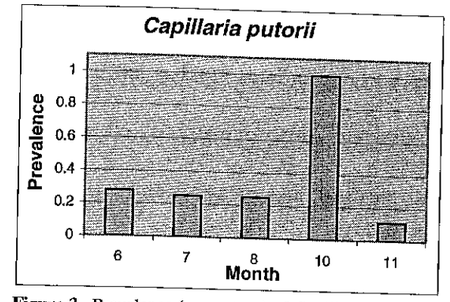

Figure 3. Prevalence (percentage) of *Capillaria putorii* found in fecal samples each month. Fraction is samples carrying / samples collected each month.

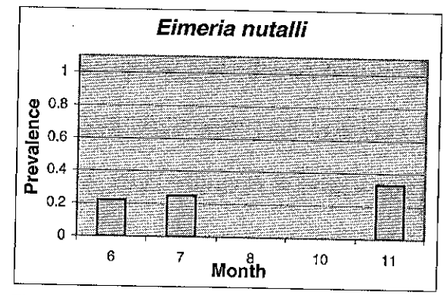

Figure 4. Prevalence of *Eimeria nutalli* found in fecal samples each month.

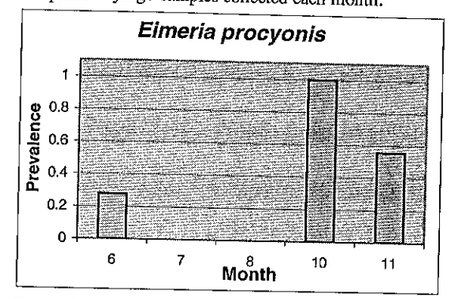

Figure 5. Prevalence of *Eimeria procyonis* found in fecal samples each month.

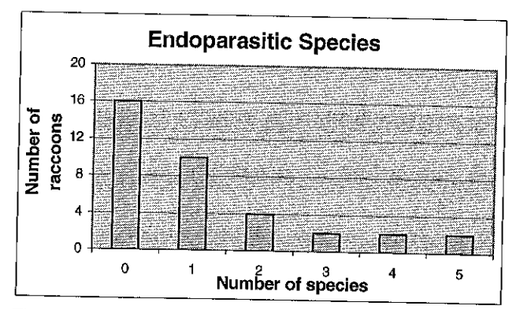

Figure 6. Frequencies (numbers) of raccoons carrying numbers of endoparasitic species in Black Rock Forest.

DISCUSSION

Movement and Denning Behavior

Radiotelemetry data were collected in the winter of 1999-2000, though more robustly from June 2000 onwards. I was interested in finding patterns of movement in different sex and age classes and seeing how these patterns affected parasite diversity and abundance. Unfortunately, due to the nacent state of the project and difficulties involved with several disappearing animals, the movement data was not sufficiently robust to answer this set of questions. Three trapped and radiocollared raccoons failed to ever be picked up by radiotelemetry, indicating equipment problems or more likely, transient raccoons passing through the forest. Several animals moved to the nearby West Point golf course or disappeared during the course of our study, and radiotelemetry skills and equipment were improved toward the end of my field session. Therefore, home range size and frequency of movement in these raccoons could not confidently be estimated. However, radiotelemetry data do show a shift from communal denning in many individuals in the winter of 1999-2000 to no communal denning among any individuals in the summer of 2000. If this shows up in future years as a seasonal pattern, it can be hypothesized that raccoons in Black Rock Forest may communally den in winter for thermoregulation. The use of only rock den sites during the winter 1999 suggests that raccoons use this type of den as opposed to tree limbs and dens to shelter themselves from colder weather. The use of tree limbs, forks, and dens during all types of weather during the summer 2000 suggests that the shift to rock dens only is not caused by rainy or otherwise inclement summer weather. Different mechanisms which may trigger the shift

to communal denning and the use of rock dens only are temperature, snow pack, and occurrence and duration of freezes.

