SPATIAL AND CONTACT BEHAVIOUR OF RACCOONS USING A COMMON FEEDING AREA

by

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A thesis submitted to the Department of Biology
in conformity with the requirements for
the degree of Master of Science

Queen's University
Kingston, Ontario, Canada
April, 1997

0-612-20706-4

ABSTRACT

Sarah Ceridwen Totton: Spatial and contact behaviour of raccoons using a common feeding area. M.Sc. thesis, Queen's University at Kingston, April, 1997.

Contact rates of 12 adult raccoons (5 female, 7 male) were measured from visual observations, using betalights to facilitate identification, as these animals fed at a rural garbage dump 40 km north of Kingston, Ontario, Canada, from June to September, 1995.

The rate of bites made and received (/hr) for adult males (0.82 ± 0.17 and 1.36 ± 0.35) vs lactating females (1.37 ± 0.56 and 1.14 ± 0.24) were not significantly different (P=0.26 and 0.71 respectively), nor were the rate of bites made and received (/hr) for raccoons which regularly (1.12 ± 0.22 and 1.49 ± 0.19) vs occasionally (0.87 ± 0.37 and 1.08 ± 0.38) fed at the dump (P=0.57 and 0.36 respectively). Contact rate was not linearly correlated with ambient temperature within the range of 17-28.5°C (R^2=0).

Focal raccoons bit and were bitten by their conspecifics an average of 0.99 (± 0.21) and 1.28 (± 0.21) times (/hr) respectively during feeding. Based on nightly average contact rates, a raccoon is 33% likely to bite one of its conspecifics while shedding rabies virus in its saliva but exhibiting no behavioural symptoms, assuming a preclinical stage of one-day duration.

The 12 raccoons above were radio-tracked an average of 24 nights each from June to October, 1995. The effective area surrounding the dump from which raccoons came to feed was 234 ha. The population density for this area was 1 raccoon/12 ha (modified Petersen Index).

Average summer and fall home ranges of the dump animals (Minimum Convex Polygon) were 69 ha (SD=32 ha) and 45.5 ha (SD=30 ha) respectively. Average grid cell summer and fall home ranges for the dump animals were 144 ha (SD=42 ha) and 117 ha (SD=32 ha) respectively based on 23-ha grid squares. There was not any significant difference in summer grid cell home range sizes between males (154 ± 20 ha) vs females (129 ± 7 ha) (P=0.31), nor between regular (130 ± 10 ha) vs occasional (157 ± 22 ha) dump visitors (P=0.27).

Based on these results, the use of common feeding sites to distribute vaccine-impregnated baits in urban areas is recommended.

Keywords: raccoon, Procyon lotor, social behaviour, contact rate, rabies transmission, home range, communal feeding, betalights

ACKNOWLEDGEMENTS

This study was supervised by Dr. Rowland Tinline in the Department of Geography, and Dr. Rudolf Harmsen in the Department of Biology at Queen's University. I would like to thank both for their helpful comments on early drafts of this thesis. I am very grateful for Dr. Tinline's assistance in producing the home range maps for my raccoons.

I would like to thank my committee members Dr. Richard Rosatte, Dr. Laura Bigler and Dr. Raleigh Robertson for their support and advice, and my field assistants, Liane Smail, Josef Lugarich, and Alix Thompson who made the project much easier to accomplish.

In addition, Dave Grieve and Mike Power helped collect and supply the equipment used in this study, and Damien Joachim and Andrew Silver aged the tooth sections. I also received help from Floyd Connor and Frank Phelan at the Queen's University Biological Station and Al Cross, owner of the Opinicon Resort who allowed me to use the garbage dump on his property for my study.

I would like to extend my appreciation to two people who made a special effort for me: Dr. John Milligan at Queen's Health and Safety for getting me permission to use betalights in my study, and Phil Gaudette at SRB Technologies in Pembroke for designing the betalights for use with raccoons.

Dennis Voigt and Dave Johnston also provided assistance in planning the project. Many thanks to Christine Adkins who wrote some of the software used to analyze the telemetry data, and to the members of the GIS lab, Peg Hauschildt and Sue Holt, for helping me to understand AutoCAD, and to Joanne Surette for being such a mastermind.

Finally, thanks to Don Cuddy at the Kemptville MNR for providing me with good quality maps of the study area and thanks to my friends in Guelph: Elaine, Tana and Renée for being there when I needed them.

This study was supported by an operating and equipment grant from the Ontario Ministry of Natural Resources. The author received funding from an Ontario Graduate Scholarship, a Queen's Graduate Award as well as a generous grant from her progenitors.

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Chapter 1

GENERAL INTRODUCTION

1.1 Rationale

Rabies is a potential health risk to humans, livestock and pets, as well as wildlife (Coyne et al. 1989; MacInnes 1988). A strain of rabies carried by foxes entered Ontario from the Arctic in 1954 and has since become enzootic in this province (Rosatte 1988). Fox rabies currently costs the Ontario and federal governments $8 million/year in post exposure treatment, case investigations, diagnosis, and rabies research; the cost to the public due to pet vaccinations is $60 million/year (C. LeBer, R. Rosatte, and C. MacInnes, unpublished).

The Rabies Unit at the Ontario Ministry of Natural Resources (OMNR) in Peterborough uses a computer model to simulate the epidemiology of fox rabies to maximize the efficiency of their oral baiting program. This program involves aerial distribution of vaccine-impregnated baits and will hopefully result in complete elimination of the fox strain of rabies from Ontario by the year 2001 (MacInnes, unpublished).

Ontario may soon have to contend with another rabies strain: raccoon rabies. The raccoon's ability to thrive in cities and its "semi-domesticated" nature make it a potentially more dangerous rabies vector than the fox

(Kappus _et al._ 1970).

Currently, raccoon rabies is at the Ontario/New York border in the vicinity of the Niagara and St. Lawrence Rivers. Its arrival in Ontario is now imminent and its impact will be substantial (Rosatte, unpublished). The predicted increase in cost to the Ontario government due to extra post-exposure human treatments, diagnosis, administrative costs, case investigations, and research, will be about $5-10 million/year (Ontario Raccoon Rabies Task Force, unpublished).

With the approach of raccoon rabies, a computer model simulating the epidemiology of this strain is being constructed; the model will assist researchers in designing baiting programs as well as trap-vaccinate-release and point infection control strategies which could eradicate this disease should it enter Canada. In order to construct this model, aspects of raccoon biology and behaviour must be known or estimated from information collected in the wild (Voigt _et al._ 1985). Of these, contact rate is one of the most important parameters in the rabies model (MacInnes 1988), but few studies on intraspecific contact rate in raccoons have been conducted (Bigler _et al._ 1973).

1.2 Raccoon biology

The raccoon, _Procyon lotor_, is native to North and Central America, occurring from southern Canada southward as far as Panama (Whitney and Underwood 1952). In Canada, raccoons can be found in southern Quebec, southern Ontario, the aspen parkland of the prairie provinces, and southern British Columbia (Whitney and Underwood 1952). They also occur throughout the Maritime provinces with the exception of Newfoundland (Whitney and Underwood 1952). Though they prefer forested habitats near waterways, raccoons may exploit a range of habitats, including urban and suburban areas (Rosatte et al. 1991; Whitney and Underwood 1952).

The breeding season occurs from the first week in February to the first week in March (Stuewer 1943), with earlier breeding at southern latitudes (Schneider et al. 1971). This period is characterized by high levels of aggressive behaviour in raccoons (Sharp and Sharp 1956). Males mate with one or more females (Fritzell 1978) and young are born 63 days later in late March, April, or May (Stuewer 1943). In southern Ontario, litters have been reported from April through September (Rosatte, unpublished).

During summer and early fall, raccoons feed voraciously to build up fat stores in preparation for the coming winter (Mech et al. 1968) when they will enter a period of dormancy (torpor) which, although characterized by a slight decrease in body temperature, is not true hibernation; if ambient temperatures during winter rise above -4°C, raccoons may emerge to forage (Sharp and Sharp

1956).

Raccoons are opportunistic omnivores consuming a diverse diet which includes fruits, nuts, grains, insects, fish, earthworms, frogs, small mammals, bird eggs, and crayfish (Johnson 1970). In addition, raccoons display a remarkable ability to exploit new feeding opportunities, such as garbage cans in the city (Rosatte et al. 1991) or garbage dumps in the countryside (Johnson 1970).

The nocturnal nature of raccoons makes observation of their social interactions difficult (Shirer and Fitch 1970). Raccoons are not generally considered social, however, temporary associations between two or more animals are common. During the breeding season these interactions are brief, making observation impractical (Seidensticker et al. 1988; Sharp and Sharp 1956). During winter dormancy, raccoons may be found in communal dens of usually fewer than eight, but as many as 23 individuals (Mech and Turkowski 1966; Twitchell and Dill 1949).

Juveniles may disperse in the fall, but those which do not may den with the sows and disperse the following spring or summer (Shirer and Fitch 1970). Direct observation of contact behaviour during dispersal, without disturbing the animals, is probably not practical.

Raccoons may also congregate regularly at concentrated food sources, some natural, such as patches of fruit trees, some artificial, such as man-made feeding stations and garbage dumps (Seidensticker *et al.* 1988; Sharp and Sharp 1956). Because large numbers of raccoons as well as other mammals may be attracted to such food sources, there is a heightened potential for both intra- and inter-specific contacts to occur (Seidensticker *et al.* 1988). In addition, these sites offer an opportunity to observe the social interaction of raccoons with minimal intrusion.

1.3 Thesis objectives and format

The objectives of this study were:

1. To determine the rate of intraspecific contacts relevant to the spread of rabies in raccoons using a well-established feeding site (garbage dump), with regard to the ambient temperature, the sex of the animal, and the frequency with which it uses the dump (Chapter 2).
2. To determine the interspecific contact rate of raccoons at the feeding site with species from which they may contract the fox rabies strain, and to which they may transmit the raccoon rabies strain (Chapter 2).
3. To determine the seasonal home ranges of raccoons using a common feeding site as a regular or occasional source of food (Chapter 3).
4. To assess the potential usefulness of baiting stations for orally vaccinating raccoons against

raccoon rabies (Chapters 2, 3 and 4).

In order to assess contact rates, direct visual observations of raccoons using a garbage dump north of Kingston, Ontario, were made from June to September 1995 (Chapter 2).

The topography and vegetation of the study area, as well as the number of animals in the study, made it impractical to locate and visually observe these animals' activities when they were not at the dump site. For this reason, radiotelemetry was employed to estimate summer and fall home ranges and movements of these raccoons from June to October 1995 (Chapter 3).

Information on the raccoons' home ranges and movements (Chapter 3) and observations of their behaviour (Chapter 2) complement each other, forming a clearer picture of the potential for rabies spread in that area. Practical aspects of these results as applied to rabies control strategies are discussed in Chapter 4.

Chapter 2

CONTACT RATES OF RACCOONS USING A COMMON FEEDING SITE IN RURAL EASTERN ONTARIO

2.1 Abstract

Contact rate is one of the most important parameters required for a model simulating the spread of raccoon rabies. Such a model could be used as part of a strategy to control the spread of raccoon rabies should it enter Canada.

Contact rates of 12 adult raccoons (5 female, 7 male) were measured visually as these animals fed at a rural garbage dump 40 km north of Kingston, Ontario, Canada, from June to September 1995. Betalights (radioactive tags) were used to aid in nocturnal identification of these raccoons.

The rate of bites made and received (/hr) for adult males (0.82 $\pm$ 0.17 and 1.36 $\pm$ 0.35) vs lactating females (1.37 $\pm$ 0.56 and 1.14 $\pm$ 0.24) were not significantly different ($P=0.26$ and 0.71 respectively). The rate of bites made and received (/hr) for raccoons which regularly (1.12 $\pm$ 0.22 and 1.49 $\pm$ 0.19) vs occasionally (0.87 $\pm$ 0.37 and 1.08 $\pm$ 0.38) fed at the dump were also not significantly different ($P=0.57$ and 0.36 respectively). Lack of significance may be a result of the small sample size.

Focal raccoons bit and were bitten by their conspecifics an average of 0.99 ($\pm$ 0.21) and 1.28 ($\pm$ 0.21) times (/hr) respectively while feeding at the dump.

Based on nightly averages, a raccoon is 33% likely to bite one of its conspecifics while shedding rabies virus in its saliva but exhibiting no behavioural symptoms of the disease, given a preclinical stage with a one-day duration.

Contact rate did not vary linearly within the ambient temperature range of 17-28.5°C (R^2=0) and interspecific contacts were not observed during the study, though raccoons and skunks often fed at the dump concurrently. Raccoon activity at the dump peaked between 22:00 and 23:00 and may have been influenced by the onset of darkness.

2.2 Introduction

2.2.1 Contact types

In order to assess contact rates for raccoons that would be useful in a rabies model, it is important to define which types of contacts are relevant to rabies transmission. In addition, for each relevant contact, the risk of transmission must be estimated from available data. Since field studies have not been done to quantify the risk of raccoon rabies transmission for different contact types, literature on rabies transmission in humans and other animal species must be used to develop a scale of relative risk. This scale is necessarily qualitative, since susceptibility is affected by host species and virus strains (West 1972), preventing direct quantitative comparisons to raccoons.

Not all contacts carry the same risk of rabies transmission (Fishbein 1991). In order to contract rabies, a sufficient quantity of the virus must enter the host through the lining of the eyes, ears, nose, or a break in the skin (West 1972).

Bites are associated with the highest risk of rabies transmission (Fishbein 1991) and bite location is known to affect this risk (Sitthi-Amorn et al. 1987; Shah and Jaswal 1976). In untreated humans, head and neck bites cause higher mortality than trunk, arm or leg bites (Fishbein 1991). For this reason, head and neck bites were deemed high risk contacts, while all other bites were rated medium risk for the purposes of this study.

Rabies is much less commonly transmitted by non-bite exposures (West 1972). It may be transmitted when the infected animal places its open or closed mouth on the healthy animal's body but only if the skin is broken at the site of contact (West 1972). This type of transmission is extremely rare (Fishbein 1991). The presence of broken glass and sharp nails at a garbage dump may present an injury risk to the raccoons, but the overall likelihood of the injury occurring in the same place as the contact is probably slim. For this reason, such contacts were deemed low risk for this study.

Licks, though more common than bites, are rarely, if ever, responsible for transmitting rabies (Fishbein 1991).

For this reason, grooming and licking were deemed low risk contacts.

Rabies virus may be present in the nasal mucous (Balachandran and Charlton 1994) as well as the saliva. Therefore, it is possible that rabies might be transmitted through either spitting or sneezing, though the literature mentions only two human cases of rabies contracted from a wolf in a similar manner (Fishbein 1991). For this reason, spitting and sneezing were deemed low risk contacts.

Exposures not deemed relevant for this study include contact of the oral mucosa or skin of one raccoon with another animal's saliva, present on the ground or on a shared piece of food. The Ontario Ministry of Health (1993) recommends no treatment for humans having such indirect contact with rabid animals, so this type of exposure was thought to carry no risk of rabies transmission for the purposes of this study.

In addition, contact with the "spray" of a skunk was not considered a potential rabies risk because the virus is not shed in the musk of rabid skunks (Beauregard and Casey 1973).

A summary of all relevant contact types and their associated risks is given in Table 2.1.

2.2.2 Males vs. females

Results of a study on the behaviour of raccoons at a winter feeding station indicated that a dominance hierarchy existed within the population (Sharp and Sharp 1956). Adult females with their young were at the top of this hierarchy, followed by groups of adults (two or more), followed by single adult animals, followed by juveniles separated from their mothers (Sharp and Sharp 1956).

Dominant animals should be bitten (high and medium risk contacts) at a lower rate than subordinate animals, assuming that bites are the result of aggression.

Assuming that low risk contacts (grooming, nose-to-nose contacts, and other non-aggressive contacts) serve to strengthen social bonds, lactating females should give and receive this type of contact at a higher rate than males or non-lactating females.

2.2.3 Regular vs occasional dump visitors

A study by Barash (1974), indicates that some form of dominance hierarchy exists <u>within</u> as well as between sexes, at least for adult male raccoons. In this study, male raccoons trapped in the wild were exposed to each other in captivity (Barash 1974). Raccoons trapped at greater than 5 km from each other fought more often and expressed non-contact subordinate-dominant behaviours less often than raccoons trapped within 5 km of each other (Barash 1974). These latter animals exhibited subordinate-dominant behaviours (threat/avoidance) with little, if any physical contact, presumably because they were familiar with each other (Barash 1974).

If Barash's (1974) hypothesis that neighbour recognition occurs in raccoons is correct, then raccoons visiting the dump occasionally would bite and be bitten more frequently than raccoons which used the dump regularly and presumably were part of an established dominance hierarchy.

Because of neighbour recognition, regular dump visitors may have a higher rate of non-bite contacts compared to occasional visitors, if non-bite contacts have a social, rather than an aggressive function.

2.2.4 Ambient temperature

Sharp and Sharp (1956) noted that lower ambient temperatures were associated with less activity in raccoons using a common feeding site in the winter. Consequently, lower temperatures should also be associated with lower contact rates in these animals if contact rate is proportional to activity.

2.2.5 Interspecific contacts

The only terrestrial strain of rabies currently endemic to southern Ontario is Arctic fox (_Alopex lagopus_) rabies. The most important vectors, as far as transmission of this strain is concerned, are red foxes, striped skunks, and domestic cats and dogs (MacInnes _et al._ 1988).

Of these species, striped skunks have similar food preferences to raccoons and are known to share foraging sites (Shirer and Fitch 1970). The extent or frequency of contact of raccoons with other species sharing a common feeding site, has not been studied.

In this study, intraspecific and interspecific contact rates of raccoons feeding at a garbage dump in rural eastern Ontario were measured using direct visual observation.

My hypotheses are:

1. Adult males will be bitten more frequently than lactating females.
2. Lactating females will have higher rates of non-bite contacts (made and received) than adult males.
3. Regular visitors to the dump will experience higher rates of non-bite contacts (made and received) and will be bitten less than occasional visitors.
4. Intraspecific contact rates will be higher at higher ambient temperatures.
5. Interspecific contact rates will be lower than intraspecific contact rates.

2.3 Study area

Trapping and behavioural observation took place around a compost bin on the grounds of the Queen's University Biological Station, (on Lake Opinicon, about 40 km north of Kingston, Ontario (latitude 44° 35'North, longitude 76° 19'West)) and at a nearby private garbage dump belonging to a local innkeeper (The Opinicon Resort, Chaffey's Locks) (Fig. 2.1).

These sites were chosen for two reasons; they are relatively close to the St. Lawrence River near Kingston which is one of the points where raccoon rabies is likely to enter Ontario from New York State (Fig 2.2). In addition, both sites are off-limits to members of the public; the compost heap is located on Queen's University Biological Station property and the dump is on private property. This is important as one of the animal marking devices used in this study, the betalight, can potentially pose a danger to the public (Appendix 2.A).

The compost bin is located a few metres from the Queen's Biological Station road in a small clearing. Universal Transverse Mercator co-ordinates for the compost bin are: Zone 18, 0394750, 4935520.

The dump area is about 2.3 ha, bounded to the north by a disused CN railway track, to the south by a two-lane county road (Opinicon Road), to the west by a large swamp and to the east by a gravel road (Indian Lake Road) and a hill covered with sumac. The hill is laced with numerous animal trails, some of which lead to den holes. Both skunks and raccoons have been observed using these trails.

The area surrounding the dump consists of farm land (livestock), forest, marsh, and numerous cottages, most of which are only occupied during the summer. Universal Transverse Mercator (UTM) co-ordinates for the dump are: Zone 18, 0393850-0394040, 4936240-4936430. Garbage was deposited across the centre of the dump area in a band about 20 metres across and 10 metres wide; fresh garbage usually occupied a smaller area within this band (Figure 2.1).

During the summer of 1995, new garbage was deposited at the dump daily between 13:00 and 14:00, and sometimes in the early evening between 18:00 and 19:00.

2.4 Methods

2.4.1 Trapping and collaring

The study began on May 19th, 1995 and ended on October 31st, 1995. The project involved live-trapping raccoons at the compost bin and at the garbage dump.

Tomahawk #106 (Tomahawk Live-trap Company, Tomahawk, Wisconsin, USA), and Havahart #1079 (Havahart Live Trap Company, Niagara Falls, Ontario, Canada) live-traps were baited with various food items (Appendix 2.B), and pinned to the ground using elbowed, steel tent pegs to prevent raccoons from flipping them over. Traps were checked daily.

All raccoons trapped were tagged with two serial-numbered metal ear-tags (National Band and Tag Company, Newport, Kentucky, USA) then vaccinated via intramuscular injection for rabies (Imrab® inactivated rabies vaccine, Rhone, Merieux, Inc., Athens, GA) and canine distemper (Fromm D, modified live virus, SOLVAY animal health, Inc., Mendota Heights, MN).

Trapping began on May 20th and continued until 15 study animals had been collared (June 27th); the number of animals thought to be manageable for a tracking schedule by the researcher and her assistant was 14 animals, however, a fifteenth animal had to be caught to replace one of the animals hit by a car at the beginning of the study (see Results, page 20).

The 15 collared raccoons (2 caught at the compost bin and 13 caught at the dump) were immobilized by intramuscular injection of ketamine hydrochloride (Rogar/STB Inc., London, Ontario, Canada N6A 4C6) and xylazine hydrochloride (Rompun) (Bayvet, Rexdale, Ontario, Canada M9W 1G6) (30 mg/kg body weight ketamine, 10:1 ratio ketamine:rompun). These animals were then weighed, measured, and vaccinated for rabies and canine distemper and a first premolar tooth was extracted for age determination by counting annual growth lines in the cementum (Johnston *et al.* 1987). The animals' general condition and any distinguishing characteristics were also recorded.

While still immobilized, each of the 15 animals was fitted with an adjustable radio collar consisting of a Lotek Engineering, Inc. 151-MHz radio transmitter mounted on a whip-antenna collar (Lotek Engineering, Newmarket, Ontario). Juveniles were not collared as expandable collars were not available for this study; had any juveniles been collared with adult collars, they would have had to have been retrapped later in the study for collar adjustment to prevent strangulation due to neck growth over the season. Since retrapping of every juvenile could not be guaranteed, only adult animals were collared.

The 13 adult raccoons (6 females, 7 males) caught at the dump were given collars marked with various patterns and colours of day-glo reflective tape (Jogalite Cut'n Peel Strip), adhered with LePage's contact cement and double-sealed with Bondo fibreglass resin for waterproofing and durability. Despite all efforts, most of the raccoons managed to peel off the reflective stickers after four to eight weeks. Identity of these animals was facilitated by a familiarity with the animals' faces and body markings. Whenever possible, telemetry equipment was used to confirm identification.

The two raccoons (2 adult females) caught near the compost bin were fitted with collars to which two betalights (SRB Technologies Inc., Pembroke, ON, Canada) had been attached, using LePage's contact cement and brass wire (Appendix 2.A).

After sufficient time was given for recovery from the anaesthetic (a few hours), all animals were released at their point of capture.

2.4.2 Contact behaviour

Researchers sat at the dump site, observing the raccoons without recording contact rates from May 22nd to June 14th. After this period, the raccoons appeared to have acclimatized to the presence of the researchers; this was also longer than the time recommended by White and Garrott (1990) for the animals to acclimate to their newly acquired radio collars. Contact observations were subsequently recorded from June 15th to September 5th. During this period, three to four times a week, beginning before dusk and ending when collared animals had been visible for at least 20 minutes, intensive, continuous observations of raccoon contact behaviour were made. After September 5th, garbage was dumped weekly, rather than daily and contact observations were terminated. Total time spent in observation at the dump was 6918 minutes (115.3 hours).