If subsequent years' data show a seasonal shift from no communal denning in summers to frequent communal denning in winters, this may have important implications for parasite abundance and transmittance in the population. Periods of communal denning could cause an increase in contact rates and transmittance of parasites and disease among raccoons. This could also cause a decrease in parasites such as ticks that may be removed by allogrooming. Though there are no previous reports of allogrooming in raccoons, the possibility exists as demonstrated by Appendix 3g (photograph), which shows that one raccoon has aided another by gnawing off this plastic ear tag. Captive brushtail possums (*Trichosurus vulpeculainteractions*) have displayed frequent interactions that included long periods of touching, as well as food sharing and allogrooming (Day et al., 2000). In this group males rarely communally denned, less than 5% time in both the breeding and the nonbreeding seasons. Female pairs in both seasons and mixed-sex pairs in the breeding season denned together frequently (84-91% days). If raccoons show similar biases in mating partners and also display allogrooming, then different classes and age structures may display different ectoparasite loads. While there is denning data for the winter of 1999-200, it is a small sample of the population and ectoparasite data from these individuals were collected in a different season. Therefore the affects of communal denning, social structure, and possible allogrooming on ectoparasite loads cannot presently be tested for raccoons in Black Rock Forest.

Potential costs of changing den sites for raccoons include time, energy, potential exposure to predators, and extra costs incurred in carrying or moving offspring. Potential

benefits include avoidance of soiled den sites that may contain parasites and their eggs as well as time and energy saved not returning to a den after traveling and foraging. Studies have shown that increased parasite load is a major cost of nest reuse and reduces the reproductive success and fitness of chicks in purple martins, *Progne subis* (Moss & Camin, 1970), cliff swallows, *Hirundo pyrrhonota* (Brown & Brown, 1986), and barn swallows, *Hirundo rustica* (Shields & Crook, 1987). Roost switching in Pallid bats (*Antrozous pallidus*) was found not to correlate with weather or roost characteristics, but rather with ectoparasite loads (Lewis, 1996). High ectoparasite loads were correlated with lower body weight in female bats, suggesting either that higher loads are costly to their fitness or that smaller females are more susceptible to ectoparasites. Both lactating and pregnant Pallid bats change roosts, but lactating bats travel shorter distances between consecutive roosts. These findings suggest that Pallid bats, like other mammals and birds, change living sites frequently to avoid increased ectoparasite loads, which are costly to their fitness. Because lactating females of this and other species incur more costs by moving their offspring between sites, they may move less frequently or move smaller distances. Furthermore, mothering females may require special habitat for roosts or den sites, which further limit their choices and movement.

Three raccoons in Black Rock Forest changed den sites frequently and infrequently returned to former den sites during the summer of 2000, whereas three raccoons displayed some den fidelity. Den fidelity, especially in the case of staying subsequent nights, implies increased parasite loads for these individuals and their offspring if any, but it is not known if this does result in decreased fitness for these individuals. My study cannot test relationships among lactating females versus non-

lactating females and males because of the inadequate denning data, which lacks den sites confirmed within 50 feet for consecutive nights and for many individuals altogether. Furthermore, the ectoparasite data was not necessarily collected at the time that individuals were lactating and/or showing den fidelity.

Ectoparasites

Hair samples collected from raccoons in Black Rock Forest during summer 1999 through summer 2000 showed a relationship between lice and sex, with males having more lice and lice per mg on average than females. This may be due to differences in levels of interaction within and between sexes. Gompper (in review) found that the presence or absence of chiggers varied significantly with the degree of host's sociality in coatis (*Nasua narica*), the closest living relative of raccoons, in Panama. Coatis have a more polarized social structure than raccoons, and the increased chigger load among coatis were experienced by members of bands, which can reach more than 20 members, rather than solitary males.