Binoculars (7 X 35) and a night scope were used to recognize individuals in addition to a large, four-cell flashlight with a fluorescent bulb which was left on continuously throughout the observation period. Observers sat at a distance of about ten metres from the most recently deposited pile of garbage.

Focal animal sampling, described in more detail by Altmann (1974), was used to record contact rates for the collared animals. If more than one collared animal was present, the most readily visible one was picked and the type and placement of its contacts with other raccoons were recorded. If the animal wandered off the dump site while other collared animals remained, another study animal was selected from the collared animals remaining, based on its visibility. In addition, efforts were made to obtain equal amounts of focal time for each collared animal, and this also influenced subject choice.

Observations of contact rates were recorded on audio tape by two observers for the first two weeks of observation until observer agreement was consistent, after which, only one observer made recordings. Type and placement of contact, time of contact, and the focal animal involved were recorded.

For the purposes of this study, a bite was defined as closure of the attacker's mouth on some part of the recipient's body. All bites were assumed to be of equal severity, however, due to the distance of the observer from the animals and the poor lighting, it was not possible to tell if each or every bite drew blood.

A bite was distinguished from a non-bite contact as the former involved a quick closure of the jaws on the recipient's body, and was characterized by some degree of aggression. During non-bite contacts, while sometimes associated with closure of the jaws, this closure was a slower, non-aggressive movement which seemed less likely to puncture skin. Also, such contacts were not preceded by threat behaviour by either the biter or the recipient. More information on the context of the various behaviours observed at the dump is given in Appendix 2.B.

Independent, 2-tailed t-tests (Zar 1996) were performed to detect any difference in contact rates between males vs females, and regular vs occasional dump users, for each contact type. In addition, paired, two-tailed t-tests (Zar 1996) were performed to compare the difference between frequencies of the different contact types.

Air temperature was recorded at hourly intervals from the Queen's University Biological Weather Station about 1.5 km southeast of the dump site.

A linear correlation analysis (Zar 1996) was performed on contact data taken from June 19th to August 21st to determine whether contact rate was affected by ambient temperature.

Attempts were made to obtain a head count of all animals feeding at the dump every 10 to 15 minutes and immediately after a contact, but this was not always possible when only one observer was present.

Every hour, a radio telemetry scan was performed to detect collared animals which were in the area but out of sight, or to confirm identity of animals with stripped collars (i.e. with the reflective tape stripped off).

2.5 <u>Results</u>

A list of the study animals, their ages and sexes, is given in Table 2.2. Thirteen raccoons were collared for behavioural observation, however F6, originally collared on June 8th, 1995, was hit by a car on the morning of June

18th, 1995. She was found alive, with head and pelvic injuries, 2.4 km east of her initial capture site. She was subsequently turned over to the Kingston Humane Society for rehabilitation and later released in Toronto near an established feeding station. Consequently, no contact data were obtained for her in this study.

M1 died around October 4th, 1995 of unknown causes. He was found dead curled up inside a hollow tree, roughly 430 m southeast of his initial capture site. Examination of the body revealed no obvious injuries, but as appropriate tools were not available, no necropsy was performed.

2.5.1 Males vs lactating females

The compost area was found to be unsuitable for behavioural observations as visibility was obstructed by the bin itself. All contact observations were therefore obtained from the garbage dump and almost all of the contact data were obtained from the animals captured at the dump (F3 - F8 and M1 - M7) (Table 2.2). F2 was observed at the dump on one occasion when she fed for 2 minutes. Because contact information on her was so limited, she was not used in statistical analyses. F1 was never observed at the dump and therefore no contact information was obtained for her.

Table 2.2 lists the frequency of high, medium and low risk contacts for all animals in the study.

No significant difference was found for high, medium, and low risk contact rates between males and lactating females (Table 2.3). An insufficient number of non-lactating females (i.e. one) were available for statistical comparisons.

Within each sex, no significant differences were found between the rates of bite vs non-bite contacts (Table 2.4). Also within each sex, no significant differences were found between rates of attacks made vs attacks received (Table 2.5).

2.5.2 Regular vs occasional dump visitors

Although the duration per night of a collared animal's visit to the dump could not be measured because of the way the data were collected, the frequency of dump visits (i.e. number of nights each animal was seen at the dump during the study season) was recorded, rendering a reliable dump visit frequency for each animal.

The 12 dump raccoons were observed at the dump on: 85%, 71%, 68%, 60%, 57%, 57%, 51%, 49%, 49%, 37%, 35%, and 11% of the observation nights. Because of the cluster of 3 animals around 50%, it seemed that splitting these 3 animals into 2 groups at this point would be an artificial division. Therefore raccoons were defined as "regular" dump users if they were observed at the dump on >51% of all observation nights (M1, M2, M3, F5, M5, and F8). "Occasional" dump users were seen at the dump on ≤51% of the observation nights (F3, F4, M4, F7, M6, and M7). Because there were no significant differences in contact rates between males and females, rates for both sexes were pooled for comparison of contact rates of regular vs occasional dump users.

No statistically significant differences were found between regular and occasional visitors for any types of contact rates (Table 2.6). Within regular and occasional dump users, no differences were found between the frequency of bite vs non-bite contact rates (Table 2.7) nor between rates of attacks made vs attacks received (Table 2.8).

2.5.3 Overall intraspecific contact rates

Because no significant differences were found between males vs lactating females, regular dump visitors vs occasionals, contact rates for all dump raccoons were pooled to compute overall average contact rates for all contact types (Table 2.9). An average of 0.99 ($\pm$ 0.21) bites were made per hour by the raccoons in this study and these animals were bitten an average of 1.28 ($\pm$ 0.21) times per hour while they were at the garbage dump.

Contact rates per hour can be converted into contact rates per night (Table 2.10), with the understanding that such calculations will be underestimates since any given focal animal was not followed for its complete stay at the dump (especially if it left only to return later when another focal animal had been chosen).

2.5.4 Contact rate vs ambient temperature

A Kolmogorov-Smirnov Goodness of Fit test (Zar 1996) revealed that the contact data used for the linear regression analysis was not normally distributed (K-S Z=1.0361, n=22); consequently, the data were logarithmically transformed. Linear regression analysis revealed that there was no linear relationship between contact rate (all types combined: high, medium, and low risk, contacts made and contacts received) and ambient temperature (R^2=0, F=0.00006, n=22) (Fig. 2.3). The temperature range for the analysis was 17.0 to 28.5°C.

2.5.5 Interspecific contacts

A qualitative mammalian species inventory for the area in and around the garbage dump is compiled in Table 2.11. Of the species occurring at the dump site, bats, skunks, and raccoons were visually observed often; whitetail deer were seen and heard occasionally; porcupines were heard occasionally, and brown rats were heard occasionally as well as trapped. Feral cats were also occasionally trapped.

Only two mammal species were observed feeding at the dump site: skunks and raccoons. These two species often fed concurrently throughout the study. (Rats were periodically heard in the area, but it is not known whether they were feeding at the same time as the raccoons or skunks.)

Skunks appeared on the dump on 71% (25/35) of all observation nights. On these nights, one (on 54% of the observation nights), two (on 14% of the observation nights), or as many as three (on 3% of the observation nights) adult skunks were observed at one time. No juvenile skunks were ever observed at the dump.

Although skunks sprayed periodically at the dump in the presence of raccoons, no physical contacts between a raccoon and a skunk were ever observed in this study. Raccoons tended to remain a minimum of about two to three metres distant from any skunks present.

Turkey vultures (Cathartes aura) were frequently seen feeding on the dump during the day, and occasionally at dusk, though rarely at the same time that raccoons were feeding on the dump. These were the only birds observed to feed on the garbage. No contacts between a vulture and a raccoon were ever observed during this study.

2.5.6 Hourly feeding activity

Figure 2.4 shows hourly feeding activity of raccoons at the dump for each hour between 17:00 and 05:00, based on two nights of observation; these nights were chosen because they were the only two nights in which observation spanned the hours from 17:00 and 05:00. Other nights for which records of night-long activity were incomplete were not used; this was done in order to avoid complications relating to different amounts and types of food available for a given night, air temperature, weather and other factors.

In Figure 2.4, two peaks were evident: one between 22:00 and 23:00, and a smaller one between 02:00 and 03:00.

Raccoons began appearing at the dump soon after evening garbage was deposited (between 18:00 and 19:00). Activity decreased sharply after 03:00 and all raccoons had left the dump by 05:00.

2.6 Discussion

2.6.1 Males vs females

The time-consuming nature of the focal animal sampling method limited the number of raccoons for which sufficient contact data could be gathered (11: 4 lactating females, 7 adult males). With such a small sample size, it would be premature to state conclusively that there are no intersexual differences in contact rates.

2.6.2 Contact rate vs frequency of dump visits

Again, although no significant differences in contact rates were found between regular vs occasional dump visitors, this may have been due to the small sample size (6 regulars, 6 occasionals), or to the definition of "regular" and "occasional" used in this study. However, if a raccoon were considered occasional if it used the dump on only 20% of the observation nights, only one raccoon would have been considered occasional.

Although no significant differences were found, raccoons at the dump did seem to display differential tolerances for one another (Appendix 2.B). Whether this tolerance was based on the dominance hierarchy proposed by Sharp and Sharp (1956) or whether Barash's (1974) hypothesis of neighbour recognition influenced the contact rate (for bites and non-bites), is not clear. Perhaps these factors work in combination to influence contact rates in these animals. To test this, more data for each type of animal (i.e. regular vs occasional, lactating vs non-lactating females) would need to be collected.

2.6.3 Overall intraspecific contact rates

Contact rates of healthy raccoons can be used to predict the potential spread of rabies from a raccoon which is in the preclinical stage of rabies (i.e. behaving normally while shedding virus in its saliva). In raccoons, this preclinical state lasts at least one day before behavioural symptoms occur (McLean 1975). Other evidence indicates that this period might be even longer; Kappus et al. (1970) reported that all nine rabid raccoons trapped during the peak of a rabies epizootic in Florida were behaviourally preclinical, and all had high titres of the virus in their salivary glands. Until more data become available, one day will be regarded as a conservative estimate of the duration of the preclinical phase.

The average number of animals contracting rabies for each rabid animal in the population is called the contact rate of the disease (Macdonald and Bacon 1982). Rabies will spread in a population if each rabid animal infects more than one healthy animal (Macdonald and Bacon 1982). Using data from Table 2.10, and if only bites are considered relevant to rabies transmission, each raccoon in this population inflicts a bite to the head or neck (high risk contact) about every four nights during feeding at the dump.

If the frequency of all bites is considered, a given raccoon will inflict a bite (high or medium risk contact) about once every three nights while feeding at the dump. In other words, in this population, there is a 33% chance that a raccoon would bite another raccoon at the dump while shedding the virus but exhibiting no symptoms.

It should be noted that these figures do not account for any contacts occurring off the dump site. It is also important to realize that the contact rates (/hr) listed in Table 2.2 represent an overestimate of actual rabies transmission since not all contacts lead to rabies infection (Fishbein 1991). However, this may be balanced by the fact that behaviourally rabid raccoons may bite their conspecifics more often than healthy animals (though no research has been published on contact rates in rabid raccoons). Another factor to consider is that the nightly contact rates represent an underestimate of the actual contact rate, as each animal was not focal for its entire stay at the dump (i.e. If it left the dump to return later, and another focal animal had been chosen in its absence, the new focal animal remained focal.).

The above arguments relate to an infective raccoon which is not exhibiting clinical symptoms of rabies.

contact rate of an infective raccoon cannot be estimated from data collected in this study, simply because the behaviour of clinically rabid raccoons differs from that of healthy animals (Winkler and Jenkins 1991).

2.6.4 Contact rate vs. ambient temperature

No linear relationship between contact rate and ambient temperature was found in this study. However, some other relationship (eg. curvilinear) may exist, especially in the region of 21-23°C.

Sharp and Sharp (1956), in a winter study of raccoon activity, did note that lower temperatures, such as those occurring in fall and winter, affected the number of raccoons using a feeding station. The temperature range in their study was -11 to 2°C. It is therefore possible that within this range, temperature is a factor influencing contact rate. This hypothesis could not be tested in my study because food availability at the dump declined after September 5th and frequency of raccoon visits also dropped sharply after this date.

2.6.5 Interspecific contacts

Data from this study indicate that intraspecific contact rates in raccoons are higher than interspecific contact rates between healthy raccoons and (presumably healthy) skunks. This does not mean that the same holds true for clinically rabid animals. The scarcity of fox rabies in raccoons is probably due more to the raccoons' resistance to the virus than to the rarity of contacts with infected skunks and foxes (McLean 1975).

Other mammals, eg. the rats and feral cats, which could also have presumably fed with raccoons may have been frightened off by the presence of the researcher and her assistant. Cats have been known to feed on garbage (Hoffmann and Gottschang 1977). It is also possible that these animals partition their feeding time to early morning or daytime to avoid encountering the raccoons. A further study of the area with remote-controlled video equipment set up in place of the researchers might reveal which of these two hypotheses is more likely.

The mammals noted by the researchers during the study do not represent a full inventory of mammals present in the dump area. Traps used in this study were targeted to mammals in the mid-size range (i.e. raccoons or skunks), so that rodents smaller than a large rat could easily escape. Also, most observations of the dump were conducted during the evening and night, so that diurnal species could easily have been overlooked.

Additional opportunities for interspecific transmission of rabies may occur off the dump site. Raccoons, skunks and foxes have been known to utilize the same daytime resting sites (though they have never been observed to use the same dens concurrently) (Shirer and Fitch 1970).

2.6.6 Hourly feeding activity

The double peak of hourly raccoon activity seen in this study was not observed by Sharp and Sharp in their 1956 study of raccoons using a winter feeding station in Nebraska. In their study, the peak feeding time (i.e. the time with the highest number of raccoons) was between 20:30 and 21:00, after which numbers slowly tapered off until dawn (Sharp and Sharp 1956). However, Sharp and Sharp (1956) noted that two different groups of raccoons appeared to be using the feeding station; one group appeared and left before midnight, and another more wary population appeared after midnight. They believed that the latter population came from more remote areas to use the feeding site. This partitioning of feeding time may minimize overcrowding at the site and thus decrease the aggressive confrontations which may result. However, in my study, the same raccoons were observed at the garbage dump before and after midnight. It is possible that the large quantities of food, combined with the large area of the dump itself prevented severe overcrowding during feeding.

The peak of raccoon activity observed by Sharp and Sharp (1956) in their study was about one-and-a-half hours earlier than the first peak observed in my study. However, Sharp and Sharp's (1956) study took place during the winter, after the clocks had been turned back for daylight savings time. If peak activity in raccoons is affected by the photoperiod, this would explain the difference in the peak activity time between my study and Sharp and Sharp's (1956). In addition, because the maximum head count graph in Fig. 2.4 was based on only two nights of observation, it is possible that the peaks observed were not representative of raccoon activity at the dump throughout the summer.

2.6.7 Sources of bias in the sampling methods used

Data collection for this study was done using a variation of focal animal sampling as outlined by Altmann (1974). Duration of sampling for each focal animal was not pre-determined but dependent instead upon how long the animal was visible. When one raccoon left the dump site, choice of the next focal animal was made from the collared animals that were feeding at the dump. Such behaviour-determined selection was used because it decreased the amount of sample time in which no contacts were being recorded while maximizing the data collected for each focal animal. Unfortunately, this method also introduced a dependence between the samples of behaviour and participants.

One of the underlying assumptions when comparing data collected in this manner (for example comparing contact rates between males and females) is that contacts in males and females are equally conspicuous. Another assumption is that all collared animals are equally conspicuous to the observer. This was not always the case in this study. For example, F7 appeared to be disturbed by the presence of observers, even late into the study season, and would often circle the feeding area while maintaining a distance from the nearby observers and raccoons.

Biases in contact rates could have resulted simply from differences in the amount of time each focal animal was visible. In order to counteract this, efforts were made to spend equal amounts of focal time with each collared animal, though this was not always possible as some animals moved away from the study area during the study season and no longer used the dump.

TABLE 2.1. Relative risk of rabies transmission associated with different types of contacts made by raccoons feeding at a garbage dump.

CONTACT TYPE	LOCATION OF CONTACT ON RECIPIENT'S BODY	RELATIVE RISK
Bite	Mouth, Head or Neck	High
	Any other part of body or area unspecified	Medium
Contact with attacker's open or closed mouth (without biting)	All parts of the body	Low
Grooming/Licking	All parts of the body	Low
Sneezing/Spitting	All parts of the body	Low

TABLE 2.2. Sex, ages and contact rates during feeding for raccoons at a garbage dump.

RACCOON[a]	AGE[b] (yrs)	# NIGHTS AT DUMP (/35)	TOTAL TIME OBSERVED (hrs)	CONTACTS MADE[c] (H/hr)	(M/hr)	(L/hr)	CONTACTS RECEIVED[c] (H/hr)	(M/hr)	(L/hr)
F1 (L)	1	0	0	-	-	-	-	-	-
F2 (L)	3	1	0.03	0.000	0.000	0.000	0.000	0.000	0.000
F3 (L)	5 or 6	18	5.58	0.179	0.179	0.179	0.536	0.000	0.357
F4	1	17	5.25	0.759	0.000	2.069	0.759	0.571	1.875
F5 (L)	5 or 6	20	3.5	1.132	0.857	0.000	1.429	0.286	0.286
F6[d]	1	-	-	-	-	-	-	-	-
F7 (L)	4	17	1.90	2.069	0.526	1.053	0.000	1.053	1.053
F8 (L)	3	23/34[e]	3.93	0.508	0.000	1.017	0.759	0.508	1.277
M1[f]	2	25	7.90	0.632	0.504	2.143	1.667	0.632	2.727
M2	2	29/34[e]	9.80	0.508	0.102	2.400	1.017	0.408	2.500
M3	2	21	9.62	0.938	0.208	0.938	0.732	0.417	0.833
M4	6	13	1.08	0.000	0.000	0.000	1.818	0.923	0.000
M5	2	20	3.80	0.789	0.526	1.304	1.053	0.000	1.304
M6	2	4	1.43	0.698	0.000	1.395	0.000	0.000	1.395
M7[g]	1	9/26	1.23	0.000	0.811	0.811	0.811	0.000	0.811

[a] F=female, M=male, L=lactating
[b] Age determined by counting cementum layers in the premolars.
[c] H=high risk contact, M=medium risk contact, L=low risk contact
[d] Hit by car June 18th.
[e] Released from trap during one observation night; that night was omitted from total.
[f] Found dead Oct. 4th 1995.
[g] Entered study June 27th 1995.

TABLE 2.3. Comparison of contact rates (± SE) for male vs lactating female raccoons feeding at a garbage dump in a rural area. Unpaired, two-tailed t-tests. N=4 females, 7 males. df=9, α=0.05.

	MALES	LACTATING FEMALES	t	SIGNIFICANCE	P
High (H) Risk Contact Rates					
Contacts Made/hr	0.51 ± 0.33	0.97 ± 0.42	1.30	NS	0.23
Contacts Received/hr	1.02 ± 0.23	0.68 ± 0.30	-0.88	NS	0.40
Medium (M) Risk Contact Rates					
Contacts Made/hr	0.31 ± 0.12	0.39 ± 0.19	0.39	NS	0.70
Contacts Received/hr	0.34 ± 0.14	0.46 ± 0.22	0.50	NS	0.74
Low (L) Risk Contact Rates					
Contacts Made/hr	1.29 ± 0.31	0.56 ± 0.28	-1.56	NS	0.16
Contacts Received/hr	1.38 ± 0.38	0.74 ± 0.25	-1.20	NS	0.26
Bites (H + M Risk) Made/hr	0.82 ± 0.17	1.37 ± 0.56	1.20	NS	0.26
Bites Received/hr	1.36 ± 0.35	1.14 ± 0.24	-0.42	NS	0.71
Total Contacts Made/hr	2.11 ± 0.42	1.94 ± 0.66	-0.24	NS	0.72
Total Contacts Received/hr	2.74 ± 0.50	1.89 ± 0.35	-1.17	NS	0.28

TABLE 2.4. Comparison of bite and non-bite contact rates for lactating female and adult male raccoons feeding at a garbage dump in a rural area. Paired, two-tailed t-tests. N=4 females, 7 males. $\alpha=0.05$.

	Sex	$\bar{D}$	t	df	Significance	P
Rate of bites vs non-bites made/hr	F	0.81	1.38	3	NS	0.27
Rate of bites vs non-bites received/hr	F	0.40	1.17	3	NS	0.33
Rate of bites vs non-bites made/hr	M	-0.48	-1.69	6	NS	0.15
Rate of bites vs non-bites received/hr	M	-0.03	-0.05	6	NS	0.78

TABLE 2.5. Comparison of attacks made vs attacks received for lactating female and adult male raccoons which use a common feeding site (garbage dump) in a rural area. Paired, two-tailed t-tests. N=4 females, 7 males. $\alpha=0.05$.

	Sex	$\bar{D}$	t	df	Significance	P
Rate of bites made vs bites received/hr	F	0.10	0.18	3	NS	0.72
Rate of non-bites made vs received/hr	F	-0.31	-1.88	3	NS	0.17
Rate of bites made vs bites received/hr	M	-0.54	1.22	6	NS	0.27
Rate of non-bites made vs received/hr	M	-0.09	0.97	6	NS	0.37

TABLE 2.6. Mean contact rates (± SE) and t statistics (unpaired, two-tailed t-tests) for raccoons which regularly vs occasionally visit a common feeding site (garbage dump) in rural Ontario. N=6 regular, 6 occasional. α=0.05, df=10.

	Regular[a]	Occasional[b]	t	Significance	P
Low Risk (non-bite) Contact Rates					
Attacks Made/hr	1.30 ± 0.36	0.92 ± 0.32	0.80	NS	0.44
Attacks Received/hr	1.49 ± 0.39	0.92 ± 0.28	1.20	NS	0.26
Bite (High + Medium Risk) Contacts					
Bites Made/hr	1.12 ± 0.22	0.87 ± 0.37	0.58	NS	0.57
Bites Received/hr	1.49 ± 0.19	1.08 ± 0.38	0.96	NS	0.36
All Contacts (H + M + L Risk)					
Contacts Made/hr	2.42 ± 0.27	1.79 ± 0.56	1.01	NS	0.34
Contacts Received/hr	2.97 ± 0.50	1.99 ± 0.35	1.67	NS	0.13

[a] "Regular" dump users were observed at the garbage dump on more than 51% of total observation nights.
[b] "Occasional" dump users were observed at the garbage dump on 51% or fewer of the total observation nights.

TABLE 2.7. Comparison of bite and non-bite contact rates for raccoons which regularly[a] or occasionally[b] use a common feeding site (garbage dump) in a rural area. Paired, two-tailed t-tests. N=6 regulars, 6 occasionals. df=5, $\alpha=0.05$.

	Type	$\bar{D}$	t	Significance	P
Rate of bites vs non-bites made	Occasional	-0.05	-0.12	NS	0.76
Rate of bites vs non-bites received	Occasional	0.16	0.29	NS	0.70
Rate of bites vs non-bites made	Regular	-0.18	-0.35	NS	0.68
Rate of bites vs non-bites received	Regular	-0.00	0.06	NS	0.77

[a] Regular dump users were observed at the dump on greater than 51% of all observation nights.

[b] Occasional dump users were observed at the dump on 51% or fewer of all observation nights.

TABLE 2.8. Comparison of attacks made vs attacks received for raccoons which use a common feeding site (garbage dump) in a rural area on a regular[a] vs an occasional[b] basis. Paired, two-tailed t-tests. N=6 regulars, 6 occasionals. α=0.05, df=5.