Raccoons of greater weight were found to carry more ticks, as assayed by checks on the ears and back. One explanation for this trend is that heavier raccoons are older and therefore have more time to accumulate ticks. There is a seasonal die-off of the adult ticks, but eggs or immature ticks may remain and accumulate on older individuals through years. Another explanation for the correlation between number of ticks and weight is that raccoons are heavier as a result of more foraging activity, which means that they cover more ground and may have more opportunity for picking up ticks. In coatis, Gompper (in review) found a higher prevalence of ticks on solitary males than on band members and found that age was not correlated with abundance of ticks. Allogrooming

may be responsible for this trend in coatis, but there is no reason to suggest that it would be responsible for decreased tick abundance in smaller raccoons.

All abundances of ectoparasites were correlated with the date and month of hair sample collection except for lice. Number of fleas, fleas per mg, and lice per mg increased from summer to winter by date and by month. Ticks decreased in number from summer to winter, with all raccoons inspected during November containing no ticks at all. The life cycles of these parasites, regular seasonal or random differences in weather, and altered seasonal contact rates in the host may contribute to these seasonal ectoparasite trends.

Hair samples and ticks assays of raccoons in from Black Rock Forest showed a relationship between the presence of one ectoparasite and the presence of another for lice and fleas, lice and ticks, ticks and fleas, lice per mg and fleas per mg, and ticks and fleas per mg, though not for ticks and lice per mg. This suggests that raccoons carrying one ectoparasite are more likely to carry another, or simply that the hair samples collected which contain one ectoparasite are more likely to carry another. Some hair samples may be more likely to carry all types of ectoparasites than others because of differences at the time of collection in combing, molting of hair, or environmental abundance of ectoparasites. My study could not examine whether certain individuals are more parasitized than others internally and externally, because the hair and fecal samples were not all collected on the same date or month, and because the hair data yields abundance not species of ectoparasites, whereas the fecal data yields species not abundance of endoparasites.

Endoparasites

Eleven out of 31 (35%) samples from identified individuals and five samples from unidentified cubs contained no ova of enteric parasites. While this is a much greater percentage than has been reported for other raccoon populations in the United States, differences in sampling of endoparasites are probably the cause. Most surveys of raccoon endoparasites that have been done either utilized whole animals for necropsies or used hundreds of fecal samples. The low prevalences of enteric parasites in my study may therefore be due to actual differences in this raccoon population or the inability of small numbers of fecal samples from different seasons to give a complete survey of endoparasites present.

Four out of the five species that were found only in the Jim's Pond site were found in only one sample. Therefore, these species may be present in low prevalences or abundances in Glycerine Hollow that have not been detected in my small sampling of feces. *Capillaria aerophilia*, which was found in three individuals in Jim's Pond and none in Glycerin Hollow, may not be present in the latter or have been detected with my survey. However, *C. putorii* was found in Glycerine Hollow and it is notable that ova of the three species of *Capillaria* identified in my study are very difficult to distinguish from one another.

Two species of enteric parasites showed trends in our population, while many species had such low rates of occurrence (1-3 raccoons) that they could not be tested with any variables. *Capillaria putorii* showed greater rates of prevalence in males than in female raccoons. This finding agrees with previous studies which have found higher rates of grouped *Capillaria spp.* and *Capillaria procyonis* in males than in females

(Hamir & Rupprechtt, 1998; Butterworth & Beverly-Burton, 1981). Prevalence of *Eimeria procyonis* was greater in fecal samples collected in winter (October-November) than those collected in summer (June-August). This relationship was also supported by an increase in *E. procyonis* prevalence through the months from June through November. However, Figure 5 shows that these relationships may be due to the 100% prevalence of *E. procyonis* during October, wherein only one sample was collected.

Figures 3 and 4 show the prevalences of *Capillaria putorii* and *Eimeria nutalli* in percentages and in samples carrying each species per samples collected for each month. There are no significant relationships among months, which may be due to small number of fecal samples. Figure 1 shows the number of endoparasite species found in fecal samples collected in the months of June through July. While June yielded the highest number of species, this may be due to the greater amount of fecal samples collected in this month relative to others (n=18 in June, n=1 in October) rather than seasonal differences in endoparasite diversity (Figure 6).

All raccoons tested negative for *Giardia* and no *Baylisascaris procyonis* has been found in the population to date. These endoparasites are thought to be ubiquitous in raccoons in the Northeast, so my findings are interesting. *Baylisascaris procyonis* can have a major impact on many species of birds and mammals, as has been described; specifically, the decline of the Alleghany woodrat (*Neotoma magister*) has been partially attributed to this roundworm (Balcom & Yahner, 1996).

Ova of *Placoconus lotoris* (Family Ancylostomatidae), a blood-sucking hookworm of the small intestine, were found in the feces of one raccoon in my study. Infection by this parasite occurs either by ingestion of or skin penetration by infective

larvae, which undergo extensive migration through the host tissue before developing into adults in the small intestine (Bowman, 1995). Infection of hosts may be completely asymptomatic or result in anemia and fatal exsanguinations in some species. The resistance of the host, as with many enteric parasites, depends on age, premunition, and acquired immunity, as well as the individual's ability to replace lost blood, which is affected by nutrition and other stresses (Bowman, 1995). This parasite can be transmitted from mother to offspring through nursing, but the infected female in this study was not observed to have physical indications of lactation.

Ova of *Macracanthorhynchus ingens* (Phylum Acanthocephala), a thorny headed worm that hooks into the intestinal wall of its terminal host, was found in the feces of one raccoon. This endoparasite of raccoons uses millipedes of the genus *Narceus* as intermediate hosts. The eggs containing *M. ingens* larvae are ingested by *Narceus spp.*, and then the larvae develop into their infective stage which can infect raccoons who eat the arthropods. Raccoons have been observed to roll these millipedes around in dust to exhaust their defensive secretions before eating them (Bowman, 1995).

Feces of three raccoons contained ova of species belonging to the Genus *Strongyloides* (Family Strongylidae). Members of this genus are mostly parasites of the large intestines and alternate free-living and parasitic (only females) generations. The free-living larvae can bore into the skin of a host, and larvae can also be transmitted through nursing in mother hosts (Williams & Zajac, 1980; Bowman, 1995). One of the three raccoons carrying *Strongyloides* is a mother with two confirmed cubs, so it is possible that her offspring also carry this parasite.

Ova of three species of the genus *Capillaria* were found in the Black Rock Forest raccoons: *C. aerophilia* in three raccoons, *C. putorii* in nine raccoons, *C. plica* in one raccoon, and *C. procyonis* in one raccoon. *C. aerophilus* is found in the host's bronchi and can be transmitted directly or through earthworms, which serve as intermediate hosts (Bowman, 1995). *C. plica* also uses earthworms as its intermediate host and attaches to the mucus membrane of the urinary tract in its terminal host. *C. putorii* are intestinal nematodes.

Ova of species belonging to the genus *Crenosoma* (family Crenosomatidae) were found in 2 raccoons in Black Rock Forest. Females of this genus deposit larvae or thin-shelled eggs containing first stage larvae inside the host, and these eggs ascend into the trachea and descend the alimentary tract to exit in the terminal host's feces. Then they develop into infective third stage larvae in snails and slugs, which serve as the intermediate host (Bowman, 1995). Ova of flukes, parasites of the order Digenea (class Trematoda), were found in the feces of two raccoons. These parasites undergo indirect development with sexual and asexual generations parasitizing alternative hosts. Mammals often serve as final hosts from eating arthropods or fish, depending on the species (Bowman, 1995).

Two species of the genus *Eimeria* (class Coccidia) were found in my study: *Emeria nutalli* in eight individuals and *Eimeria procynis* in 11 individuals. These protozoan parasites can be transmitted from predator to prey or by fecal to oral contact (Bowman, 1995).