	Status[c]	$\bar{D}$	t	Significance	P
Rate of bites made vs bites received/hr	R	-0.37	-1.45	NS	0.21
Rate of non-bites made vs received/hr	R	-0.35	-1.72	NS	0.16
Rate of bites made vs bites received/hr	O	-0.21	-0.353	NS	0.32
Rate of non-bites made vs received/hr	O	0.01	0.04	NS	0.78

[a] Regular dump users were observed at the dump on greater than 51% of all observation nights.
[b] Occasional dump users were observed at the dump on 51% or fewer of all observation nights.
[c] R=regular dump user, O=occasional dump user

TABLE 2.9. Average contact rates (± SE) for raccoons eating at a garbage dump in rural eastern Ontario. N=12.

Contact Type	Contacts Made (per hour)	Contacts Received (per hour)
High Risk	0.684 ± 0.16	0.882 ± 0.17
Medium Risk	0.309 ± 0.09	0.400 ± 0.10
Low Risk (Non-bites)	1.110 ± 0.23	1.202 ± 0.24
Bites (High + Medium Risk)	0.993 ± 0.21	1.282 ± 0.21

TABLE 2.10. Number of contacts per night, number of nights observed, and average contact rate per night for raccoons sharing a common feeding site (garbage dump).

RACCOON	NUMBER OF NIGHTS AT DUMP (/35)	NUMBER OF NIGHTS CONTACT OBSERVATIONS MADE (/35)	NUMBER OF CONTACTS (ATTACKS MADE) PER NIGHT (H/M/L)[a]			NUMBER OF CONTACTS (ATTACKS RECEIVED) PER NIGHT (H/M/L)[a]		
M1	25	20	0.25	0.2	0.85	0.65	0.25	1.1
M2	29/34[b]	25	0.2	0.04	0.96	0.4	0.16	1.0
F3	18	15	0.07	0.07	0.07	0.2	0	0.13
M3	21	17	0.53	0.12	0.53	0.41	0.24	0.47
F4	17	12	0.33	0	0.92	0.33	0.25	0.83
F5	20	13	0.31	0.23	0	0.38	0.08	0.08
M4	13	6	0	0	0	0.33	0.17	0
M5	20	14	0.21	0.14	0.36	0.29	0	0.36
F7	17	8	0.5	0.13	0.25	0	0.25	0.25
M6	4	3	0.33	0	0.67	0	0	0.67
F8	23/34[b]	17	0.12	0	0.24	0.18	0.12	0.29
M7	9/26[c]	5	0	0.2	0.2	0.2	0	0.2
AVERAGE CONTACTS			0.24	0.94	0.42	0.28	0.13	0.45
AVERAGE BITES			0.33			0.41		

[a] H=high risk contact M=medium risk contact L=low risk contact
[b] Trapped on one of the observation nights.
[c] Collared after contact observations began.

TABLE 2.11. Qualitative mammalian species inventory for a rural Ontario area (40 km north of Kingston, Ontario) listing species which were seen (S), heard (H), or trapped (T) within a local garbage dump, or only in the surrounding area (O), and those which were not seen, heard or otherwise encountered (N).

Common Name	Species Name	Status	Common Name	Species Name	Status
Opossum	*Didelphus marsupialis*	N	Striped Skunk	*Mephitis mephitis*	S,H,T
Shrews	various species	N	Coyote	*Canis latrans*	O
Moles	various species	N	Red Fox	*Vulpes vulpes*	O
Bats	various species	S	Lynx	*Lynx canadensis*	N
Black Bear	*Ursus americanus*	O	Bobcat	*Lynx rufus*	N
Raccoon	*Procyon lotor*	S,H,T	Woodchuck	*Marmota monax*	O
Fisher	*Martes pennanti*	N	E. Chipmunk	*Tamias striatus*	O
Weasels	various species	N	Squirrels	various species	O
Mink	*Mustela vison*	N	Beaver	*Castor canadensis*	O
River Otter	*Lutra canadensis*	N	Mice	various species	O
Voles	various species	N	S. Bog Lemming	*Synaptomys cooperi*	N
Muskrat	*Ondatra zibethica*	O	Whitetail Deer	*Odocoileus virginianus*	S,H
Norway Rat	*Rattus norvegicus*	T,H	Moose	*Alces alces*	O
Porcupine	*Erethizon dorsatum*	H	Domestic Cat	*Felis domestica*	T
Snowshoe Hare	*Lepus americanus*	N	Domestic Dog	*Canis familiaris*	O
European Hare	*Lepus europaeus*	N	Domestic Horse		O
E. Cottontail	*Sylvilagus floridanus*	O	Domestic Cow		O

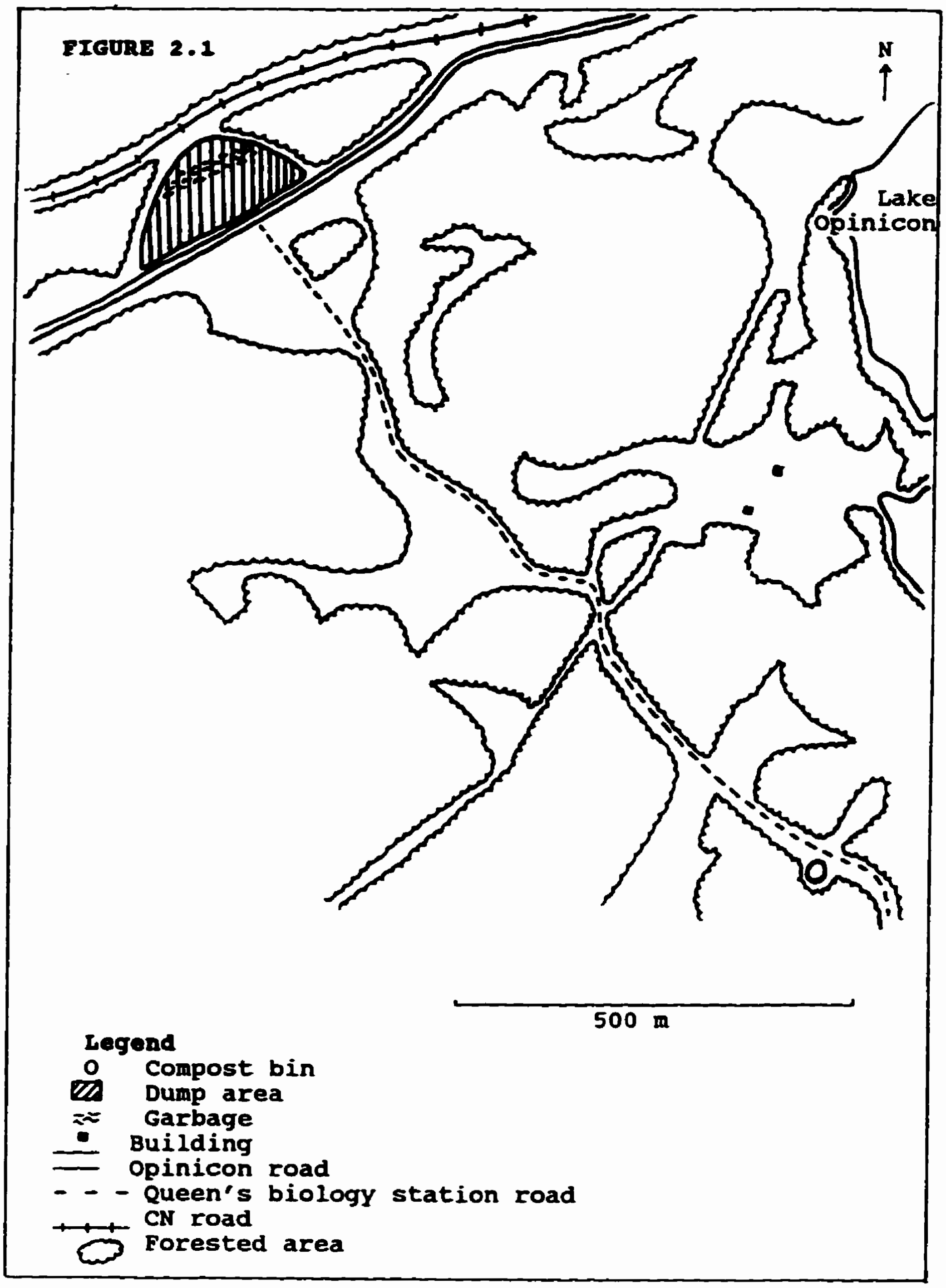


FIGURE 2.1. Relative positions of the garbage dump and compost bin sites used for trapping and behavioural observation of raccoons using a common feeding site in rural eastern Ontario.

FIGURE 2.2

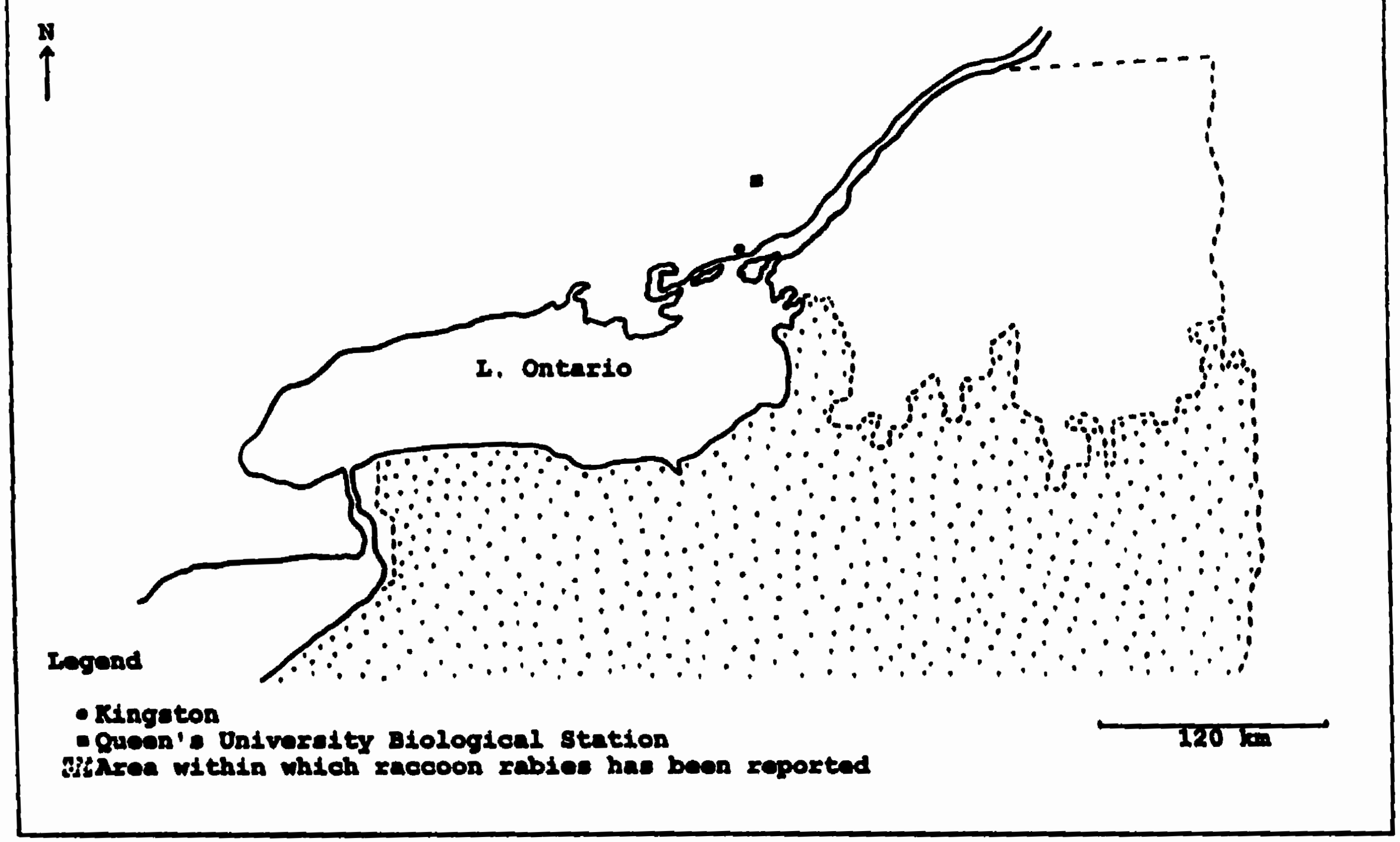


FIGURE 2.2. New York State raccoon rabies status as of 3/31/95. (modified from Rabies Laboratory, Wadsworth Center for Labs and Research 1995, Empire State Plaza, Albany, NY).

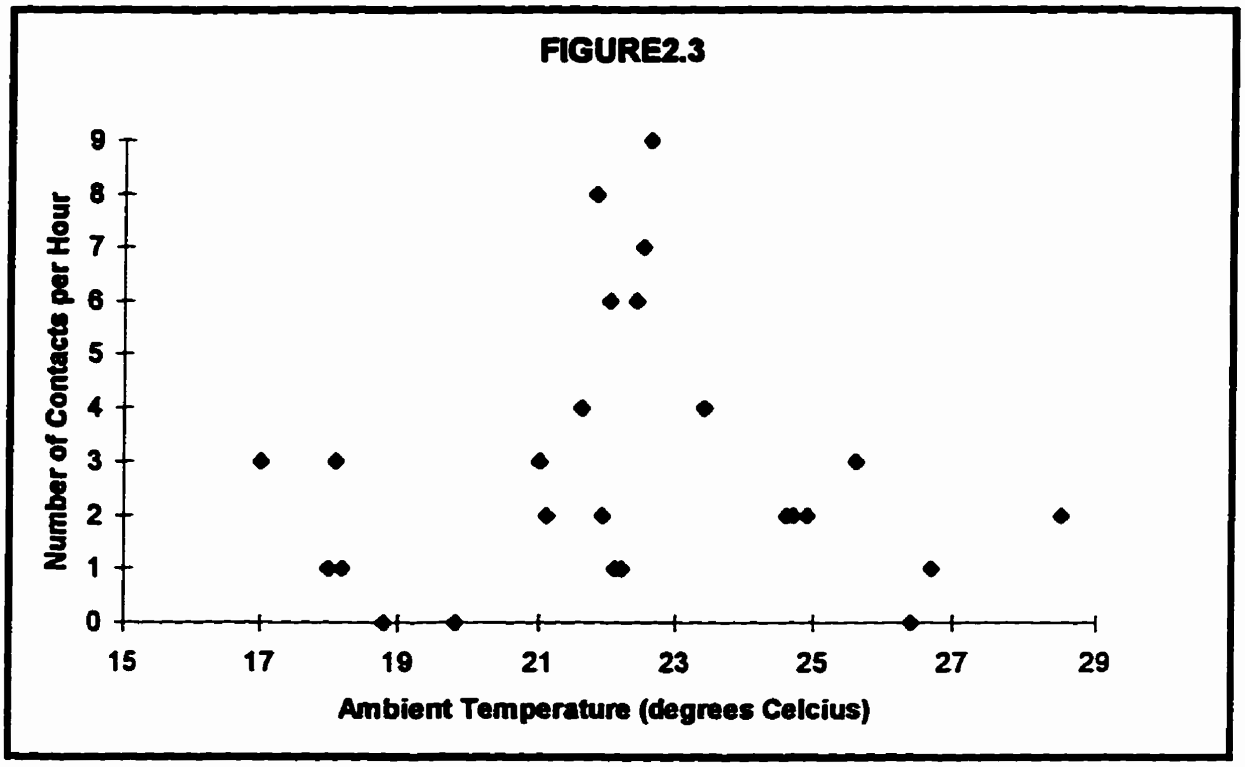


FIGURE 2.3. Frequency of intraspecific contacts (high, medium, and low risk) per hour vs. ambient temperature for raccoons feeding at a garbage dump during the summer (June to August). N=25.

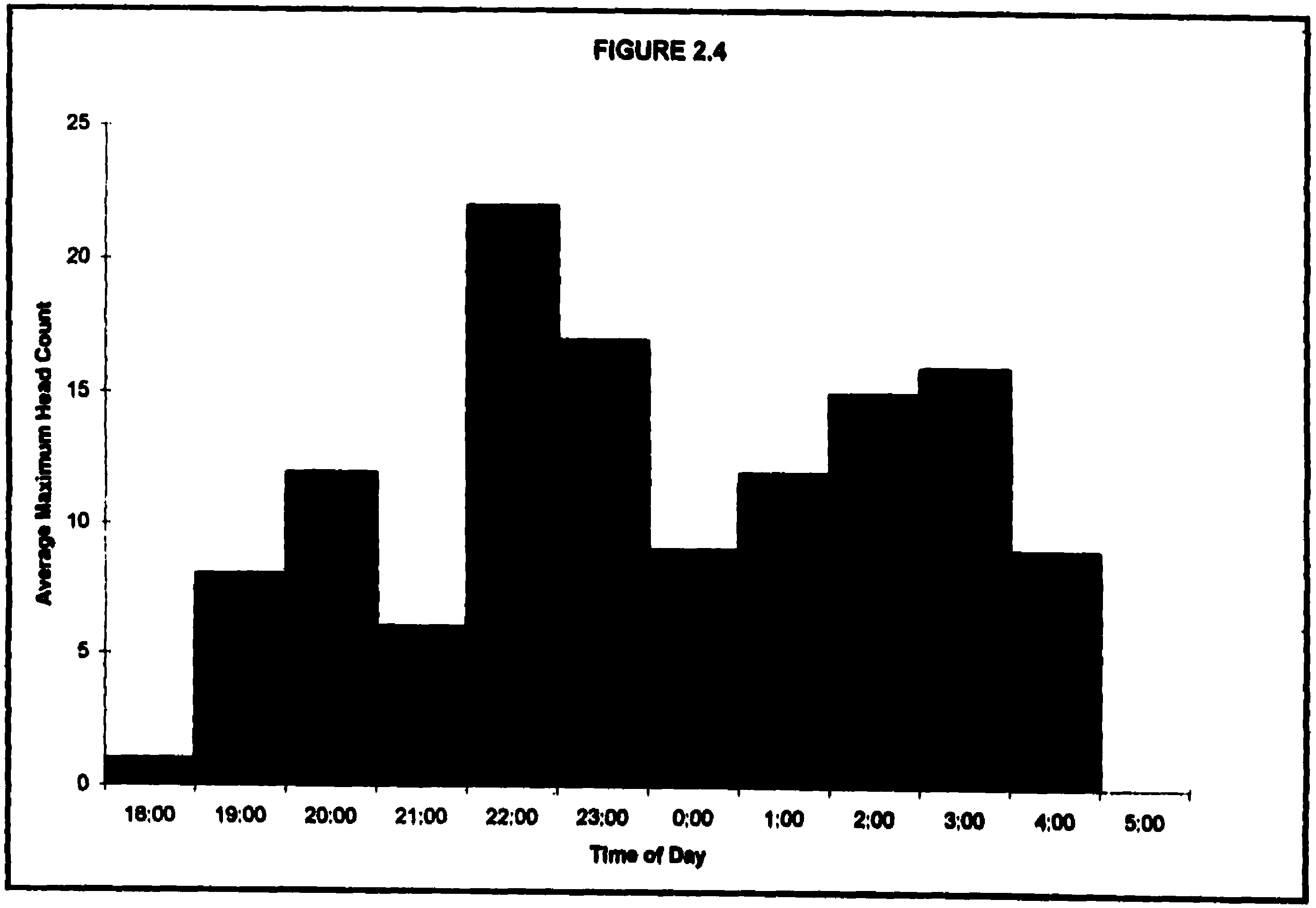


FIGURE 2.4. Hourly feeding activity between 18:00 and 05:00 (based on the cumulative maximum head count for each hour over two nights) for raccoons feeding at a rural garbage dump north of Kingston, Ontario, during the summer.

Chapter 3

SEASONAL HOME RANGES OF RACCOONS USING A COMMON FEEDING SITE IN RURAL EASTERN ONTARIO

3.1 Abstract

Twelve adult raccoons (5 females, 7 males) which fed at a garbage dump 40 km north of Kingston, Ontario, were radio-tracked an average of 24 nights each from June to October, 1995 to assess their seasonal home ranges and movements. The average summer and fall home ranges for these animals (Minimum Convex Polygon) were 69 ha (SD=32 ha) and 45.5 ha (SD=30 ha) respectively. Average grid cell summer and fall home ranges for the dump animals were 144 ha (SD=42 ha) and 117 ha (SD=32 ha) respectively based on a grid square size of 23 ha.

There was no significant difference in summer grid cell home range sizes between males (154 $\pm$ 20 ha) vs females (129 $\pm$ 7 ha) (P=0.31), nor between regular (130 $\pm$ 10 ha) vs occasional (157 $\pm$ 22 ha) dump visitors (P=0.27).

Yearling raccoons travelled an average summer maximum distance from the dump of 2610 m (SE=1140 m, N=3), more than double the distance of the adults ($\geq$2 years) at 1200 m (SE=156 m, N=10). The population density for the study area in late August was 1 raccoon/12 ha (modified Petersen Index), based on an effective area surrounding the dump of 234 ha.

In addition, grid cell home ranges for 2 adult females feeding at a nearby compost bin, calculated from daytime resting sites over the summer and fall of 1995 were 127 ha (SD=16 ha) and 104 ha (SD=16 ha) respectively.

3.2 Introduction

The spatial distribution of food is known to influence contact rates in raccoons (Seidensticker et al. 1988). Specifically, clumped food resources such as garbage dumps, or other common feeding sites, may increase potential contact rates as they cause members of a population from a wide area to congregate and exploit the resource. The size of this area may influence rabies transmission in this population (Seidensticker et al. 1988).

While contact rates in raccoons during feeding at a common resource are a useful indicator of potential rabies spread, so is the range of movements of these animals when they are not feeding. Such information can be used to design effective baiting strategies to vaccinate these animals against rabies.

In this study, movements of raccoons using a common feeding site 40 km north of Kingston, ON, were determined by radiotelemetry to assess the size of their summer and fall home ranges as well as the area over which the raccoons were travelling to use the dump. The same 12 raccoons for which contact data were obtained in Chapter 2 were used in this study. In addition, two raccoons, caught at a smaller feeding site (compost heap) were tracked periodically to determine their daytime resting sites.

Another factor which may influence contact rate in a population of raccoons is population density. For this reason, the population density of raccoons in the dump area was also measured.

For the purposes of this study, a raccoon's home range was defined, using White and Garrott's (1990) criteria, as the area within which the animal normally moved in a specified time frame, in this case the summer and fall. Home ranges of raccoons tend to shift with seasonal changes in behaviour and therefore must be calculated separately for each season (Kauffmann 1982); summer is the family rearing period when lactating mothers and their offspring travel together and it is also the main dispersal period for yearling males (Fritzell 1978; Mech et al. 1968). Fall is a time when the juveniles may disperse and raccoons prepare for the coming winter dormancy period (Shirer and Fitch 1970).

Home ranges of raccoons tend to average around 100 to 300 ha (Kauffmann 1982), but may range from 18 to 2560 ha for adult males in North Dakota, or 5.1 to 372 ha for adult females (Fritzell 1978; Hoffmann and Gottschang 1977; Stuewer 1943). Urban raccoons tend to have smaller home ranges than rural raccoons (Rosatte et al. 1991). Range size may also vary with differences in season, data collection methods and type of home range estimator (Harris et al. 1990). The distribution and abundance of food also affect home range size. Small home ranges are associated with high population densities and abundance of food (Hoffmann and Gottschang 1977).

My hypotheses are:

1. Male raccoons will have home ranges averaging around 300 ha. Home ranges of females will average around 100 ha. Male and female home range sizes will be significantly different.
2. Raccoons which regularly use the dump will have summer home ranges around 150 ha. Those which visit it occasionally will have ranges around 500 ha. Range sizes between the two will be significantly different.
3. Yearlings will range further (>5 km) from the dump in summer than raccoons two years and older (<5 km) because this is the season during which many yearlings disperse.