CONLUSIONS

The results of this study provide an indication of seasonal communal denning and a parasitological survey of raccoons in Black Rock Forest, NY which will contribute to the knowledge base necessary to understand and monitor parasitism and disease in mammal populations. Furthermore, this study will serve as a foundation for continuing research in this population on the interactions of movement and social behavior with parasitism and disease. Relationships were found between lice and sex, ticks and weight, *Capillaria putorii* and sex, and *Eineria procyonis* and season in this raccoon population. Ova of eleven species of endoparasites were found, several of which can be transmitted through to other animals through the feces of raccoons. *Baylisascaris procyonis* and *Giardia*, both thought to be common in northeastern raccoons and a serious concern for wildlife management, were not found in raccoons in Black Rock Forest.

Raccoons commonly deposit their feces at the entrance of their dens or at the base of trees they sleep in. When raccoons display den fidelity or communally den, large amounts of feces can build up in raccoon latrines, which can increase transmittance of parasites carried in these feces within raccoon populations or to other animal populations. Raccoons in Black Rock Forest were found to carry several enteric parasites which can be transmitted though their feces, and were found to variably display den fidelity and communal denning. Further research on the denning behavior and social structure of raccoons can give insight into how endoparasites and ectoparasites that cause disease interact with these factors.

RECOMMENDATIONS FOR FUTURE RESEARCH

Presently, the continued research of Dr. Matthew Gompper and Amber Wright in Black Rock Forest is further examining the interactions of social behavior and parasitism and disease in this population of raccoons. More hair samples are needed to provide ectoparasite data, such that comparisons of lice, fleas, and ticks among individuals of different age, sex, lactation status, weight, and length can be performed within different seasons. Gompper (in review) found that tick intensities in coatis were higher in the wet season than in the dry season in Panama, and my study found that no ticks were found on animals during the winter. Species identification of the ectoparasites should be performed, particularly to see if the tick *Ixodes dammini* is present in the population and carrying *Borrelia burgdorferi*, the agent of Lyme disease. *Borrelia burgdorferi* was found in only 1.9% of host-associated ticks, but *B. burgdorferi* spirochetes were cultured in blood of 23 (26%) of 87 raccoons in a study in North Carolina (Quellete et al., 1997).

More movement and denning data needs to be collected to examine den fidelity and communal denning in raccoons in Black Rock Forest and elsewhere in conjunction with parasitological trends among individuals displaying these behaviors. Genetic analysis of relatedness between these individuals can be used to assess how social structures in raccoons populations are formed and how they affect parasitism and disease dynamics.

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Appendix 1. Enteric parasites found in raccoons, Procyon lotor, in the United States and Canada

		Ching, Leighton, Stephen 2000 BC,Canada	Butterworth, Beverly-Burton 1981 ON,Canada	Pietrzak, Pung 1998 GA	Kerr, Henke, Pence 1997 TX
Nemotoda	Aelurostrongylus sp.				
	Arthrocephalus lotoris	x			
	Baylisascaris procyonis	x			x
	Capillaria sp.	x	x		
	Capillaria procyonis		x		
	Capillaria putori		x		
	Capilaria plica				
	Cosmocephalus sp.				
	Crenosoma goblei		x		
	Dioctophyma renale				
	Dracunculus insignis				
	Gnathostoma procyonis				
	Molineus barbatus				
	Physaloptera rara				
	Trichinella spiralis				
Digenia	Alaria (Paralaria) taxideae	x			
	Aschorhytis charadriformis	x			
	Brachylaima fuscatum	x			
	Cryptocotyle jejenum	x			
	Microphallus similis	x			
	Neodiplostomum cratera	x			
	Notocotylus sp.	x			
	Plagiorchis vespertilionis parorchis	x			
	Pricetrema zalophi	x			
Acanthocephala	Macracanthorhynchus ingens				
	Profilicollis botulus	x			
	Prosorhynchus cylindraceus	x			
Cestoidea	Atriotaenia procyonis				
	Mesocestoides sp.				
	Mesocestoides variabilis				
	Proceroid sp.	x			
	Spirometra mansonoides				
Trematode	Apophallus cenustus				
	Brachylaima virginiana				
	Euparyphium beaveri				
	Euryhelmis squamula				
	Eurytrema procyonis				
	Eurytrema squamala				
	Fibricola cratera				
	Fibricola texensis				
	Gyrosoma singularis				
	Lyperosomum sinnosum				
	Mariteminoides nettae				
	Mesostephanus appendiculatoides				
	Metagonimoides oregonensis				
	Paragonimus kellicotti				
	Paragonimus rudis				
	Parallelorchis diglossus				
	Phagicola dimunata				
	Phagicola longa				
	Pharyngostomoides procyonis				
	Procyotrema marsupiformis				
Protozoan	Eimeria spp.				
	Sarcocystis sp.				
	Trypanosoma cruzi			x	

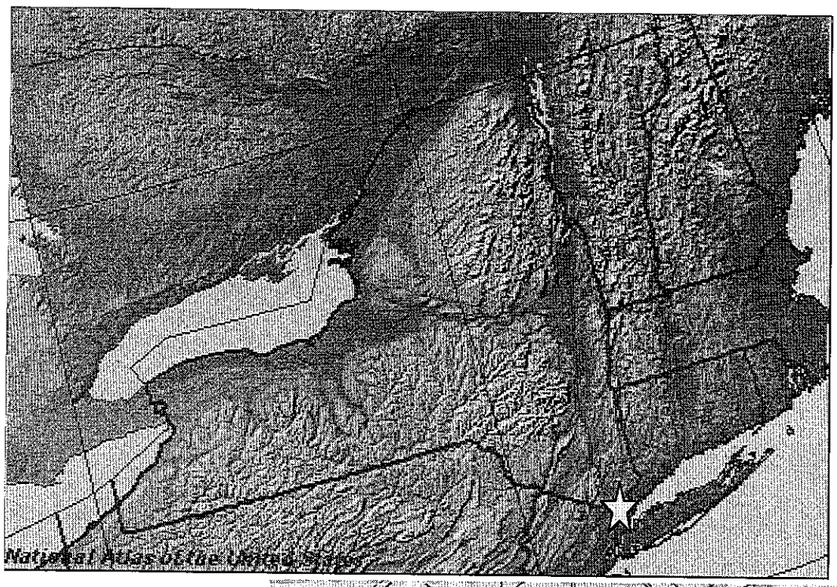
Appendix 1. (continued)