3.3 Study area

Trapping for population density estimates took place at the dump. The raccoons used in this study were caught at the dump and at a nearby compost heap (Figure 2.1); both are described in detail in Chapter 2. The surrounding area where most of the tracking took place is described in Appendix 3.A and illustrated in Figure 3.1.

3.4 Methods

3.4.1 Radiotracking

Trapping and collaring techniques are outlined in Chapter 2. The tracking system used in this study consisted of a 4-element Yagi antenna, 151 MHz (FM) transmitters mounted on whip antenna collars, 1 programmable hand-held receiver (Lotek model SRX-400; Lotek Engineering, Inc., Newmarket, Ontario) which operated in the 151-152 MHz range, one hand-held compass, and a 4-wheel drive pick-up truck.

Animals were given at least 7 days to acclimatize to their collars before radiotracking began, in accordance with White and Garrott's (1990) recommendations. The tracking period lasted from June 21st to October 16th, 1995, during which time 12 raccoons (F3-F5, F7, F8, and M1-M7 from Chapter 2) were monitored for an average of 24 nights each (2 to 3 times per week).

Since only one telemetry receiver was available, sequential rather than simultaneous bearings had to be taken. A maximum interval between first and last bearings of 10 min was set to minimize telemetry error caused by animal movement (except for bearings taken during the day when the animals were inactive, at which time the interval may have been longer) (Appendix 3.A).

Continuous radiotracking (i.e. location of the animals at least every 15 minutes (Harris et al. 1990)) was not feasible with only one receiver; therefore, for this study, discontinuous tracking was performed; location estimates were made for each animal three or four times from dusk until dawn at roughly 2 hour intervals, and once during the following afternoon to determine daytime resting sites.

The tracking schedule was constructed by randomly selecting six of the twelve collared animals trapped at the dump for one given tracking night; the remaining six were then tracked on the next scheduled night. A different set of six animals was randomly chosen for the following tracking night and so on. Dates of tracking nights were randomly selected for each week. For each bearing taken, the observer recorded the date, time, receiver location, bearing angle, and the study animal involved. Data from this part of the study was used to determine home ranges.

For the two animals caught at the compost heap (F1 and F2 from Chapter 2), daytime resting sites were periodically determined beginning May 22nd and ending when the animals were finally recaptured for collar removal (Sept. 27th, 1995 for F1, and April 25th, 1996 for F2).

Three types of location estimate techniques, each associated with different levels of accuracy, were used in this study: scanning, triangulation, and homing.

Scanning involved tuning into the collar frequencies of the dump animals while the researcher sat in the middle of the dump area. Data from telemetry accuracy tests indicated a mean transmitter-receiver distance ($\pm$ S.E.) of 240 m $\pm$ 30 m (N=20) when the signal was picked up at a gain (sensitivity setting on the receiver) of 10. An animal was therefore considered to be in a radius of this distance from the centre of the dump area if its signal was detected from there at a gain of 10 or less.

Most of the locations for the dump animals were obtained by triangulation. This technique involves taking directional bearings from two to three different receiver sites at known locations and using these to estimate the true location of a remote transmitter on the animal's collar (White and Garrott 1990).

Accuracy tests (Appendix 3.A) were performed to determine the error associated with locations estimated by triangulation in this study. Screening criteria derived from telemetry accuracy tests (Appendix 3.A, Discussion) were applied to all bearings to eliminate errors due to signal bounce. Before any location calculations were performed, 9° was subtracted from all bearings to correct for system bias (Appendix 3.A). In addition, all locations involving distances between transmitter and receiver of over 1 km were inspected for plausibility.

A computer program written by Christine Adkins

(TRIANG 1991) was used to estimate animal locations from triangulated bearing pairs and to calculate the distance between receiver and transmitter for each bearing. TRIANG did not compute animal locations when three bearings were taken. In this case, locations were determined by plotting the bearing angles in AutoCAD and estimating the centre of the triangle created by the intersection of the bearings.

Locations for F1 and F2 were usually obtained by homing. This technique involves following the signal of an animal's transmitter as the signal strength increases until the animal, or its den, is located (White and Garrott 1990). Locations of animals determined by homing are not affected by error in the telemetry system, however they are affected by the researcher's ability to pinpoint the den location on a map (White and Garrott 1990). All locations determined by homing in my study were plotted by hand on 1:10,000 maps of the area to ± 50 m to obtain UTM co-ordinates.

3.4.2 Home ranges

Home ranges were estimated using the minimum convex polygon (MCP) method (Mohr 1947), since this is the only home range method that is strictly comparable between studies (Harris et al. 1990). Ranges for both seasons were combined to compare degree of overlap between seasons.

Because it is advantageous to use more than one home range estimate technique (Voigt and Tinline 1980), the grid cell method of home range analysis (Siniff and Tester 1965) was also used. Size of the grid cells was chosen to reflect radio fix accuracy based on the results of accuracy tests (Appendix 3.A). Grid cell dimensions were determined by using the average transmitter-receiver distance from non-test data to calculate locational uncertainty from Formula A.3.1 (Appendix 3.A) with T=2.0, SD=20° and N=63 based on accuracy test data. A square was formed to enclose all locations within this uncertainty span, resulting in a grid square with 340 m sides (Figure 3.2). Unfortunately, this size of grid square would not enclose the uncertainty area associated with "scanning" the dump for transmitter signals. A grid square would have to measure 480 m to a side for this to occur (Figure 3.2). Therefore this was the size of grid square (23 ha) used. The grid was oriented by centring a grid square over the dump site.

Summer home ranges were calculated from telemetry data collected in June, July, and August. September and October fixes were used to calculate fall home ranges.

Before any statistical comparisons between home ranges could be made, it was important to first ensure that the ranges involved were asymptotic; in other words, the home range size of each animal had to be based on equal numbers of fixes to avoid pseudoreplication (Harris et al. 1990). To determine how many point locations to use, fixes were added randomly to a graph of grid home range area vs number of fixes for each animal. The point at which 11/12 of the dump raccoons' summer home ranges reached an asymptote occurred at 46 fixes. Therefore the home ranges of all raccoons at 46 fixes were used for statistical comparisons within the summer season.

Unpaired t-tests (Zar 1996) were used to compare sizes of summer grid cell home ranges of males vs females, and regular vs occasional dump visitors for all raccoons trapped at the dump. Regular dump users were defined, as in Chapter 2, as those raccoons which were seen feeding at the dump site on >51% of all contact observation nights.

3.4.3 Population density

Trapping for population estimates took place from August 28th to September 19th, 1995. At this time, juveniles were larger and therefore easier to mark and handle than they had been earlier in the summer.

Estimates of the number of raccoons in the study area were made using a modified Petersen Index (Begon 1979). Density of the dump population was not based solely on the area of the trapping site (garbage dump = 2.3 ha) because it was evident from telemetry data that some raccoons were travelling from a much wider area to feed at the dump. Instead, using the number of raccoons calculated by the methods above, estimates were made of the crude density of the population as defined by Seidensticker et al. (1988) based on the average maximum width of the dump raccoons' summer (MCP) home range (1530 m, N=12). Since Seidensticker et al. (1988) did not specify how this distance was used to calculate overall area, a circle was drawn on the study map using this distance as the radius and the dump as the centre. In addition, a square, centred over the dump was drawn with each side equal to the distance calculated. The circle enclosed large areas where the study raccoons had never been located. The square was more representative of the area included in the study raccoons' home ranges, therefore this shape was used for calculation of crude density; its area was 234 ha.

3.5 Results

3.5.1 Radiotracking

For locations determined by triangulation, distance between the observer and estimated transmitter location ranged from 8.3 m to 1837.9 m and averaged 330.5 m (SD=239.3 m). Uncertainties in raccoon position for triangulated bearings (tan20° X trans-receiver distance) ranged from ±3.0 m to ±668.9 m with a mean of ±120.3 m and standard deviation (SD) of 87.1 m (N=1181). Overall locational uncertainty, including that associated with scanning and homing techniques as well as triangulation was ±146.6 m (N=1110).

3.5.2 Home ranges

Minimum convex polygon (MCP) home ranges for all study animals except F6 are given in Table 3.1.

Average MCP summer and fall home ranges for the dump animals were 69 ha (SD=32 ha, N=12) and 45.5 ha (SD=30 ha) respectively. Average MCP summer/fall home range overlap for the dump animals was 30.5 ha (N=12).

Grid cell home ranges are given in Table 3.2. Average grid cell summer and fall home ranges for the dump animals were 144 ha (SD=42 ha, N=12) and 117 ha (SD=32 ha) respectively. Average grid cell home range overlap between summer and fall was 95.8 ha.

3.5.3 Males vs females

Average summer grid cell home ranges for males and females were 154 (SE=20 ha) and 129 ha (SE=7 ha) respectively; there was no significant difference ($t=1.04$, N=7 males, 5 females, $\alpha=0.05$, $P=0.31$). Average summer grid cell home range for lactating females was 132 ha (SE=6 ha). There was also no significant difference between lactating females and males in the size of these home ranges ($t=0.81$, N=7 males, 4 lactating females, $\alpha=0.05$, $P=0.41$).

3.5.4 Regular vs occasional dump visitors

Average summer grid home ranges for regular (M1, M2, M3, M5, F5, F8) and occasional (M4, M6, M7, F3, F4, F7) visitors to the dump were 130 (SE=10 ha) and 157 ha (SE=22 ha) respectively. There was no significant difference in range sizes between the two groups ($t=-1.13$, df=10, $\alpha=0.05$, $P=0.27$).

3.5.5 Yearlings vs adults

Only three yearlings were trapped at the dump in this study (F4, F6, and M7), and home range data were available for only F4 and M7. Consequently, statistical comparisons between adult and yearling home range sizes were not performed.

Home ranges for F6 could not be calculated as only two locations were determined for her: her initial capture site at the dump and her second capture site 2.4 km east of the dump, where she was hit by a car ten days later (Appendix 3.B).

M7 was the most widely ranging raccoon in the study (Appendix 3.B). Originally trapped at the dump on June 27th, he was later located by telemetry near a farmhouse 4 km northeast of the dump on July 16th. By July 18th, he was visually identified at the dump site again where he remained until August 8th. At this time, he was located by telemetry near the same farmhouse east of Chaffeys Locks. He was still at this location when the study ended in October.

Locations determined for M7 clustered around either the dump area or the farmhouse with no points between these two clusters. Had M7 utilized the area between these two summer ranges, his MCP home range would have been 310 ha. However, since he was never discovered in the intervening area, this extra ground was not considered part of his "normal" range, according to the home range definition used for this study. For this reason, his MCP summer home range was divided into two discrete ranges for area calculation.

The only other yearling of the dump raccoons, F4, wandered a maximum of 760 m from the dump during the summer. The average distance of the furthest fix from the dump during the summer for the yearling raccoons was 2610 m (SE=1140 m, N=3) and for the adults ($\geq$ 2 yrs), 1200 m (SE=156 m, N=10). A t-test comparing the two averages could not be performed as the assumption of equal variances was violated (F=16.09, α=0.05, df=2,9).

3.5.6 Compost raccoons

An insufficient number of fixes was obtained for F1 and F2 for asymptotic grid cell home ranges to be calculated. Average summer and fall grid home ranges for these animals were 127 ha (SD=16 ha) and 104 ha (SD=16) respectively. Average MCP summer and fall home ranges were 107 ha (SD=122 ha) and 40 ha (SD=0.4 ha) respectively.

3.5.7 Population density

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. Crude density was therefore 1 raccoon/12 ha.

3.6 Discussion

3.6.1 Radiotracking

Since only one telemetry receiver was available, and hence discontinuous locational fixes had to be obtained, detailed information on the movement patterns of raccoons in this study was not possible. In addition, the telemetry system used was not sufficiently precise to allow for the analysis of habitat preferences or calculation of potential contact rates of the dump raccoons when they were away from the dump.

3.6.2 Home ranges

The coarseness of the grid used for grid cell home range analysis in this study may have led to an overestimate of home range sizes based on the fixes obtained in this study (White and Garrott 1990) and would explain why the grid home range estimates were larger than the MCP estimates. The advantage of the grid cell method over the MCP method is that the grid method takes into account the precision of the telemetry system (White and Garrott 1990).

Raccoons in Hoffmann and Gottschang's (1977) study in suburban Ohio with a raccoon density of one/1.46 ha had average home ranges of 5.1 ha. Fritzell's (1978) study with a very low density of raccoons in the spring and summer averaged 2560 ha. Raccoons in my study fell between these two extremes, though their home ranges appeared to be smaller than average. However, home range estimates obtained from my study data are probably underestimates of actual home ranges. This is because the study animals were monitored discontinuously over only two seasons. In a Niagara-St. Lawrence trap-recapture study, annual movements of raccoons averaged 10 km and ranged up to 150 km and in a similar Barrie, Ontario study, nightly movements of 4 km were common (Rosatte 1996). It is easy to miss such movements when using discontinuous tracking (Rosatte, pers. comm.). Unless raccoons are tracked continuously with an accurate system for a long period of time (eg. a year), their movements and home ranges will be underestimated. With the advent of a satellite-based GPS (Global Positioning System) transmitter small enough to be attached to a raccoon, continuous, long-term monitoring may soon be possible.

3.6.3 Males vs females

Home ranges of males tend to be larger than those of females (Fritzell 1978; Stuewer 1943). The reason why no difference was found in this study may be because either there was no difference, or the small sample size prevented the difference from being found.

3.6.4 Regular vs occasional dump visitors

Again, lack of a difference between home ranges of regulars and occasionals in this study may have been the result of either a true lack of difference or the small sample size involved. It may also be that the definition for "occasional" was not adequate for comparative purposes. Technically, F2, should have been considered an occasional dump visitor because she was only seen on 1/35 (3%) of the contact observation nights; unfortunately, not enough fixes were obtained for her to calculate an asymptotic home range estimate for comparative purposes.

3.6.5 Yearlings vs adults

Radiotelemetry indicated that M7 occupied two distinct and widely separated areas during the summer of 1995. The fact that no points were located between these two ranges may have been because he traversed the distance between the two areas in the time between tracking nights.

The distance between the two discrete areas was 4km. Raccoons have been known to travel this distance in a single night (Rosatte 1996). In addition, the main dispersal period for yearling males is May to June (Fritzell 1978) and this might have inclined M7 to make such a movement if he were dispersing.

A second explanation for M7's summer home range pattern is that he may have been aided by a vehicle. The owner of the farmhouse where M7 was located owned some horses in a field opposite the dump site. Periodically he would drive his tractor and wagon to this field to deliver hay to the horses and it is possible that M7 boarded the tractor and rode on it back to the farmhouse. He may have done this again to return to the dump two days after his first visit to the farmhouse. Raccoons have been known to ride on such vehicles as boats, transport trucks and rail cars (Raccoon Rabies Task Force, unpublished).

F4, another yearling dump raccoon, did not travel as far from the dump as F6 or M7, indicating that she may have been a post-disperser, having immigrated to the dump area the previous fall.

Two out of three of the yearlings in this study were found in excess of 2 km from their initial capture site within the same season of their capture; this indicates that the potential for rabies spread in an unvaccinated population using a common feeding site is probably exacerbated by dispersal of the yearlings from the site during the summer. As with the home ranges, mentioned above, these movements are probably minimum estimates of actual distances travelled by the dump raccoons.

3.6.6 Compost raccoons

Most of the locations for F1 and F2 were obtained by homing in on their daytime resting sites. Although this telemetry technique is more accurate than triangulation, it is also much more time consuming; this limited the number of locations that were obtained for each animal and consequently, asymptotic home ranges for these two animals could not be calculated for comparative purposes with the dump raccoons. In addition, the majority of locations used to calculate the home ranges of these animals were daytime resting sites; in other words, movements occurring during the activity period were not recorded. Therefore, the home ranges calculated for F1 and F2 probably represent minimum estimates.

3.6.7 Home range overlap

Contact rates for foxes used in rabies simulation models are estimates of potential contact rates drawn from analysis of home range overlap obtained from radio telemetry data (Blancou et al. 1991). Radio telemetry can also be used to analyze home range overlap, spatial relationships, and potential contact rates for raccoons where the precision of the telemetry system allows. The low precision of the telemetry system used in this study prevented such analysis; it was not possible to tell, with the coarseness of the grid used for grid cell home range analysis, the potential for raccoons with overlapping ranges to contact each other. Two raccoons could be within the same 23 ha grid cell area at the same time and yet be unaware of each other.

Data from this study indicated extensive overlap of home ranges within the population. However, detailed conclusions about intra- and intersexual interactions would have required the collaring of a larger sample of the dump population. Territoriality does not normally occur in raccoons (Seidensticker et al. 1988; Kauffmann 1982) and has only been found for adult males in the spring and summer in North Dakota, at the northern edge of the raccoons' range. This behaviour is thought to be due to competition for access to females (Fritzell 1978). Studies from more southern latitudes failed to demonstrate territoriality in raccoons (Johnson 1970; Stuewer 1943).

3.6.8 Seasonal changes in home range

Raccoons in this study continued to visit the garbage dump during the fall, even though food was only dumped weekly in this season, rather than daily, as in the summer. This indicated that while raccoons may have been using alternate food sources in the fall, they were still relying to some extent on the dump.

3.6.9 Population density

Although caution should be used in comparing densities between studies, especially if different methodologies, seasons, and habitats are involved, population densities for raccoons are usually around one raccoon per 8-10 ha (Kauffmann 1982) but may range from one raccoon per 100 ha in North Dakota and northern Ontario (Rosatte 1996; Fritzell 1978) to one raccoon per 0.4 ha in more favourable habitat (Twichell and Dill 1949). In southern Ontario, raccoon density averaged over 200 plots sampled was one raccoon/9-33 ha (Rosatte, unpublished) though densities of up to 1 raccoon/1.8 ha have been recorded in forested park areas of Scarborough, Ontario (Rosatte et al. 1991). Density for my study area falls within the high end of the average range for raccoon density in southern Ontario. It should also be noted that in my study, trapping for population estimates occurred at the end of summer when the local population expanded because the young-of-the-year enter the population. Causes of mortality for raccoons include starvation, heavy parasitism, poison, dogs, automobiles, hunting, trapping, canine distemper, and of course, rabies (Rosatte and MacInnes 1989; Mech et al. 1968); however, the hunting season in this area ran from October 15th to December 31st (OMNR 1996), after trapping for density estimates was finished. Also, a considerable number of the dump population were trapped early in the study and vaccinated for rabies and distemper, therefore, the major source of mortality in this population at the time of the study was probably automobiles. Apart from roadway mortality, death rate of juveniles in this population was probably very low until winter food shortages set in. For this reason, the density estimated for my population probably represents a peak annual value.

3.6.10 Applications of the data

Although caution should be exercised in using data from healthy animals to predict the behaviour of rabid ones, telemetry studies on two other species indicate that movements of rabid animals are not very different from the movements of healthy ones. Storm and Verts (1966), determined that the movements of a radio-tracked rabid skunk in its last weeks of life were not statistically different from the movements of non-rabid skunks.

Also, a radiotelemetry study by Artois and Aubert (1985) on three wild foxes inoculated with rabies indicated that these animals occupied a comparable home range before and during the phase at which the virus would have been shed. To date, no information has been published on the movements of rabid raccoons (Laura Bigler, pers. comm.). However, if the same rules hold true for raccoons as they do for skunks or foxes, then rabid raccoons are likely to encounter the same conspecifics as they would while they were healthy. This indicates that data obtained from this study have direct relevance to potential movements of raccoons in the study population should they become infected with rabies; dispersing yearlings, therefore, would probably be the main vectors spreading the disease into areas beyond the population using the common feeding site.

It would have to be acknowledged however, that once a rabid raccoon had encountered a healthy conspecific, the interactions between the rabid raccoon and the other raccoon would likely be different than if the two animals involved were healthy.

TABLE 3.1. Summer (June to August) and fall (September to October) home ranges (minimum convex polygon) of 12 raccoons which fed at a rural Ontario garbage dump, and 2 raccoons (F1 and F2) which fed at a compost heap in 1995.

Raccoon	Summer # Points	Summer Area (ha)	Fall # Points	Fall Area (ha)	Overlap Area (ha)
F1	15	20.4	5	39.9	1.5
F2	22	193.6	9	40.4	39.9
F3	69	117.1	28	95.3	37.3
F4	54	39.3	33	29.9	22.8
F5	57	69.5	50	7.2	7.2
F6[a]	2	-	0	-	-
F7	62	46.1	35	12.6	11.3
F8	59	63.2	38	43.7	36.2
M1	47	31.1	17	20.7	8.7
M2	59	43.1	25	43.3	30.4
M3	52	48.3	37	48.8	36.0
M4	51	55.8	41	19.8	17.2
M5	50	79.0	26	91.7	49.6
M6	47	106.9	41	75.7	64.3
M7	47	126.8	25	57.2	45.4

[a] F6 was located only twice; once at her initial capture and again, 10 days later when she was hit by a car on Opinicon Road.

TABLE 3.2. Summer (June to August) and fall (September to October) home ranges (grid cell method) of 12 raccoons which fed at a rural Ontario garbage dump, and 2 raccoons (F1 and F2) which fed at a compost heap in 1995.

Raccoon	Summer # Points	Summer Area (ha)	Fall # Points	Fall Area (ha)	Overlap Area (ha)
F1	15	115	5	92	23
F2	22	138	9	115	23
F3	46	138	28	138	115
F4	46	115	33	115	92
F5	46	138	50	92	92
F7	46	115	35	69	46
F8	46	138	38	115	115
M1	46	92	17	92	46
M2	46	115	25	115	92
M3	46	138	37	115	115
M4	46	138	41	115	115
M5	46	161	26	161	92
M6	46	184	41	138	138
M7	46	253	25	138	92

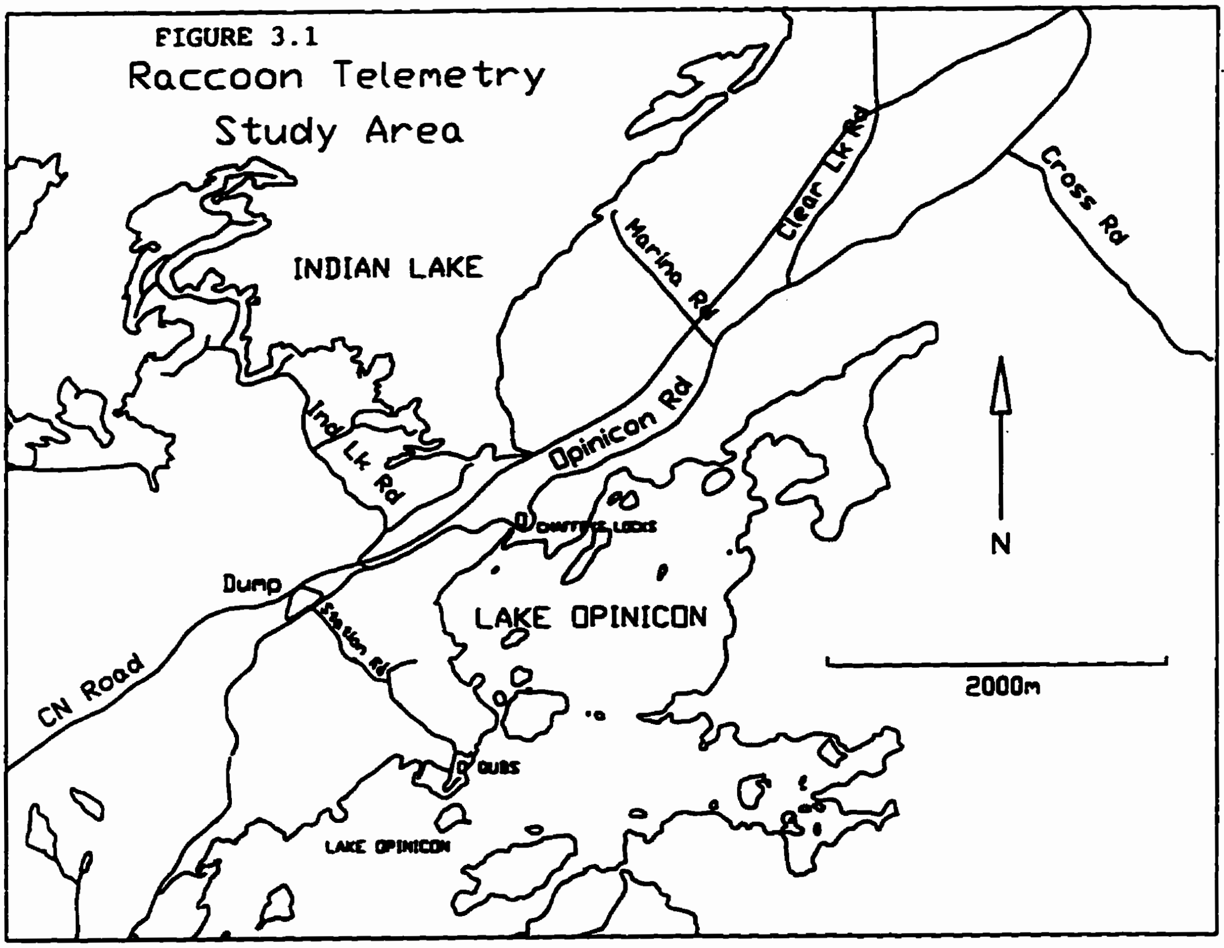
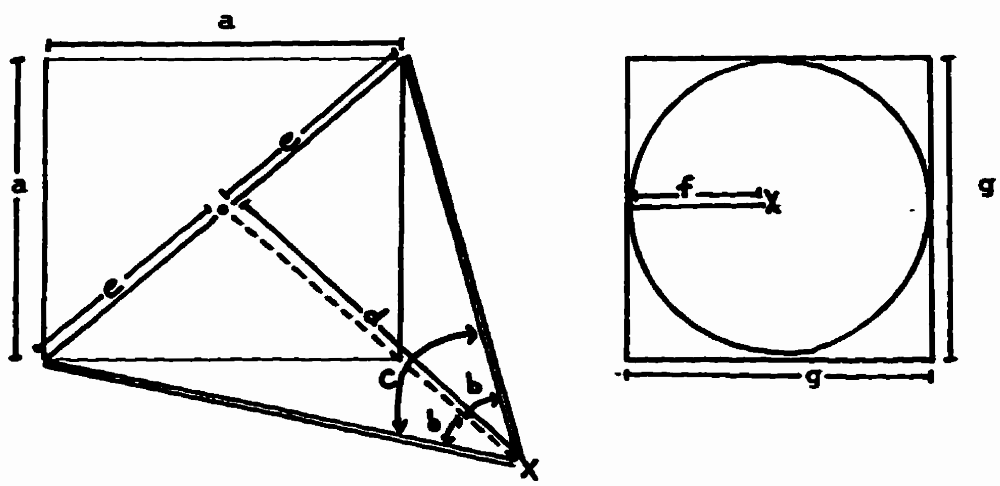


FIGURE 3.1. Study area used for radiotracking raccoons feeding at a garbage dump in rural eastern Ontario. Universal Transverse Mercator (UTM) co-ordinates are Zone 18, 03900-03950, 49350.

FIGURE 3.2



$2a^2 = 4e^2$
$2a^2 = 4 \times 120.3$ m
$a = 340$ m

$g = 2f = 480$ m

Legend

- X receiver location
- . estimated animal location
- ---- estimated bearing
- ═══ boundary of error arc

a=length of grid square side
b=system precision=SD of bearing errors=20^{0}
c=error arc=estimated bearing $\pm$ 2 X b
d=average transmitter-receiver distance for non-test bearings=330.5m
e=locational uncertainty= $\tan 40^{0}$ X d
f=radius of circle within which transmitter signal was picked up at a receiver sensitivity setting of 10 = 240 m
g=length of grid square side

FIGURE 3.2. Calculation of grid square dimensions for grid cell home range analysis based on locational uncertainty of radiotelemetry-determined bearings. (drawing not to scale)

Chapter 4

GENERAL DISCUSSION

4.1 Limitations of the study

It is important to realize that the contact rates of raccoons in this study are specific to the time and study area in which the data were collected. Season, population density, food supply, food type, and other habitat characteristics may all influence contact rate in raccoons (White et al. 1995; Seidensticker et al. 1988; Sharp and Sharp 1956).

Caution should be exercised in applying results of this study to other seasons because of seasonal variations in raccoon behaviour. This study took place in the summer and fall during the family rearing period. Differences in contact rates between males and females, while apparently absent during this time, may exist at other times; intraspecific aggression escalates from late winter to early spring with the advent of the breeding season, during which time male raccoons may breed with several females and may also share dens with them, further increasing the opportunity for rabies transmission (Seidensticker et al. 1988; Sharp and Sharp 1956).

In addition, raccoons are known to den communally during the winter months (Mech and Turkowski 1966; Sharp and Sharp 1956) which may result in higher contact rates than in summer.

Results of this study give an indication of the potential contact rate for raccoons which feed at a concentrated, common food source, available for part of the year (summer). In areas where the habitat consists of food distributed in a relatively uniform pattern, contact rate would presumably be lower. However, in urban and suburban areas, clumped food resources are available throughout the year (Seidensticker et al. 1988) and intraspecific contact in these areas is probably even greater there than in the area observed in this study.

Population density has been shown to have a major impact on contact probabilities, at least in foxes (White et al. 1995). My study population had a density of 1 raccoon/12 ha, however in urban areas, for example Scarborough, Ontario, where densities may be as high as 1 raccoon/1.8 ha in forested-park areas, (Rosatte et al. 1991) contact rates may be much higher. In areas where the population density of raccoons is lower (eg. in northern Ontario where density may be as low as 1 raccoon/100 ha or lower (Rosatte 1996)), contact rates would presumably be lower (Bruggemann 1992).

Finally, data from my study is based on healthy raccoons and is only applicable to raccoons which are shedding the rabies virus in their saliva while exhibiting no behavioural symptoms of the disease (i.e. the preclinical phase of the disease=1 day). The infectious period of rabies (i.e when virus is being shed in the saliva) ranges from 3 to 8 days (average=5.5 days) (Winkler and Jenkins 1991; Coyne et al. 1989).

The behaviour of clinically rabid raccoons is distinct from the behaviour of preclinical or healthy raccoons (Winkler and Jenkins 1991; Kappus et al. 1970). These behavioural changes make it difficult to model the behaviour of rabid raccoons based on healthy ones. Contact rates of rabid animals would probably be higher, but by some unknown amount (White et al. 1995).

Raccoons which become infected with rabies will either die of the disease or become immune (Coyne et al. 1989); there do not seem to be any "carriers" which continue to shed the virus without dying from the disease. Between 5 and 36% of a raccoon population develop immunity after initial exposure and this immunity may last up to two years (Coyne et al. 1989). Since not all members of the population are susceptible, contact rates observed in the field will be an underestimate of infection rate in raccoons in a rabies endemic area.

4.2 Applications of the results

4.2.1 Raccoon rabies model

Planning for the control of rabies in a population has been facilitated in the past by the development of computer models which simulate the epidemiology of the disease (Macdonald and Bacon 1982). In particular, a model for fox rabies has been used by the Ontario Ministry of Natural Resources to plan effective vaccination strategies for this species.

Coyne et al.'s (1989) computer simulation was designed to model the raccoon strain of rabies; its purpose was to evaluate vaccination and culling as rabies control strategies. The Coyne et al. model used a theoretically derived rabies transmission rate: one rabid raccoon infects one susceptible raccoon every 11 days. In comparison, raccoons in my study bit one of their conspecifics on average once every 3 days (using nightly average contact rates), though every bite would not necessarily lead to infection and data is specific to my study area and conditions.

Data from my study reveal that at a population density of 1 raccoon/12 ha, raccoons using a common food resource in rural eastern Ontario in the summer, bite and are bitten an average of 0.93 and 1.28 times/hr respectively. Although specific to the study site, these are the first intraspecific contact rates for raccoons to be calculated from field data rather than derived theoretically. Such calculated results can be used to provide a frame of reference and to help determine a reasonable range of intraspecific contact rates for raccoons.

Prior to this study, no one knew whether contact rates used in models should be 1, 10 or 100 bites/hr. The rates calculated in my study can be used to model rabies spread in areas similar to my study area to design rabies control strategies for these populations. In addition, the rates may now be used to refine estimates of contact rates in raccoons at other population densities, in other habitats, geographic areas and climates.

One of the assumptions of the Coyne _et al._ (1989) model is that contact rates in raccoons are not significantly different between adults and juveniles, or males and females. Data from my study support the latter assumption, though larger sample sizes are needed to make this conclusion with any certainty.

4.2.2 Bait distribution strategies

The Ontario Ministry of Natural Resources currently employs a trap-vaccinate-release (TVR) program to immunize urban raccoons against rabies; this technique involves live-trapping and vaccination by intramuscular injection (Rosatte _et al._ 1992). TVR is now being used to establish an immunized population of raccoons in areas of Ontario where infected animals are liable to enter Canada from the United States (Raccoon Rabies Task Force 1992). Though TVR is labour-intensive and more costly per unit area than bait distribution (Rosatte _et al._ 1992), it is the only means of immunizing raccoons in Ontario until a licensed oral raccoon vaccine becomes available. Once the vaccine is licensed, an efficient, safe and cost-effective method to distribute vaccine-impregnated baits to the raccoon population must be devised.

Should raccoon rabies enter Ontario, the potential area it could affect would be about 150,000 km^2 (Rosatte, pers. comm.). With an area this large, the most feasible method of vaccination is to uniformly distribute baits using aircraft (Rosatte et al. 1992) and this is the method that should be used in rural areas. However, distribution of baits from aircraft is not accurate enough to target small pockets of habitat within urban areas (Rosatte et al. 1992). In urban areas, therefore, baits may be distributed at artificially created feeding stations.

Because of their lack of territoriality and their opportunistic feeding habits, raccoons quickly learn to exploit new, concentrated food sources. Seidensticker et al. (1988) discovered that within 27 days, an average of 14 raccoons were regularly using a newly created feeding site each night and that 21 of 23 collared raccoons living in the area had visited it at least once. The feeding site in Seidensticker et al.'s rural study area was 0.5 ha in diameter and attracted raccoons from 127 ha of the surrounding area. However, in urban areas, where home ranges of raccoons tend to be smaller, the effective range of a baiting station would presumably be smaller and more baiting stations would have to be created to immunize a raccoons in a given area.

Timing of baiting should be in the summer and early fall; during the breeding season, and during the winter, use of common feeding sites by raccoons appears to decrease (Sharp and Sharp (1956)).

Spot baiting of raccoon habitats using common feeding areas would probably cost less than TVR for raccoon vaccination and is therefore a suitable method to vaccinate raccoons in urban areas.

4.3 Future research approaches

This study was a preliminary attempt to quantify intraspecific contact rate in raccoons with respect to potential rabies transmission.

The intensive and time-consuming nature of both the telemetry field work and contact observation limited the number of animals for which sufficient behavioural data could be obtained. The resulting small sample size made it difficult to draw definitive conclusions; no one portion of the population was adequately studied. To rectify this, a larger sample of the dump population should be collared and studied, including more males and females to determine if a statistically significant difference in contact rates exists within (i.e. lactating vs non-lactating females) and/or between sexes and age classes (juvenile, yearling and adult). Rate of immigration and emigration of the dump population would also be useful in determining the potential spread of rabies.

The study should also be set over the winter and spring to determine what happens to the dump raccoons during seasons when the food is no longer available.

In addition, raccoons trapped at the feeding site should be carefully examined for the presence of healed or fresh bite wounds to better assess the rate of contacts which may lead to rabies transmission.

For comparative purposes, study of contact rates in raccoons feeding at an urban or suburban garbage dump would be interesting and more useful as a model for vaccinating raccoons via baiting stations.

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Appendix 2.A

COMMENTS ON THE FEASIBILITY OF BETALIGHTS AS AN ANIMAL MARKING TOOL

In this study, two devices were used to facilitate nocturnal identification of raccoons: reflective tape, and betalights (manufactured by SRB Technologies Canada, Inc., 320 Boundary Road, Pembroke, ON, K8A 6W5). As far as I know, this is the first study in North America in which betalights have been used for this purpose.

A betalight consists of a sealed capsule internally coated with a phosphor and filled with radioactive tritium gas (^3H) (Davey et al. 1980). The capsule is impervious to tritium and absorbs any beta radiation not already absorbed by the phosphor (Davey et al. 1980). These tags have been successfully used in the United Kingdom for night tracking of foxes (Macdonald 1978), badgers (Kruuk 1978), and rabbits, and, as long as the outer capsule remains intact, they do not present any radiation hazard (Davey et al. 1980). In some cases, the capsules are made of glass (Davey et al. 1980), but in this study they were made of a sonically welded polycarbonic housing, capable of withstanding the direct impact of a car tire, or an eight kilometre drop to the ground (Phil Gaudette, pers. comm.).

Before attaching a betalight to a free-ranging animal, there are several responsibilities which any researcher using this tool must assume. There is a potential risk to a member of the public should he or she encounter a betalight (eg. on a dead raccoon hit by a car on the roadside) and tamper with the outer casing (though to breach the outer casing, enormous force would have to be used). The tritium in the lights would not pose a health hazard unless the casing was broken in an enclosed, unventilated space and the gas was inhaled.

In order to exceed the allowable limit outdoors, ten to twelve betalights would have to be broken in the same week in the same location (Phil Gaudette, pers. comm.). To use betalights, a researcher must obtain a licence to own the source (tritium), as well as permission from the Atomic Energy Control Board for the specific application of the betalights for that particular study. In addition, it is the researcher's responsibility to ensure:

1. that the possibility of a betalight coming into contact with a member of the public is minimized.
2. that those members of the public who might come into contact with betalights are educated about their purpose and potential danger.

In this study, objective 1 was met by putting betalights on only two animals, both of which were caught on property owned by the Queen's University Biological Station to which public access was restricted. Locations of both raccoons were regularly determined to ensure that they did not move out of the range of the telemetry system. In addition, the collars of these two animals were labelled with the name, address, and phone number of the researcher as well as an offer of a reward should the collar be found.

Objective 2 was met by holding a public meeting near the study site. The meeting was advertised on a local radio station and both local newspapers. At the meeting, the researcher explained the use of betalights in the study, their appearance, and their potential hazard. The public were also informed that if they found a betalight, they were to make note of where they had found it and contact the researcher to retrieve it. Information leaflets were also distributed to all cottages in the surrounding area.

Four shapes of betalights were available for this study: solid circle (Fig. A.2.1), ring (as for solid circle but only the outside rim of the circle contains tritium and is therefore luminous), crescent (as for solid circle but only half of the outside rim is illuminated), and rectangle (Fig. A.2.1). Pre-field tests revealed that the solid circular lights were the most readily visible. The most conspicuous colours were red, blue, yellow, and green. Orange and red were difficult to distinguish between, as were blue and white. Tritium content varies with the shape, colour, and intensity of the betalight. The average tritium content of the lights used in this study was 0.24 Ci. These units have a half-life of six years (Phil Gaudette, pers. comm.) and can be distinguished at 15 metres with the naked eye in the absence of ambient light. With the aid of binoculars, this distance is even greater, but the maximum distance could not be determined for this study as thick vegetation limited visibility beyond the confines of the dump area.

Three betalights were used in this study on two animals (two betalights on one animal, one on the other). Two were glued onto one collar with contact cement, and the third was attached to a second collar with brass wire. The betalight attached with wire remained on the animal for the eleven months over which she carried it. Glue was used by Davey et al. (1980) to attach betalights to ear tags on rabbits, however, in my study the two betalights which were glued onto the other raccoon's collar fell off after between one and seven days, possibly facilitated by the dextrous fingers of the raccoon or her offspring. Loss of the betalights was discovered when the animal was retrapped a few days later. Because the betalights were no longer attached to the collar, they could not be relocated with telemetry equipment. Daytime resting sites for the animal for the past seven days had been recorded and these sites were searched as well as the nightly travel routes known to be used by this raccoon. A thorough search was not possible as sometimes the resting sites were inside tall, live trees, so it is possible that one or both betalights were located at one of these sites. All of these sites were on Queen's University property.

After the search was completed and the betalights had not been found, a full report was written up and turned over to the Queen's University Environmental Health and Safety Department with a map indicating the resting sites which were not completely searched. A further search could then be conducted by the department using a Geiger counter, although this would only detect the presence of the betalight(s) if the outer casing had been cracked and it was leaking tritium. If the betalights were inside one of these den trees and the casings were intact, the risk to the public (or animals using the den site) is exceedingly low.

Avoidance of this type of loss can be prevented by incorporating the betalight into the radiocollar. In Kruuk's 1978 study on badgers, each betalight was epoxied into a collar with the transmitter during manufacture. This was an ideal arrangement as it ensured that telemetry could always be used to locate a lost light. Unfortunately, in my study, the collars had already been manufactured before permission to use the betalights had been obtained. Consequently, the lights had to be attached to the outside of the collar.

Another marking tool consisting of a string of flashing red LED's to be fastened around the radiocollar, was deemed too impractical for use in this study. First, although visible at night at a greater distance than the betalights, it required a 9 Volt battery which would have to be replaced, requiring further capture and handling of the animal during the study. Second, the added weight of the lights, the battery and the waterproofing epoxy which would be required to render the unit durable in the field, exceeded that which a normal adult raccoon could carry without encumbrance.

A comparison of betalights and reflective tape as marking tools is presented in Table A.2.A. Because betalights last for such a long time, if betalights alone are used to mark a wild raccoon, the marker should last for the entire lifespan of the animal (or at least the lifespan of the battery in the radiocollar). It would never have to be recaptured during the study for remarking with the potential disruptive effects that might have on the animal's behaviour. However, at the end of the study, the researcher must ensure that all betalights are retrieved or that, if they cannot be retrieved, that they cannot pose any danger to the public.

Reflective tape allows identification of individuals by daylight, at dusk, and when ambient light (eg. from a flashlight) is present at night. During the day and when strong ambient light is present, the colour of a betalight cannot be distinguished (i.e. They all appear white.). However, because betalights can be distinguished at night, without any ambient light, a combination of reflective tape and betalights allows identification of animals at all times of day.

If betalights are to be used, I recommend:

1. In the case of raccoons, betalights be epoxied inside the collars. If internal attachment is not possible, betalights can be wired to the outside of the collars.
2. Two betalights should be used per animal, one on each side of the collar (facing left and right), so that the animal's position does not obscure the lights.
3. The study should be set on either private property, or in an area to which the public has restricted access.
4. Collars with batteries which are likely to run out should be replaced. Betalights which are wired on can be easily removed from the old collar and attached to the new one.
5. Make sure the public is educated, not hysterical. Betalights pose no risk if handled properly.
6. Animal locations should be determined at least once daily to ensure that deaths are detected within 24 hours, and that long distance movements outside the

range of the telemetry system do not occur.

In conclusion, this author recommends betalights as a useful tool for identifying nocturnal or crepuscular animals which are less mobile than raccoons, when the behaviour of these animals occurs largely in areas which are free of visual obstructions and closed to members of the public. This author does not reccommend the use of betalights with animals which are prone to move long distances or are largely diurnal.

TABLE A.2.A. A comparison between reflective tape and betalights as an animal marking tool.

	Betalights	Reflective Tape
Lifespan	6 years	1-3 months[a]
Cost (1995)	$54.00 each	< $1.00 for 15 cm
Requires Licence to Use?	Yes[b]	No
Risk to Public?	Very small	None
Colours visible in daylight?	No	Yes
Visible without ambient light?	Yes	No
Visibility (m) (naked eye)	15	10
Colours available	6	7

[a] Reflective properties diminished due to accumulation of dirt, and/or raccoons managed to remove the tape from their collars within this time.
[b] Permission to use betalights in Canada must be obtained from Atomic Energy Canada.

FIGURE A.2.A

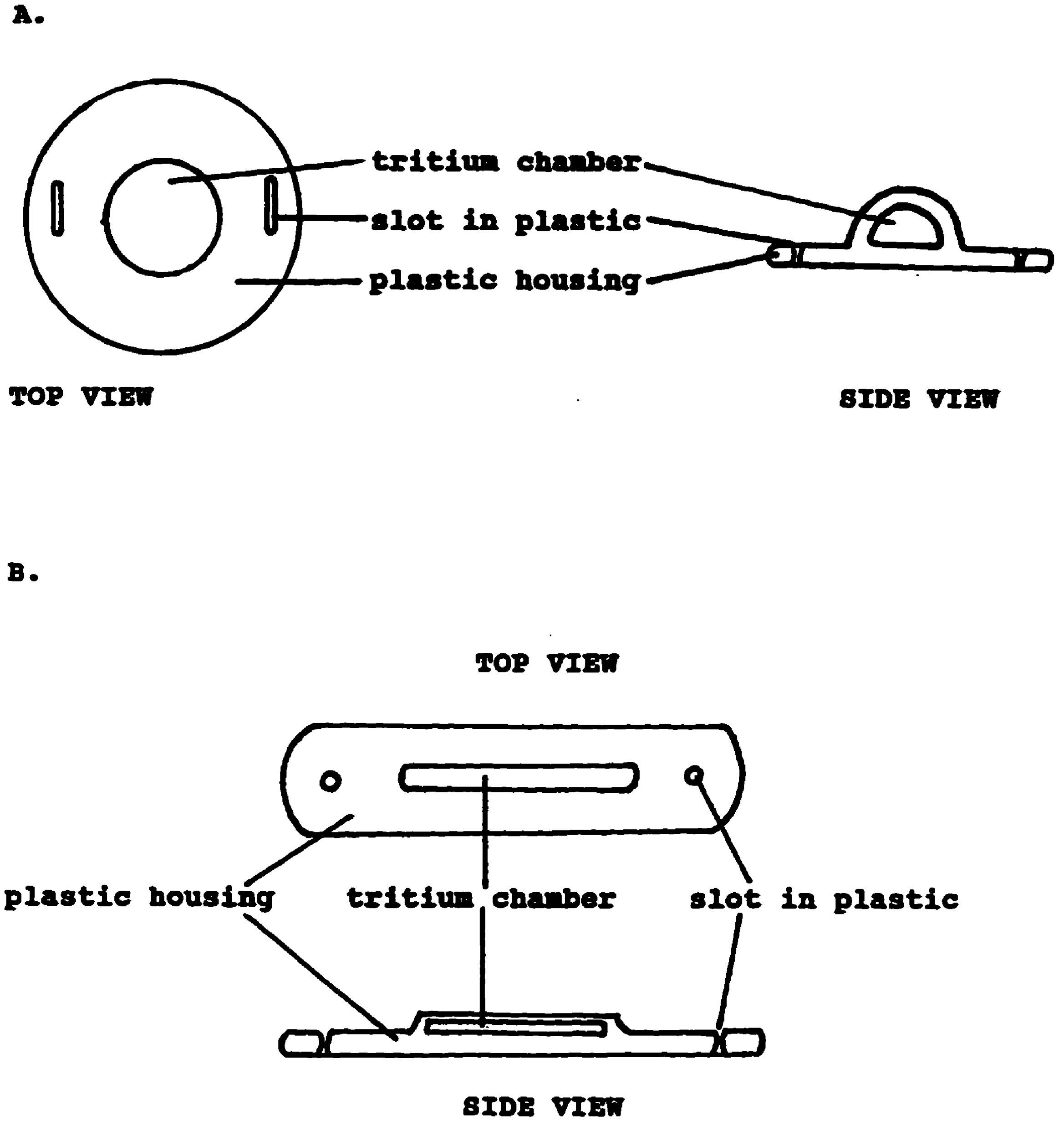


FIGURE A.2.A. Betalights (actual size) used to facilitate nocturnal identification of wild raccoons. A) Solid circle-shaped model. B) Rectangular-shaped model.