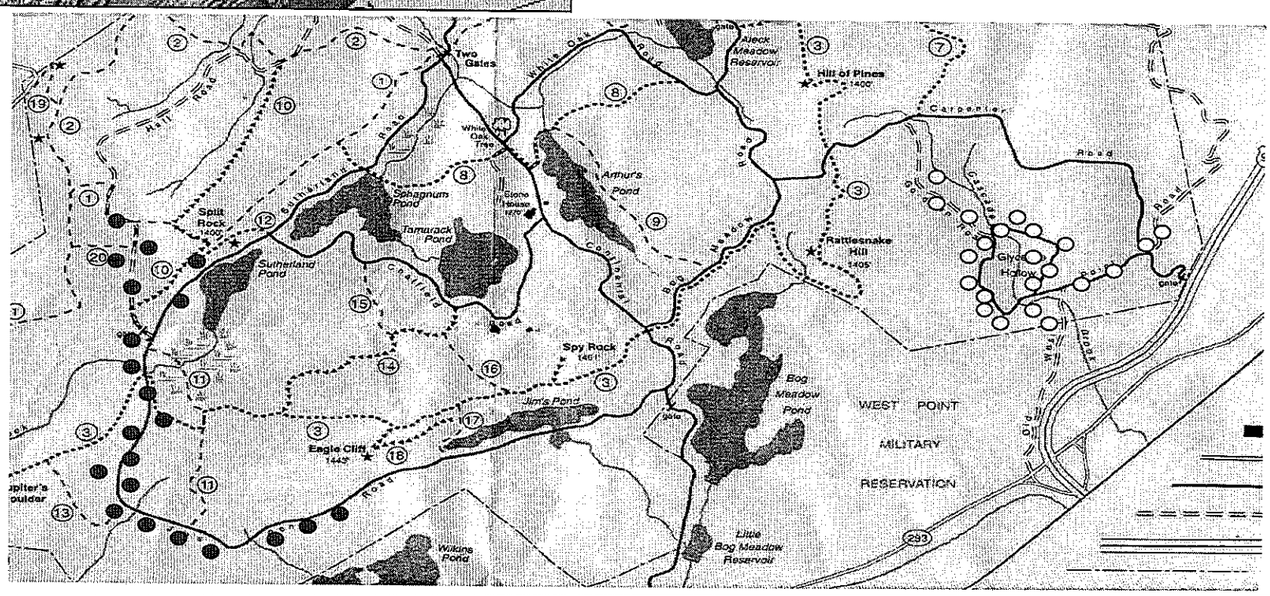
		Hamir, Rupprechtt 1998 VA,SC,PN	Robel, Barnes, Upton 1989 KS	Snyder, Fitzgerald 1985 IL	Kidder, Wade, Richmond,Scvhwager 1989 NY(Ithaca)
Nemotoda	Aelurostrongylus sp.				
	Arthrocephalus lotoris			x	
	Baylisascaris procyonis		x	x	x
	Capillaria sp.	x			
	Capillaria procyonis			x	
	Capillaria putori			x	
	Capilaria plica				
	Cosmocephalus sp.				
	Crenosoma goblei			x	
	Dioctophyma renale				
	Dracunculus insignis			x	
	Gnathostoma procyonis				
	Molineus barbatus		x	x	
	Physaloptera rara		x	x	
	Trichinella spiralis				
Digenia	Alaria (Paralaria) taxideae				
	Aschorhytis charadriformis				
	Brachylaima fuscatum				
	Cryptocotyle jejenum				
	Microphallus similis				
	Neodiplostomum cratera				
	Notocotylus sp.				
	Plagiorchis vespertilionis parorchis				
	Pricetrema zalophi				
Acanthocephala	Macracanthorhynchus ingens		x	x	
	Profilicollis botulus				
	Prosorhynchus cylindraceus				
Cestoidea	Atriotaenia procyonis		x	x	
	Mesocestoides sp.		x	x	
	Mesocestoides variabilis				
	Proceroid sp.				
	Spirometra mansonoides				
Trematode	Apophallus cenustus				
	Brachylaima virginiana				
	Euparyphium beaveri			x	
	Euryhelmis squamula				
	Eurytrema procyonis				
	Eurytrema squamala				
	Fibricola cratera			x	
	Fibricola texensis				
	Gyrosoma singularis			x	
	Lyperosomum sinnosum				
	Mariteminoides nettae				
	Mesostephanus appendiculatoides				
	Metagonimoides oregonensis				
	Paragonimus kellicotti				
	Paragonimus rudis				
	Parallelorchis diglossus				
	Phagicola dimunata				
	Phagicola longa				
	Pharyngostomoides procyonis				
	Procyotrema marsupiformis				
Protozoan	Eimeria spp.		x		
	Sarcocystis sp.		x		
	Trypanosoma cruzi				

Appendix 1. (continued)