Appendix 2.B

ADDITIONAL NOTES ON THE BEHAVIOUR OF RACCOONS FEEDING AT A RURAL ONTARIO GARBAGE DUMP

2.B.1. Contact behaviour

In Sharp and Sharp's (1956) study, large groups of raccoons (consisting of more than one lactating female and their offspring) fed without dispute in a very small area. In my study, this was also observed with groups of raccoons (eg. 10 animals) feeding peacefully within a 1 m radius.

In Sharp and Sharp's (1956) study, adult raccoons approaching the dump alone were threatened by the raccoons already feeding; in my study, behaviour of raccoons toward their conspecifics at the dump varied. When one raccoon was already feeding and a new animal appeared, the lone animal was either driven off the dump, was allowed to find another patch of the garbage to feed on, or was completely ignored. Behaviours described by Barash (1974) as those displayed by the dominant and submissive animal (i.e. laying back the ears and raising the hackles--lowering the head and body, retreating) were commonly observed by raccoons feeding at the dump. Apparently some form of hierarchy existed within this population, but its basis is obscure.

I did not test whether lone adult males were dominant over yearling males or how non-lactating females related to them and each other; this was because only a small sample of the population was marked and dominance interactions that did not include physical contact were not recorded. In addition, for unmarked animals, it was difficult to distinguish between non-lactating females and small adult males. Also, because only adults were marked in this study, it was not possible to tell whether any adult-juvenile contacts were in fact mothers contacting their own offspring.

Threat behaviour in raccoons feeding at the dump was sometimes followed by biting. Raccoons occasionally bit each other in disputes over a food source (eg. piece of chicken), but fights were not always associated with feeding. On a few occasions, raccoons were heard fighting on the dump site but out of sight of the garbage pile.

Most non-bite contacts (i.e. muzzle-to-body contacts, nose-to-nose contacts, grooming) were non-aggressive and may have served to strengthen social bonds (as when they occurred between a lactating female and her offspring).

2.B.2. Food

Garbage left at the dump site consisted of potato chip bags, garbage bags, plastic bags, pop cans, beer cans, broken glass, chicken (cooked), milk cartons, cracker boxes, cereal boxes, ice cream cartons, lettuce boxes, fruit (grapes, oranges), paint cans, pails of lard, peanut bags, cigarette packs, broken glass, nails, wood, and liquid floor cleaner. Higher numbers of raccoons were associated with the presence of chicken at the dump; this was the first food to be eaten, when present. Raccoons also fought over the lard pails. Raccoons were also observed to eat artificially sweetened breakfast cereals or other sweet foods, which were periodically present in small quantities at the dump. This agrees with Johnson's (1970) observations that raccoons seem to prefer foods high in sugar, though preferences may vary between populations and individuals.

Individual raccoons in this study were also observed to feed first on different food items. This may be because raccoons feeding at concentrated food sources, such as garbage dumps, may be limited in their feeding opportunities for favoured foods because of their position in the social hierarchy (Johnson 1970).

Supplementing the dump food source with marshmallows and peanut butter for one night, did not result in an increased number of raccoons utilizing the dump; on this particular night, a maximum nightly head count of 9 raccoons resulted, compared to a maximum nightly head count of 14, averaged over all study nights for which a head count had been recorded (N=31). This could possibly be because only a few (about 12) peanut butter-covered marshmallows were set at the dump. If more had been used, a greater response may have occurred.

2.B.3. Trapping

Several different types of baits were used in the traps in this study: plain and peanut butter-covered marshmallows, peanut butter alone, bacon fat, sardines, or raspberry-flavoured popcorn. Raccoons were captured in traps containing plain marshmallows, peanut butter, peanut butter-covered marshmallows, sardines, or bacon fat. Although raccoons could be caught with a variety of baits, when marshmallows alone were used, no other mammal species were ever caught in the traps.

When peanut butter was used, squirrels were often trapped. When bacon fat and sardines were used, rats and feral cats were also trapped. When sardines or raspberry-flavoured popcorn were used as bait, skunks were often trapped. Therefore, plain marshmallows seem to be the best bait for trapping raccoons specifically.

Appendix 3.A

ASSESSING TELEMETRY BEARING ACCURACY

3.A.1 Introduction

Many factors affect the accuracy of location estimates determined by telemetry; these include equipment, electromagnetic interference, topography, vegetation, and the distance between transmitter and receiver (Lee *et al.* 1985). Extent of the effects of these factors typically varies with each study (Lee *et al.* 1985). For this reason, it is essential that bearing accuracy be assessed for every study using radiotelemetry to locate animals (Lee *et al.* 1985).

Bearing accuracy has two components: bias (the average error, or difference between the true bearing and the bearing estimated by the receiving system for a series of receiver-transmitter locations), and precision, which is the standard deviation of these errors (White and Garrott 1990). Precision is used to form an error arc for each bearing by the following formula:

estimated bearing angle $\pm T_{(\alpha,n-1)}SD$ (Formula A.3.1)

Intersection of the error arcs from two or more bearings forms an error polygon (Heezen and Tester 1967). The intersection of two 95% confidence bearing arcs forms the 90% confidence error polygon (the two probabilities are multiplied) (Springer 1979). Overlap of two or more error polygons indicates that no detectable movement of the animal has occurred (Springer 1979). Size and shape of the error polygon is affected by system precision, distance from receiving sites to transmitter, distance between receiving sites, and the intersection angle of triangulated bearings (Saltz and Alkon 1985).

3.A.2 Study area

Testing took place in and around the town of Chaffeys Locks and the Queen's University Biological Station, about 40 km north of Kingston, Ontario. The surrounding area consists of lakes (Opinicon L., Indian L., Clear L., and Benson L.), farmland (livestock), fields, forest, hills, cliffs, a garbage dump (2.3 ha), swamp, and cottages (most of which are occupied only during the summer). One paved road (Opinicon Road) from which branch several unpaved cottage roads, (Indian Lake Road, Marina Road, Clear Lake Road) runs northeast and roughly bisects the study area. In addition, a disused CN (Canadian National) railway road runs roughly parallel to Opinicon

Road along a high, rocky ridge. Power lines are adjacent to all but the CN road. Use of all roads by cars is relatively infrequent (i.e. One car may pass every 20-30 min.).

The entire study area is about 460 ha. Universal Transverse Mercator (UTM) co-ordinates for the study site are: Zone 18, 03900-03950, 49350.

3.A.3 Methods

To test the accuracy of the telemetry system, the operator recorded compass bearings from 23 different receiver sites to collars hidden by a field assistant in 24 different locations. Transmitter locations were chosen to reflect a variety of topographical conditions. Receiver sites were those most commonly used under non-test conditions; nearly all were on roads with adjacent electrical power lines. In addition, receiver gains (sensitivity settings) were recorded for each bearing to determine ranges for each sensitivity setting.

In total, bearing errors were recorded for 91 different pairs of receiver-transmitter locations. These locations were plotted by hand to $\pm$ 50 m on 1:10,000 scale maps of the study area to obtain UTM co-ordinates. The true or actual bearing angle for each receiver-transmitter pair, as well as the distance between the transmitter and receiver, was then calculated by trigonometry. The actual bearing was then subtracted from the estimated bearing to obtain the bearing error. A histogram of all bearing errors was made and examined visually for outliers and normality. A set of criteria were devised to screen the outliers; bias and precision were then calculated from the remaining data.

3.A.4 Results

The histogram of the bearing errors appeared to be normally distributed with a few outliers (Figure A.3.A). Bearing errors (including outliers) ranged from -142° to +144°. Outliers were attributed to signal reflection and/or distortion, also referred to as "bounce", from environmental features, such as hills, cliffs, dense vegetation, as well as power lines.

Nearly all of the bearings with large errors (believed to result from signal bounce) did not intersect with bearings taken from other receiving sites on the same transmitter. A screening process was applied to the test data whereby all bearings which did not intersect with other bearings taken on the same transmitter were removed. In addition, certain receiving sites were associated with more signal bounce than others; all bearings taken from these sites were removed from subsequent analysis. Also, bearings taken when the transmitter-receiver distance was >2000 m tended to have large errors; these bearings were also removed. Screening using the above three criteria resulted in a new sample size of 63 bearings.

Average transmitter-receiver distance for the test bearings was 670 m (SD=420 m, N=63). The bias, or average bearing error for the telemetry system in this study, was 9° (i.e. estimated readings tended to be too far clockwise); this bias was significantly different from 0° ($t=3.61$, $N=63$, $p<0.001$; one sample t-test (Zar 1996)). Precision (standard deviation) of the system was ± 20°.

3.A.5 Discussion

The large bias found for this study may have been due to the fact that bearings were obtained using a hand-held compass and sighting along the wooden handle of the antenna. This handle may not have been perfectly parellel to the receiving path of the antenna. Because of this bias, 9° should be subtracted from all bearings taken in non-test situations.

Standard deviation of bearing errors in excess of 10° (low precision) have been documented in previous studies (Adkins 1991; Lee et al. 1985) and are often associated with hand-held antennas and mobile receiving systems (White and Garrott 1990), such as were used in this study.

Based on the results of accuracy tests, three screening criteria can be applied to all non-test data after correction for bias. These are:

1. All bearings which do not intersect with other bearings taken on the same transmitter

for a given location fix should be removed from the data pool. This will eliminate most errors caused by signal bounce.

2. All bearings taken from receiver sites associated with high levels of signal bounce (i.e. large bearing errors) should be excluded from the data pool. This should eliminate the remainder of the errors caused by signal bounce.

3. All bearings associated with large transmitter-receiver distances ($\geq$2000 m) should be discarded. This should eliminate the remaining outliers. The receving system used in this study has an outer range around 2000 m (Adkins 1991).

Another type of error which may occur is termed animal movement error. Because only one receiver was available for this study, bearings had to be obtained sequentially. In the test situation, this did not introduce extra error as the hidden collars were stationary. In non-test conditions, however, bearings were often taken while the animals were moving. This movement could be detected as the transmitter on each collar would produce a modulating signal if the animal were active.

If an animal is moving, it will be at a new location for each bearing (White and Garrott 1990). It is possible that the time delay between bearings taken as the operator moves from one receiving site to the next allows the animal to move a certain distance, thus introducing additional error into the location estimate (Schmutz and White 1990). The greater the distance an animal moves, the greater the error (Schmutz and White 1990). This animal movement error is independent of precision and bias associated with the equipment and operators (Schmutz and White 1990), as calculated above.

Researchers in telemetry studies have minimized error introduced by animal movements by limiting time intervals between first and last bearings to between three and ten minutes (Schmutz and White 1990). Although it is impossible to calculate animal movement error for each bearing, as this quantity varies with each reading (White and Garrott 1990), it is possible to estimate.

A conservative estimate of movement for a given time interval could be calculated from the maximum speed of the species being studied, however, given topography and vegetation in this study area, this speed is probably unrealistically high, especially for an undisturbed animal.

It was not possible to determine how fast raccoons in this study were moving while readings were being taken, as even small movements of the collar produced a modulating signal (When the animal was completely inactive, the signal was a steady pulse.). However, McClearn (1992) gives a "moderate" speed for a raccoon of 1 m/s. If a cut-off of 10-minutes between bearings were used for this study, the maximum distance a raccoon could cover between readings at 1 m/s would be 600 m; this is assuming the animal is moving in a straight line in one direction, and that movement is in the horizontal plane (i.e. It is not climbing down or up a tree, or a steep hill.). This is less than the maximum location error of the system (calculated below).

Overall location error for this study, exclusive of animal movement error, is equal to:

trans-receiver dist. X <u>tan</u>(precision)   (Formula A.3.2)

(White and Garrott 1990). From the accuracy test results above, after the screening process, 1680 m was the largest transmitter-receiver distance for which a bearing was taken. Therefore:

maximum location error = 1680 m X tan(20°)

= 610 m

A more typical location error can be computed from the average transmitter-receiver distance of the bearings in the accuracy tests.

average location error = 670 m X tan(20°)

= 240 m

According to Schmutz and White (1990), large antenna standard deviations (precision) (>5°) can "swamp" movement-induced location error (Schmutz and White 1990). However, given the above calculations and a "worst-case" scenario for raccoon speed, animal movement error for this study appears to swamp system error.

Although a 10-minute cut-off introduces a potentially large animal movement error, using a 5-minute cut-off instead for this study would result in the loss of an average of 25% of locations determined by telemetry per animal. Similarly, in a 1996 study by Gert and Fritzell, 23% of the locations came from triangulations with between-bearing intervals in excess of 8 min. For this reason, the 10-minute cut-off was deemed adequate for this study. This cut-off does not apply to readings taken during the day when the animals were inactive, evidenced by the non-modulating signals produced by their collars.

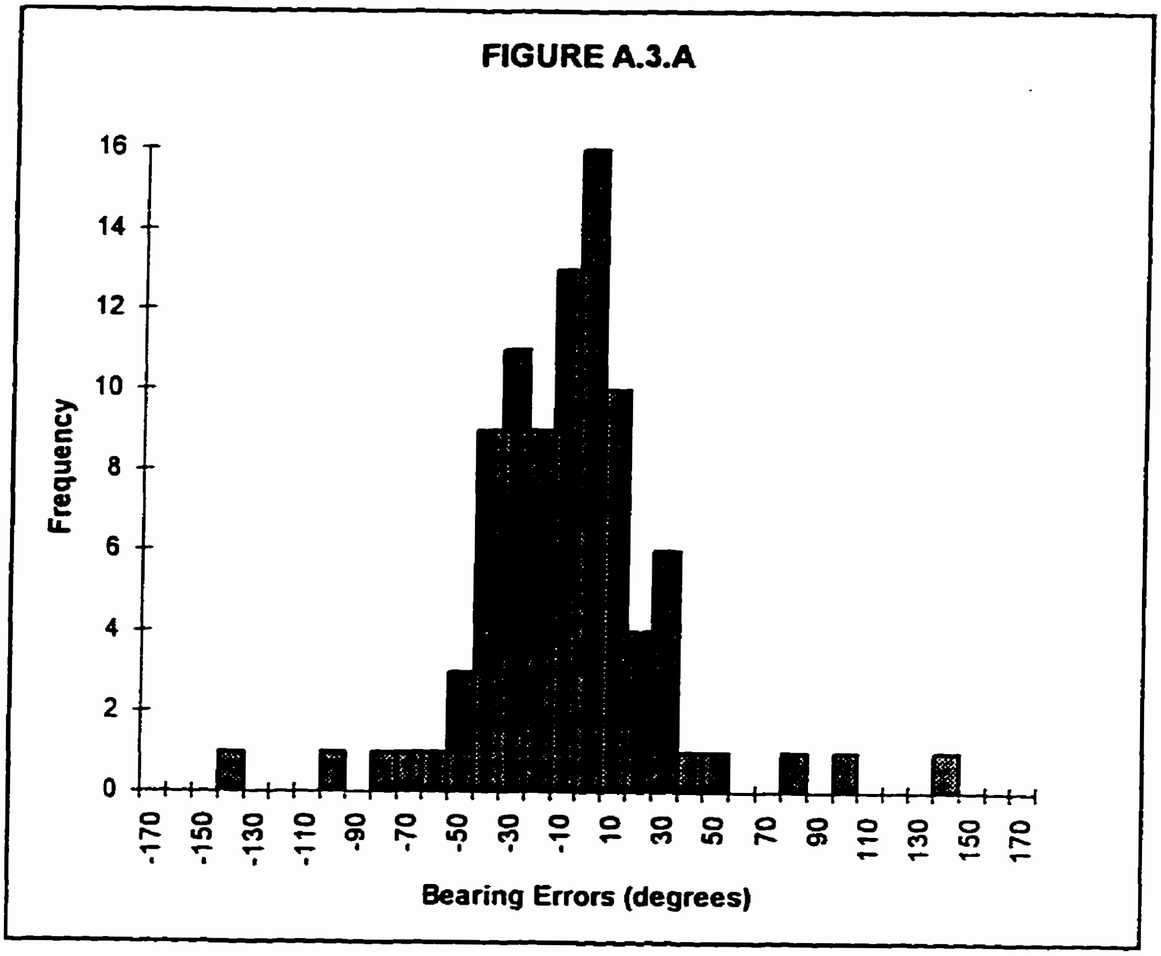


FIGURE A.3.A. Frequency histogram of bearing errors = estimated bearing minus actual bearing (°) from 23 different receiver sites to 24 different transmitter sites. N=91 pairs.

Appendix 3.B

RACCOON HOME RANGES

FIGURE A.3.B. Summer (June 15th to August 31st, 1995) and fall (September 1st to October 16th, 1995) locations and minimum convex polygon home ranges of raccoons feeding at a garbage dump 40 km north of Kingston, Ontario. Sample sizes are given in Table 3.1. Each symbol represents at least one location estimate. (Symbols which are overlapped by others are not visible.) Mean error associated with point locations is ±146.6 m (N=1110).

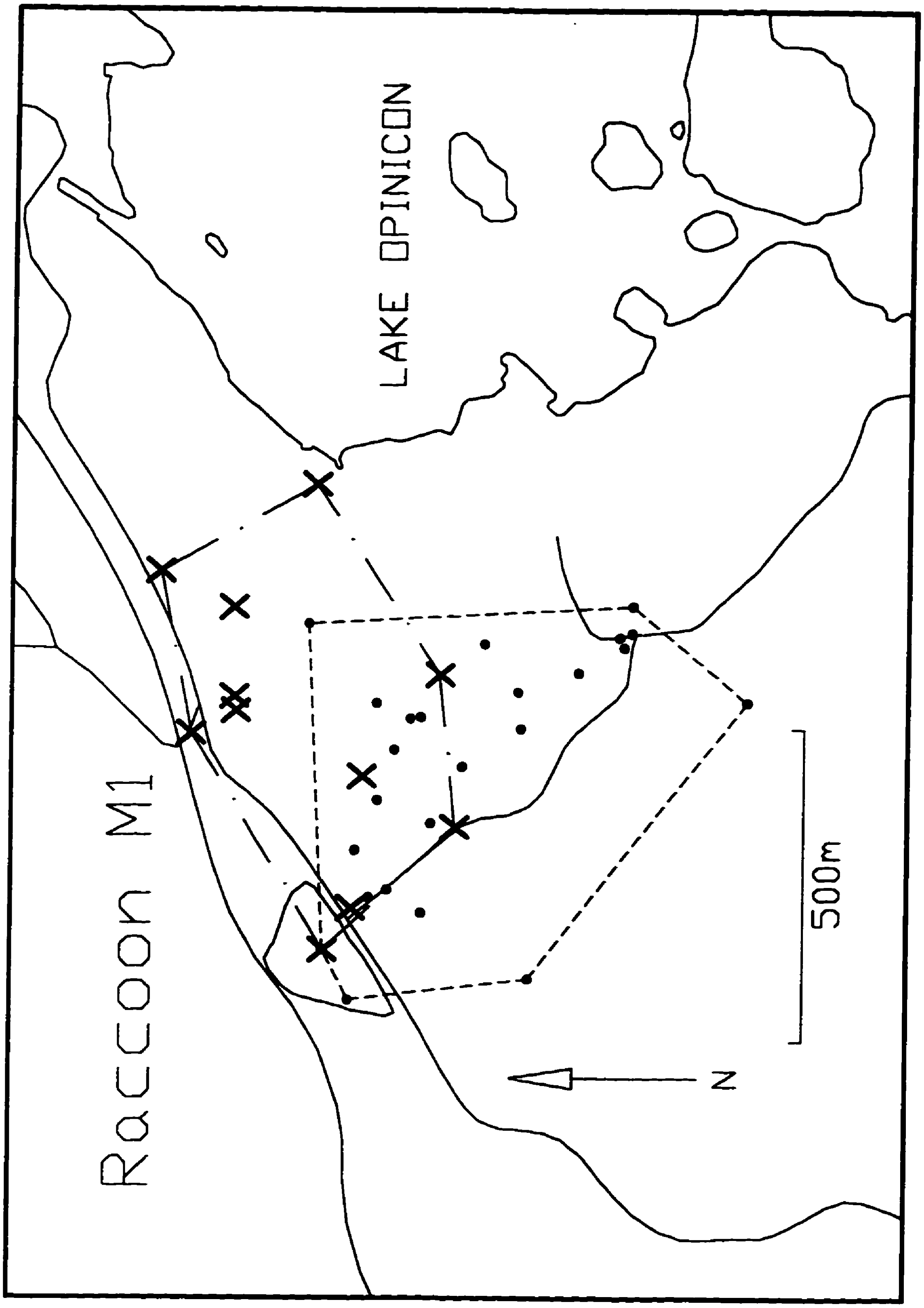
Legend

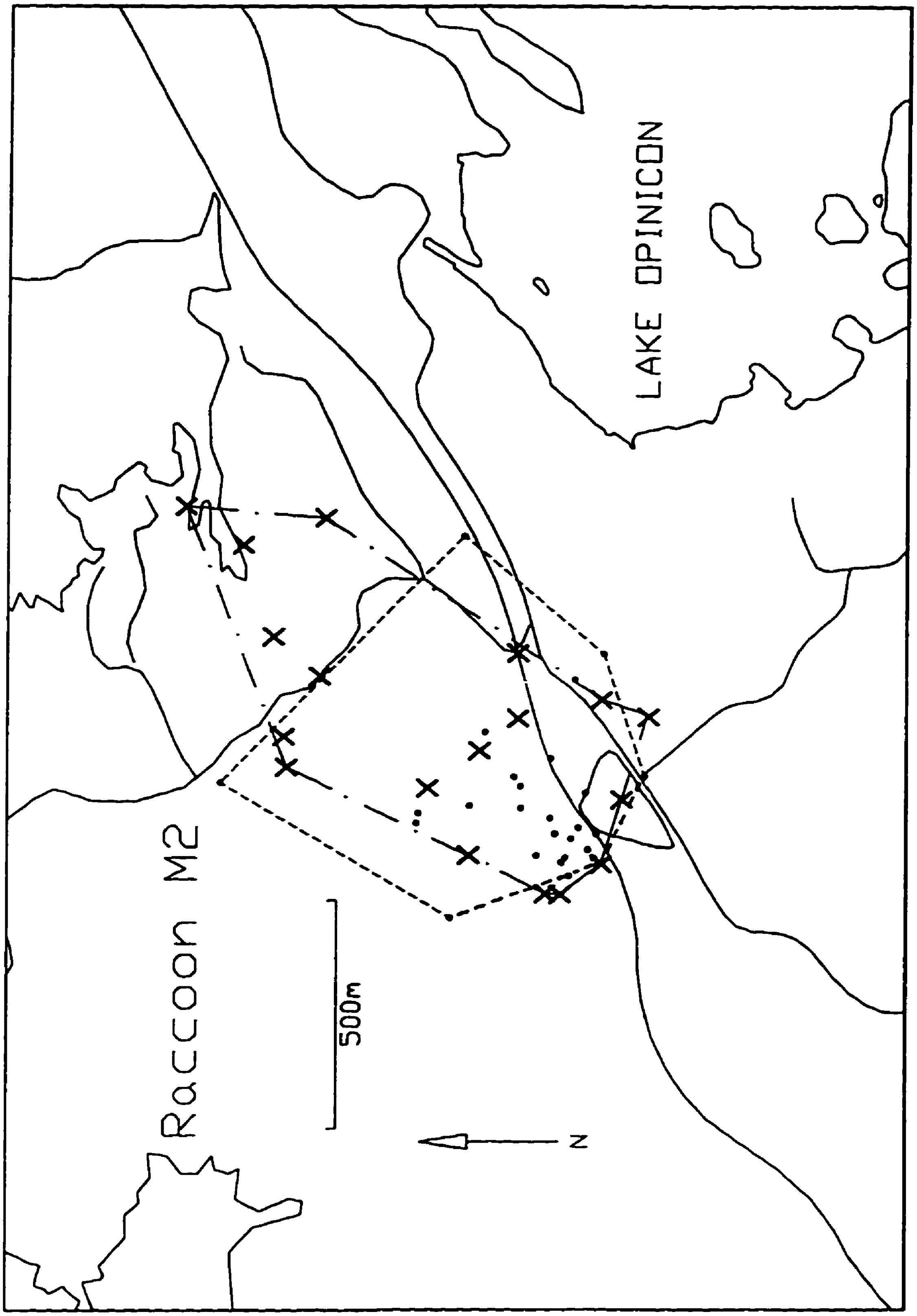
. = summer location

X = fall location

- - - - = summer home range boundary

.__.__.__ = fall home range boundary


LAKE OPINICON
Raccoon M1
500m
N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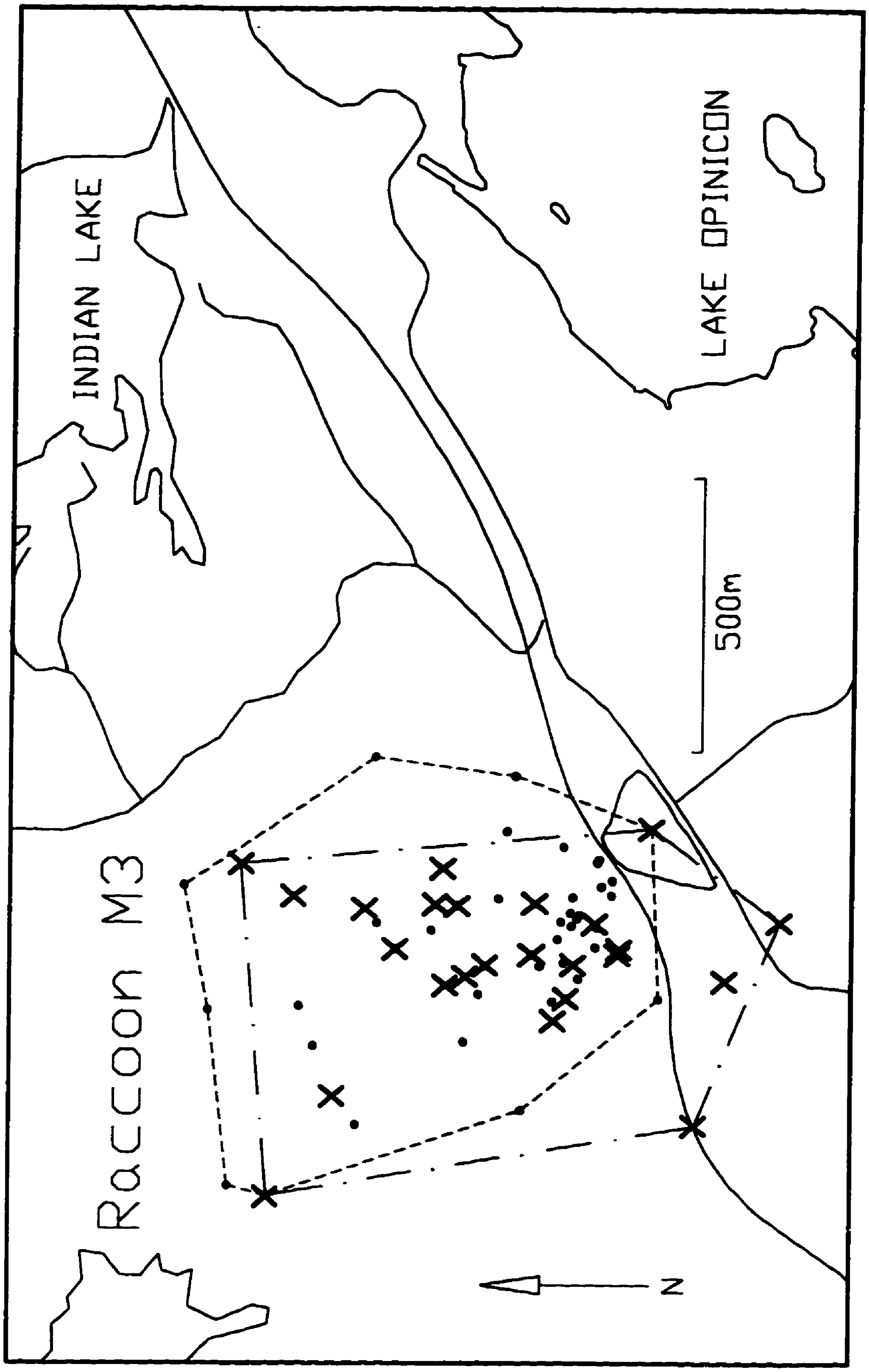
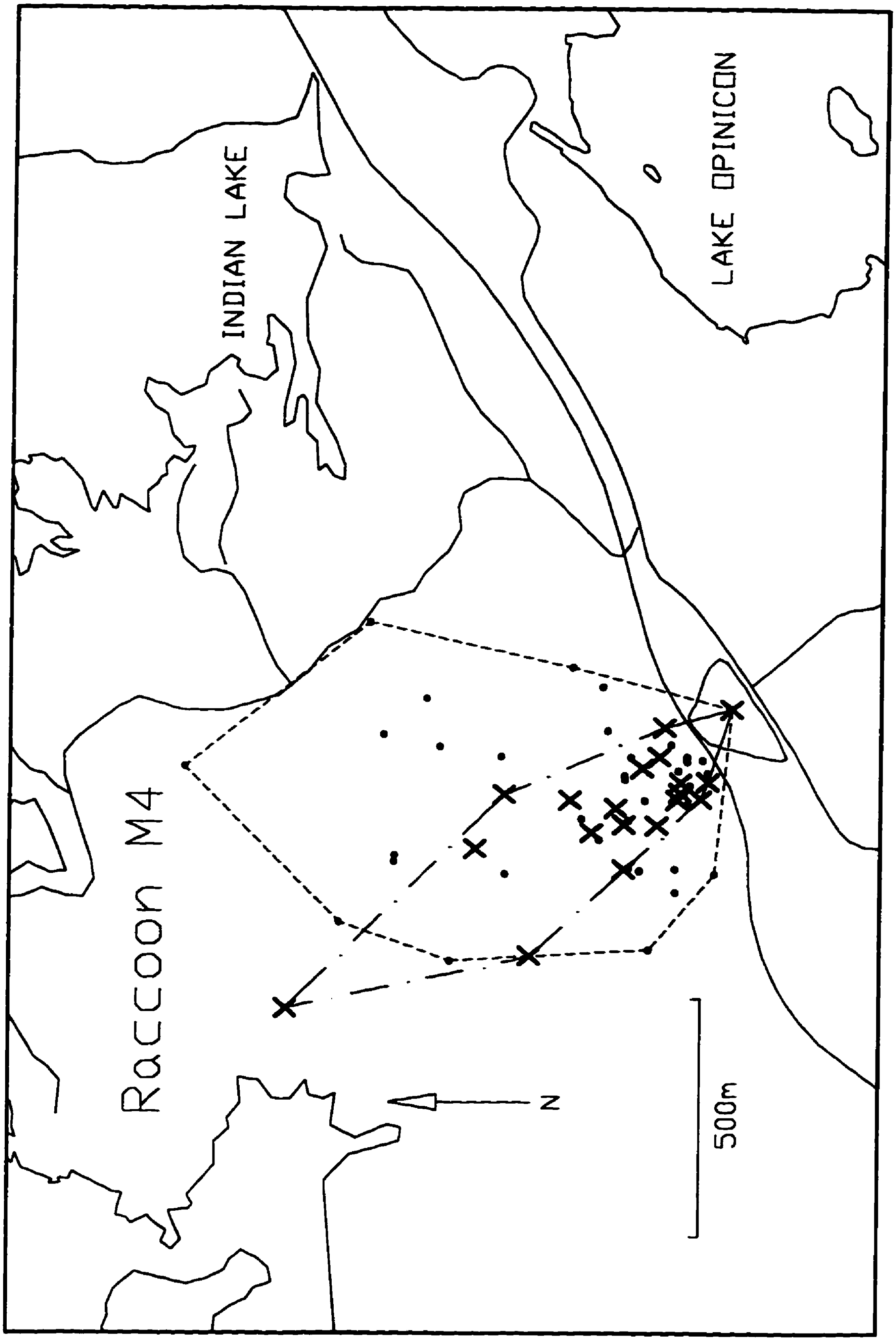
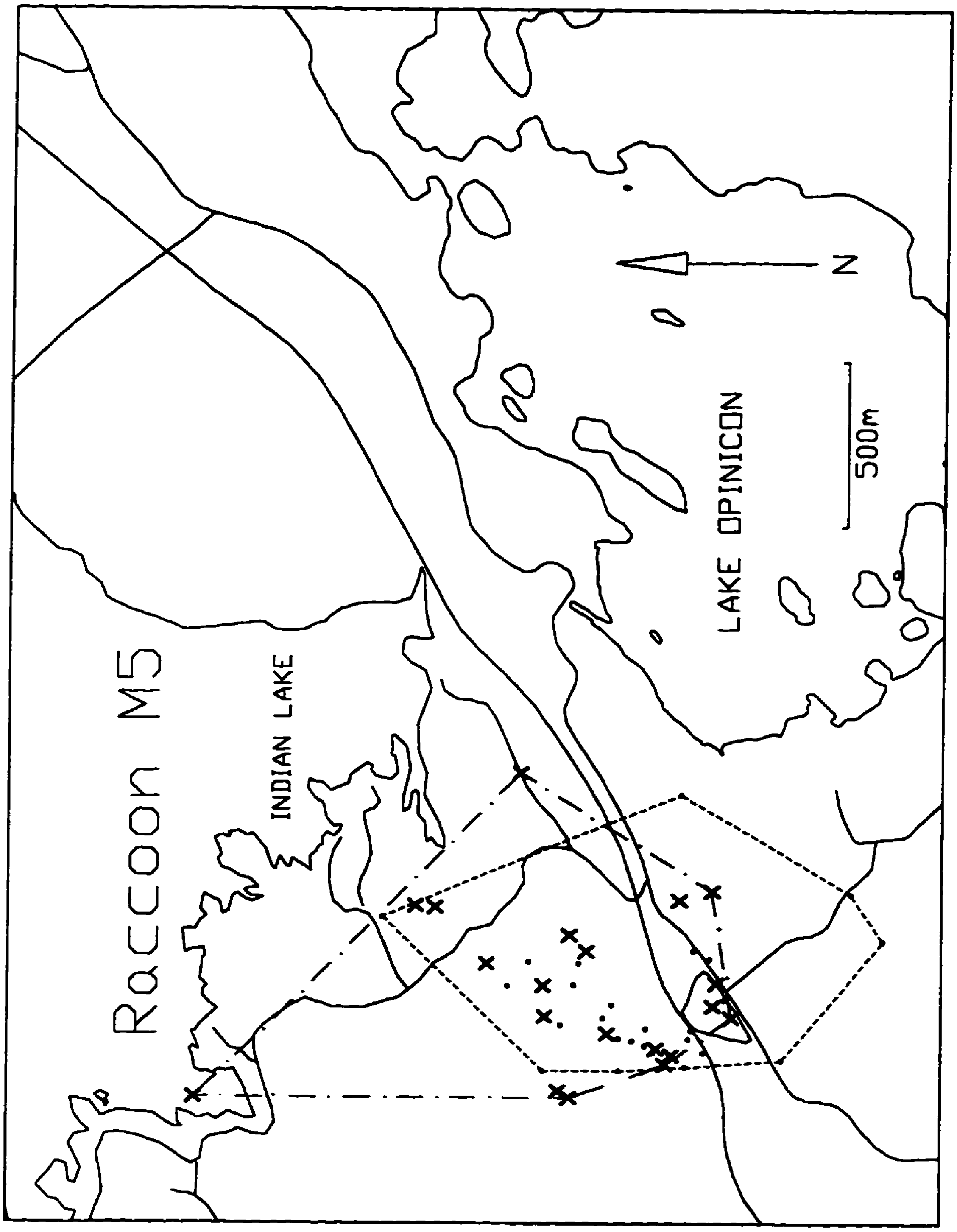
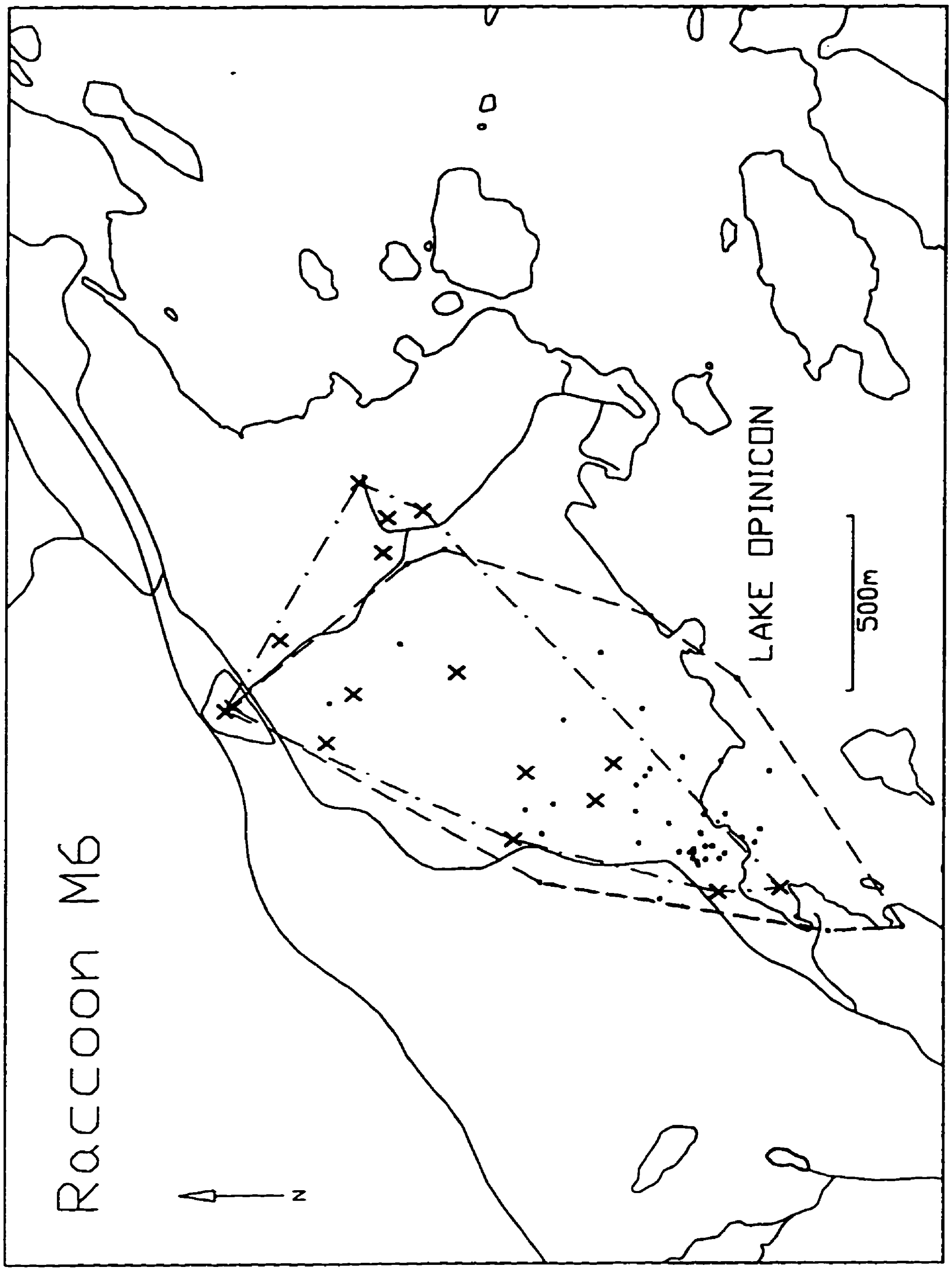
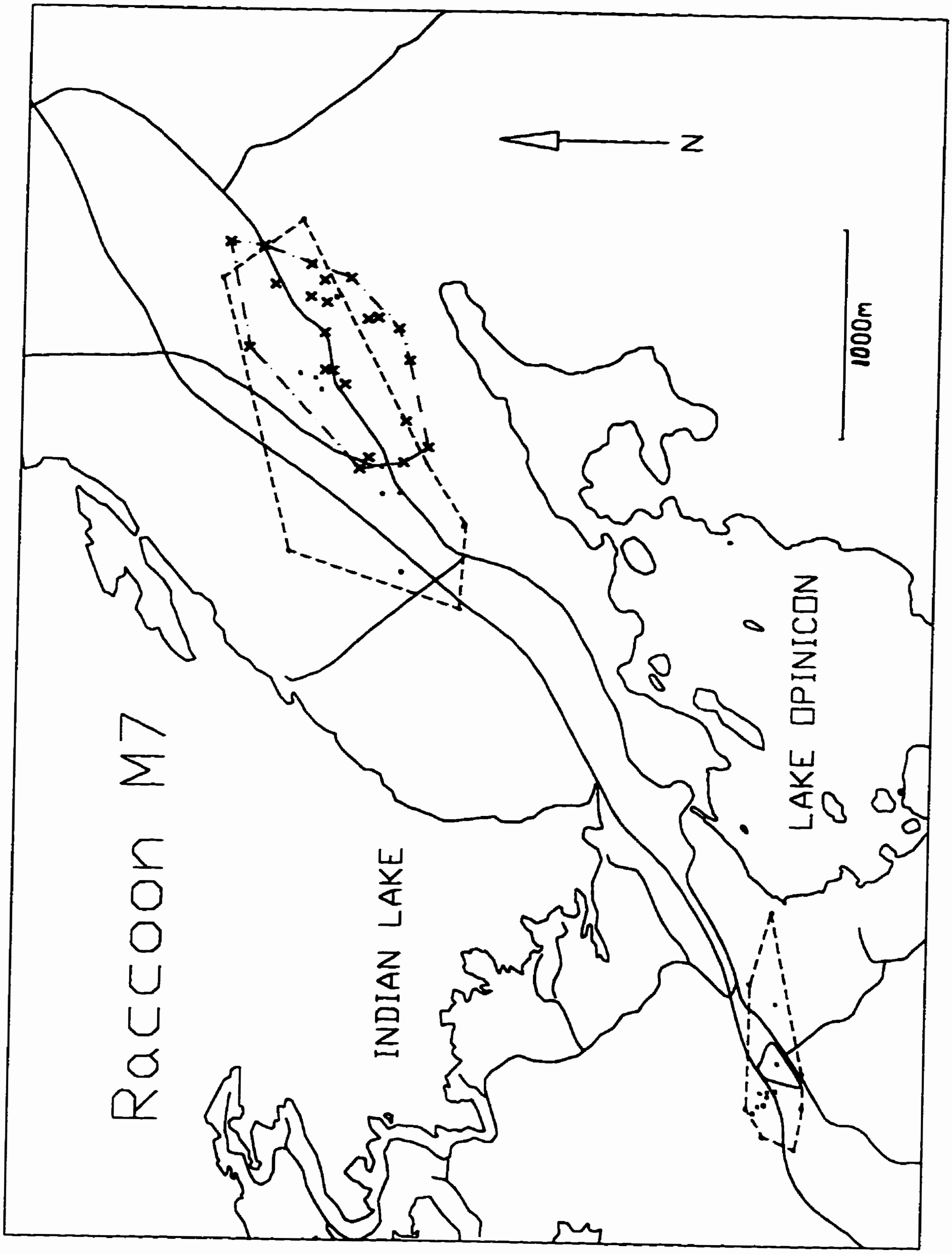
Raccoon M2
500m
N