		Cole, Shoop 1987 KT	Bafundo,Wilhelm, Kennedy 1979 TN	Harkema, Miller 1964 review: southeastern US
Nemotoda	Aelurostrongylus sp.			x
	Arthrocephalus lotoris	x	x	x
	Baylisascaris procyonis	x	x	
	Capillaria sp.			
	Capillaria procyonis			
	Capillaria putori	x		
	Capilaria plica	x		x
	Cosmocephalus sp.			x
	Crenosoma goblei	x		x
	Dioctophyma renale			x
	Dracunculus insignis	x		x
	Gnathostoma procyonis	x	x	x
	Molineus barbatus	x	x	x
	Physaloptera rara	x	x	x
	Trichinella spiralis	x		
Digenia	Alaria (Paralaria) taxideae			
	Aschorhytis charadriformis			
	Brachylaima fuscatum			
	Cryptocotyle jejenum			
	Microphallus similis			
	Neodiplostomum cratera			
	Notocotylus sp.			
	Plagiorchis vespertilionis parorchis			
	Pricetrema zalophi			
Acanthocephala	Macracanthorhynchus ingens	x	x	x
	Profilicollis botulus			
	Prosorhynchus cylindraceus			
Cestoidea	Atriotaenia procyonis	x	x	x
	Mesocestoides sp.			
	Mesocestoides variabilis	x	x	x
	Proceroid sp.			
	Spirometra mansonoides			x
Trematode	Apophallus cenustus			x
	Brachylaima virginiana	x		
	Euparyphium beaveri		x	x
	Euryhelmis squamula	x		x
	Eurytrema procyonis	x	x	x
	Eurytrema squamala			
	Fibricola cratera	x		x
	Fibricola texensis		x	
	Gyrosoma singularis	x		x
	Lyperosomum sinnosum		x	
	Mariteminoides nettae	x		x
	Mesostephanus appendiculatoides	x		
	Metagonimoides oregonensis	x	x	x
	Paragonimus kellicotti	x		
	Paragonimus rudis			x
	Parallelorchis diglossus		x	x
	Phagicola dimunata			x
	Phagicola longa			x
	Pharyngostomoides procyonis	x	x	x
	Procyotrema marsupiformis			x
Protozoan	Eimeria spp.			
	Sarcocystis sp.			
	Trypanosoma cruzi			

Appendix 2. Study Site:
Black Rock Forest, Cornwall, NY





Appendix 3. Photographs of field work

a. Sedating trapped raccoon

b. Rachel Goodman with sedated raccoon

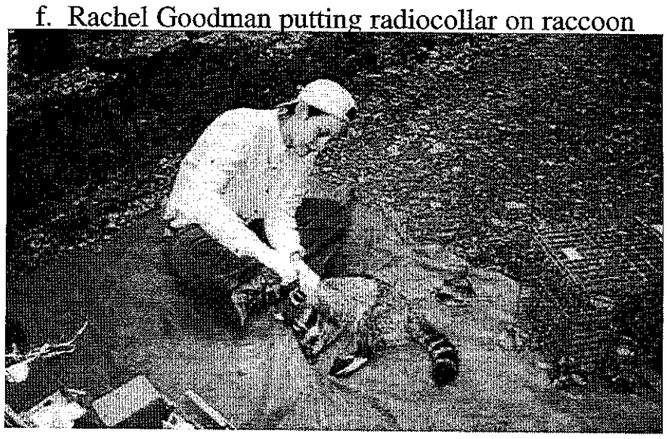
c. Checking raccoon's teeth for wear, discoloration, breakage

d. Checking raccoon's back for ticks

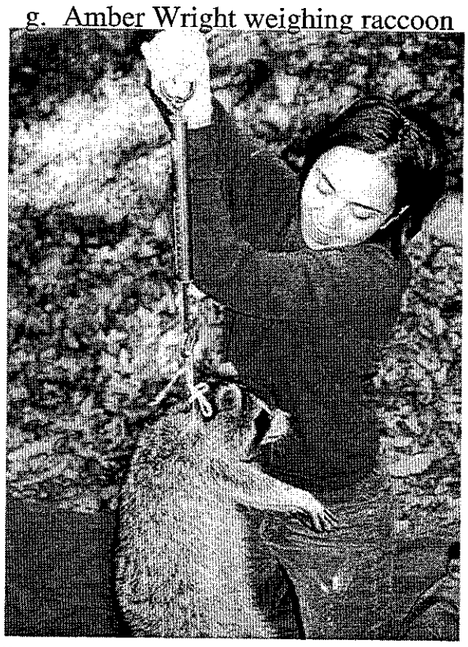
Appendix 3 (continued). Photographs of field work

e. Chris Fiorello shaving raccoon's neck

f. Rachel Goodman putting radiocollar on raccoon



g. Amber Wright weighing raccoon



h. Taking radiotelemetry coordinates