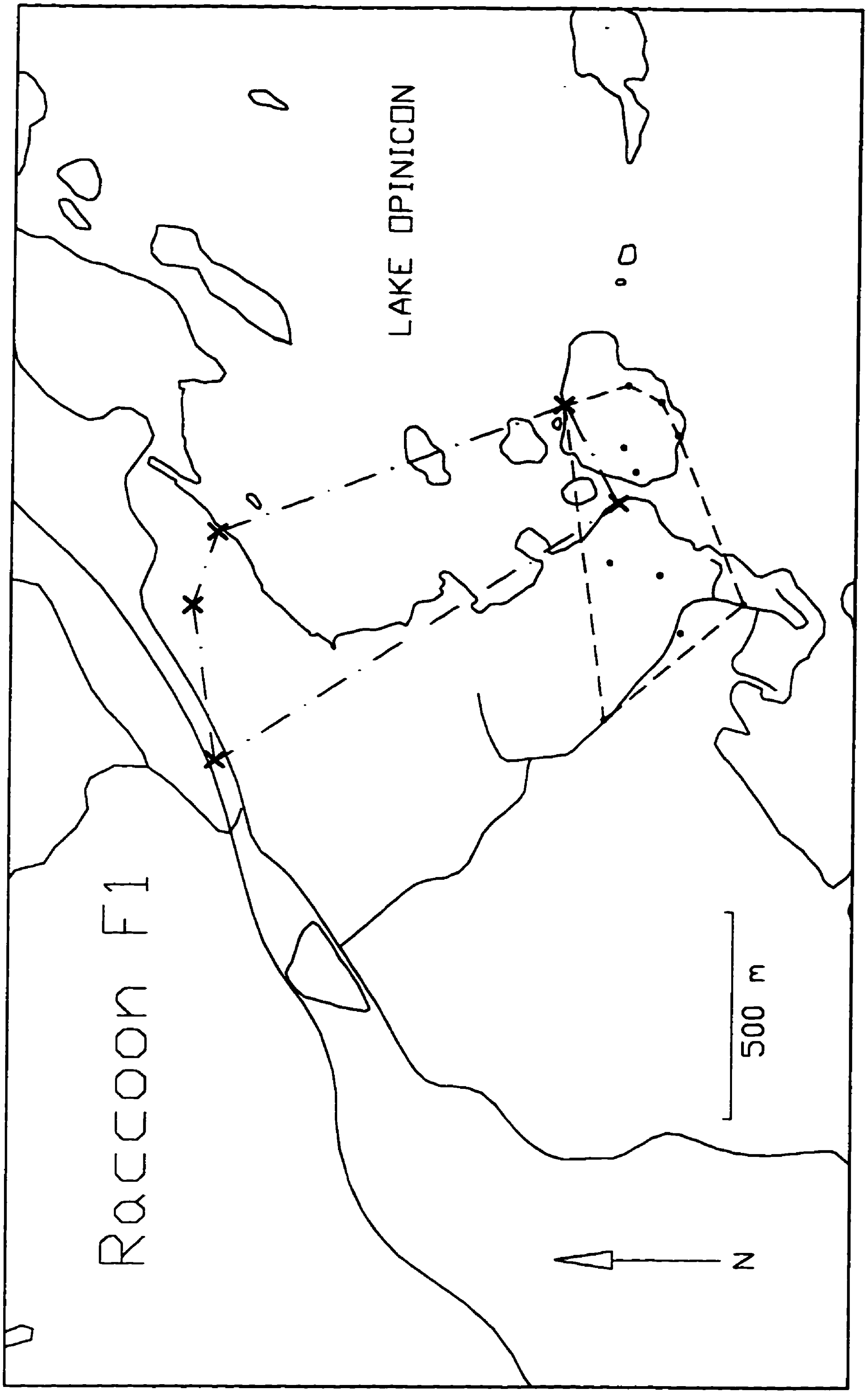

INDIAN LAKE
LAKE OPINICON
500m
Raccoon M3
N

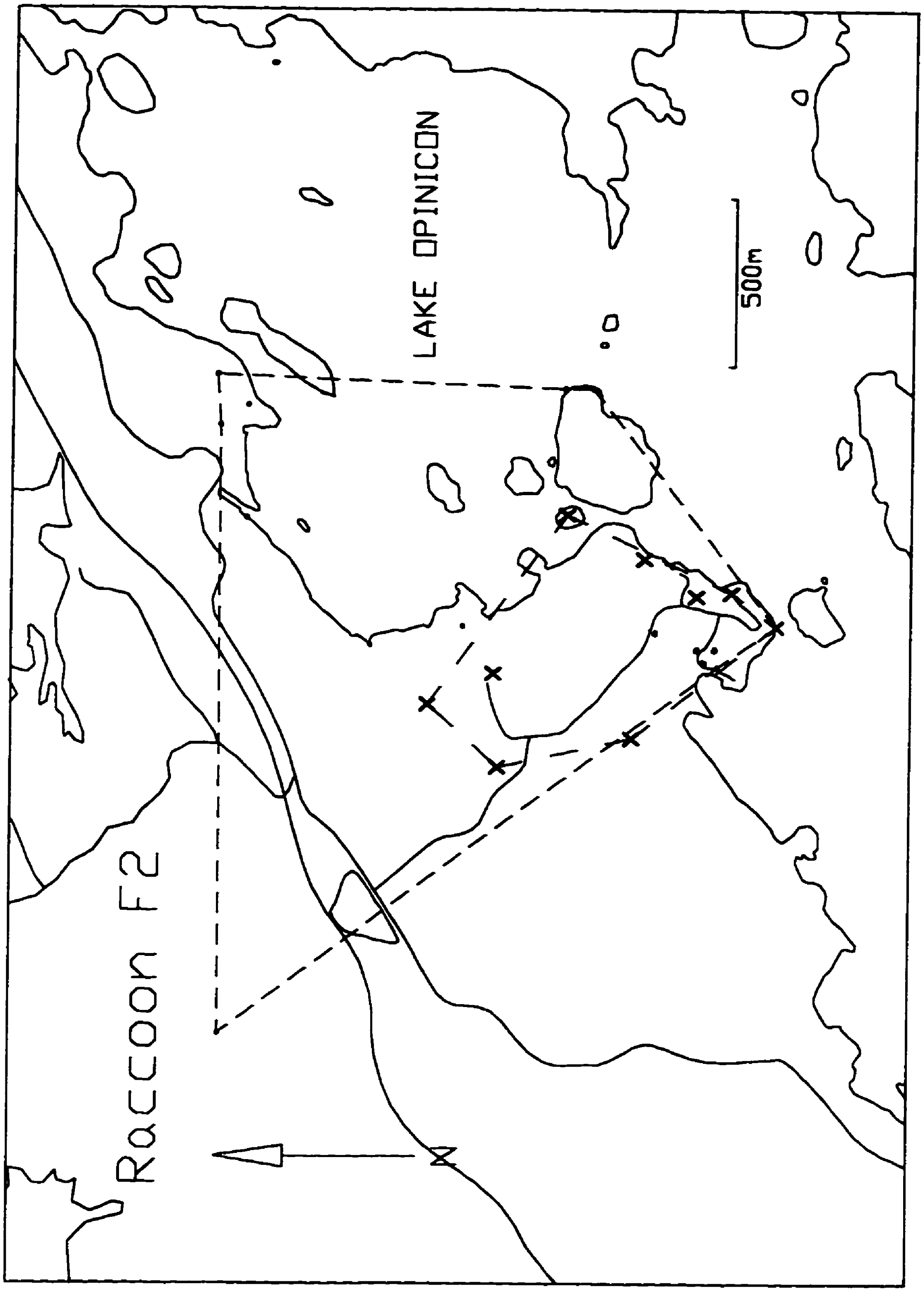

INDIAN LAKE
LAKE OPINICON
Raccoon M4
N
500m

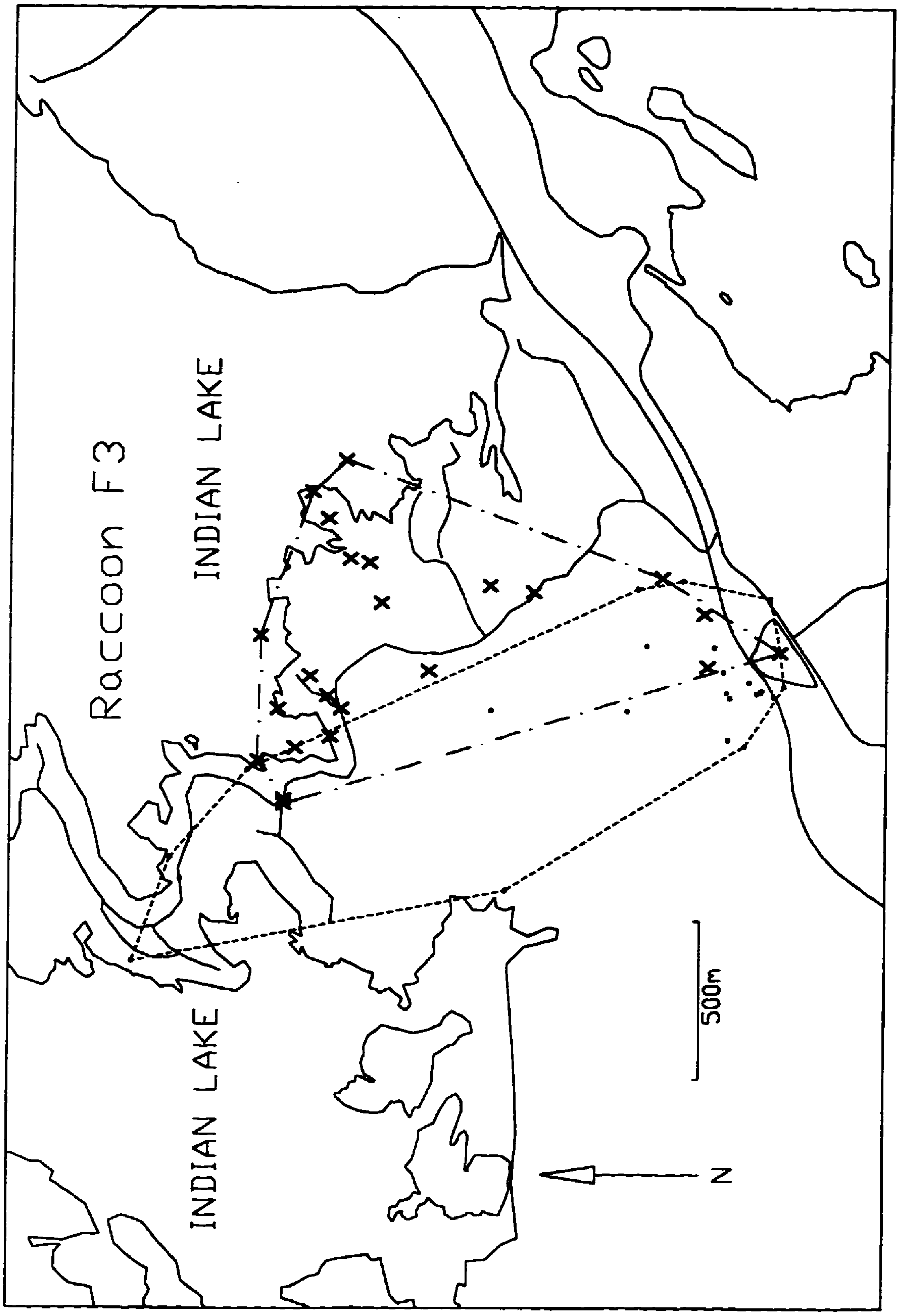

Raccoon M5
INDIAN LAKE
LAKE OPINICON
N
500m

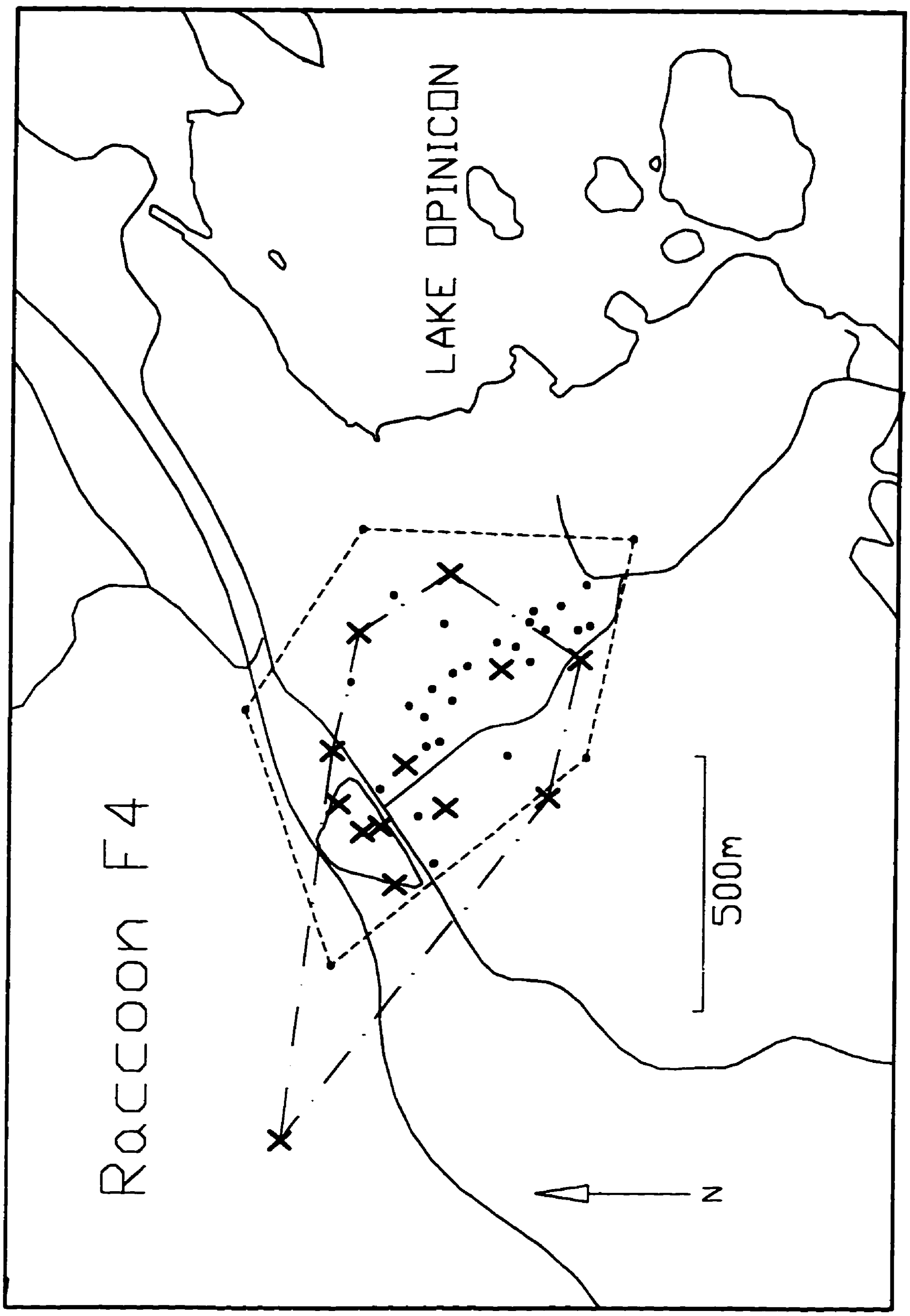

Raccoon M6
N
LAKE OPINICON
500m

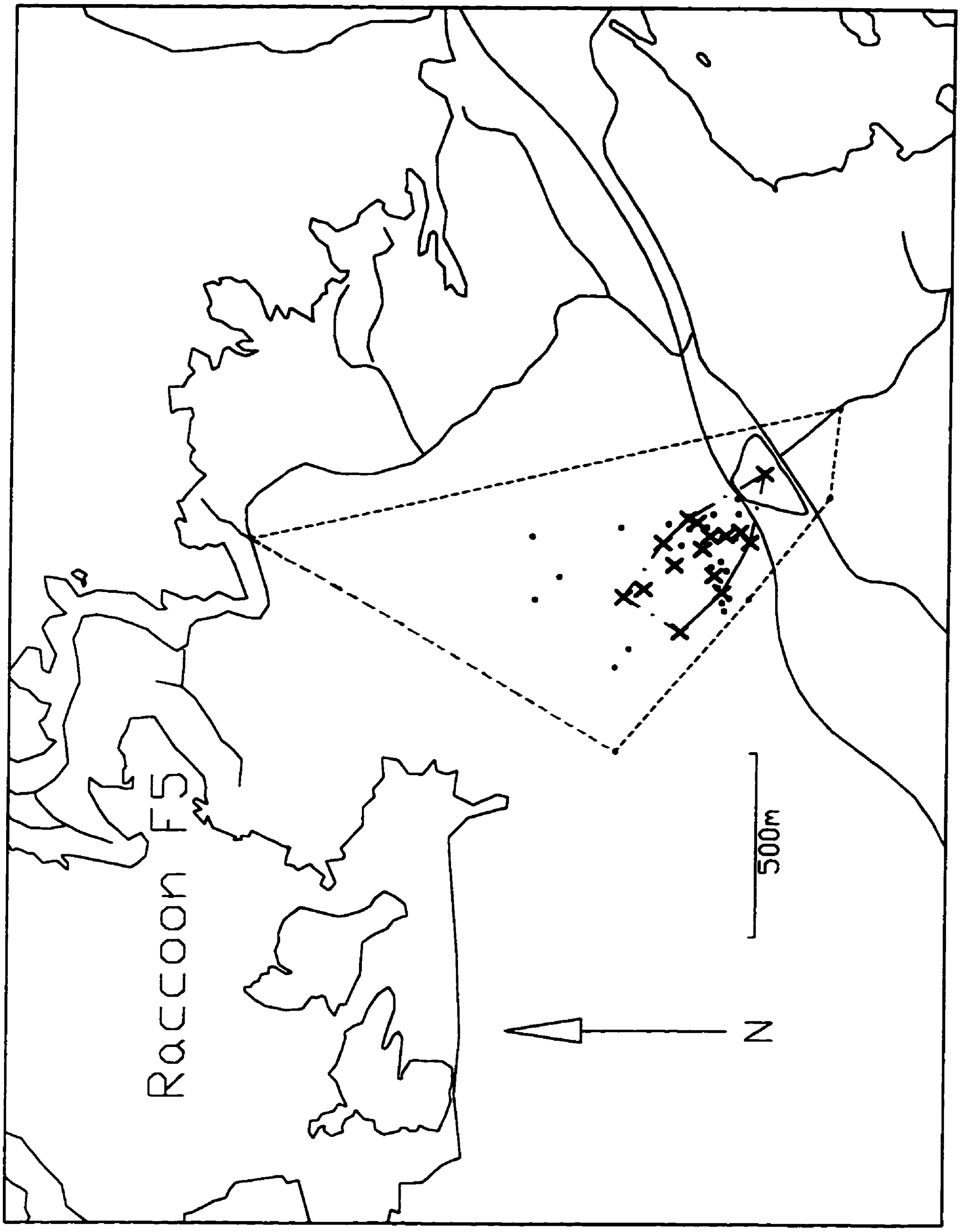

Raccoon M7
INDIAN LAKE
LAKE OPINICON
1000m
N

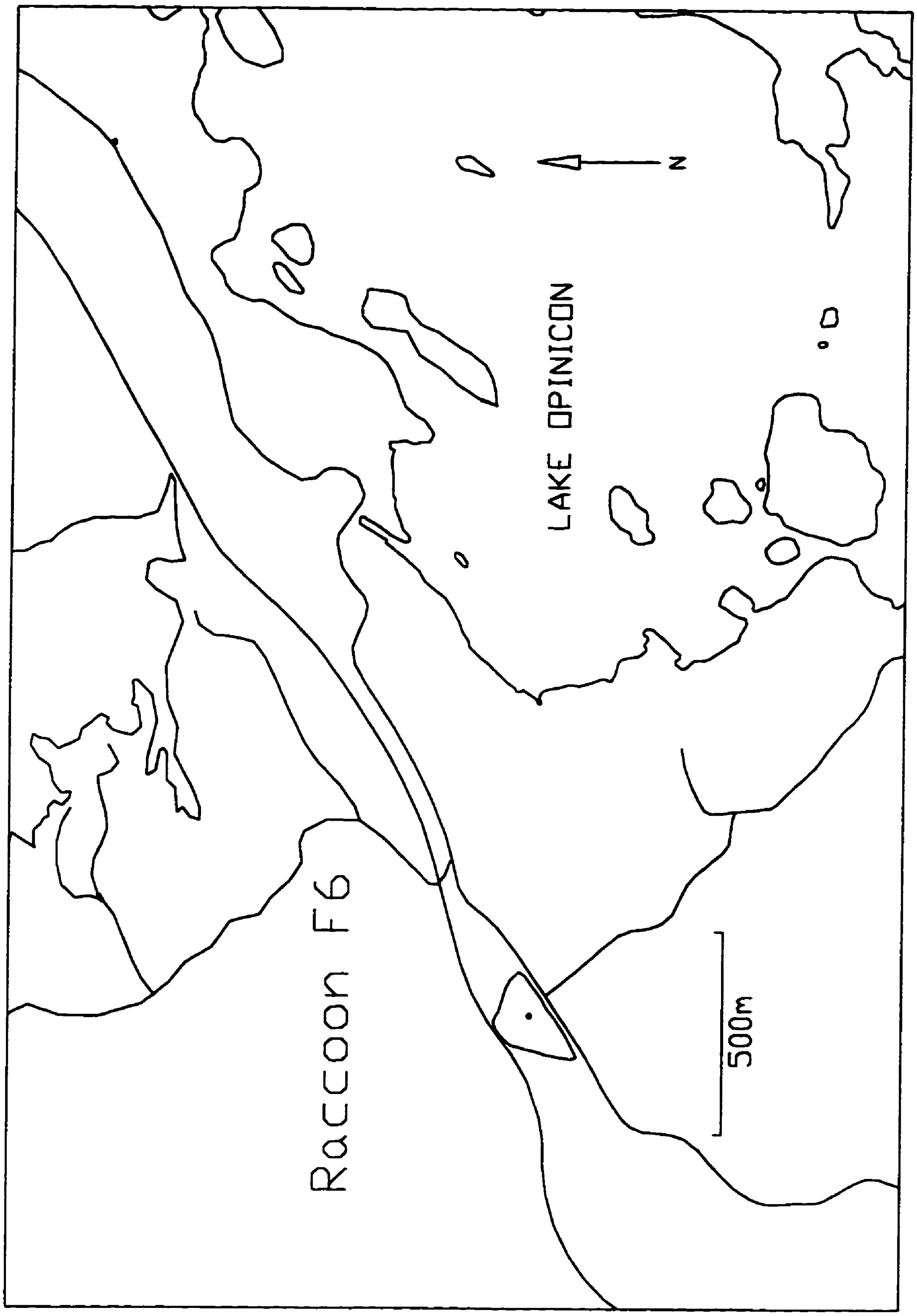

Raccoon F1
LAKE OPINICON
500 m
N

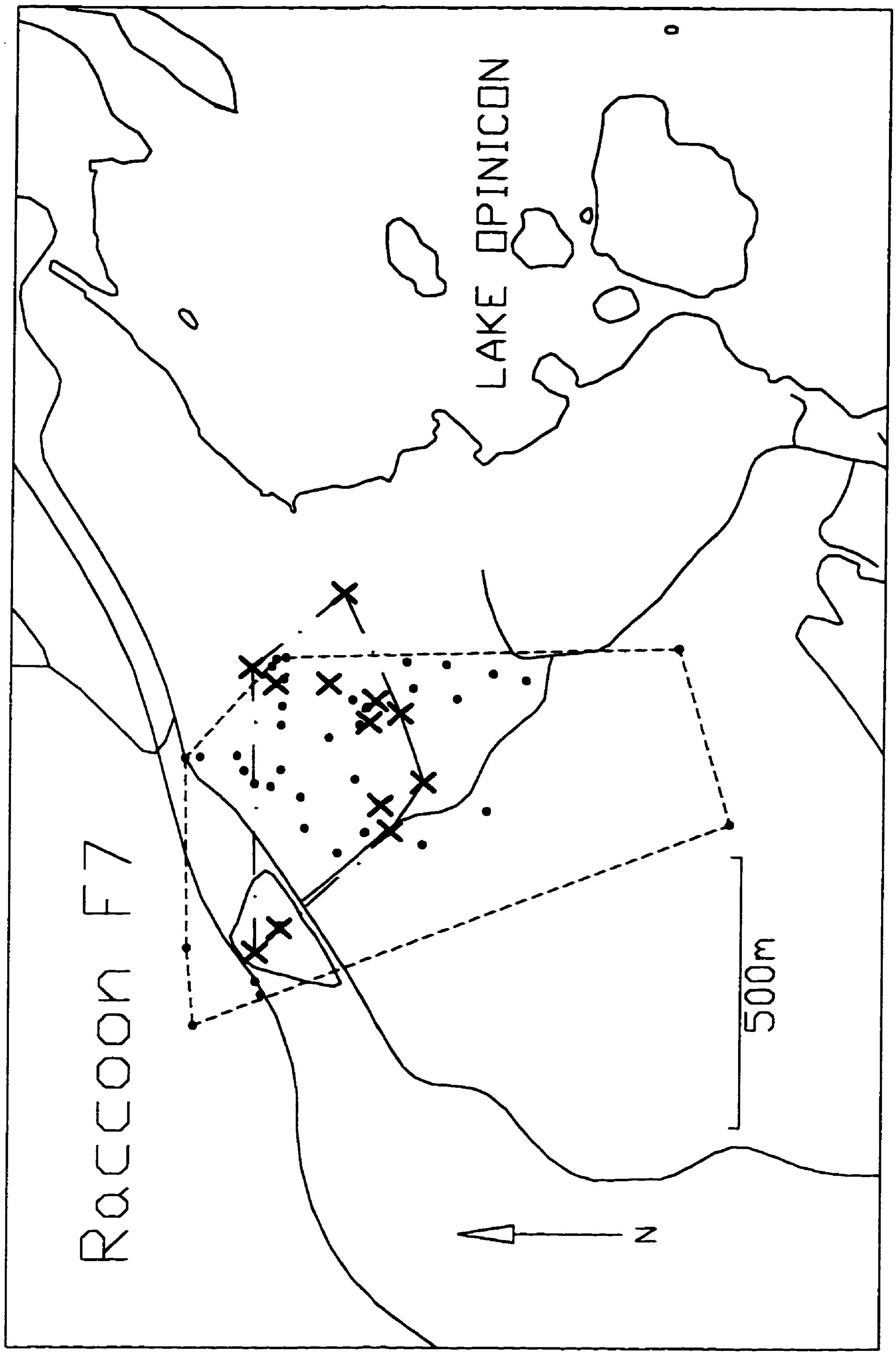

LAKE OPINICON
500m
Raccoon F2

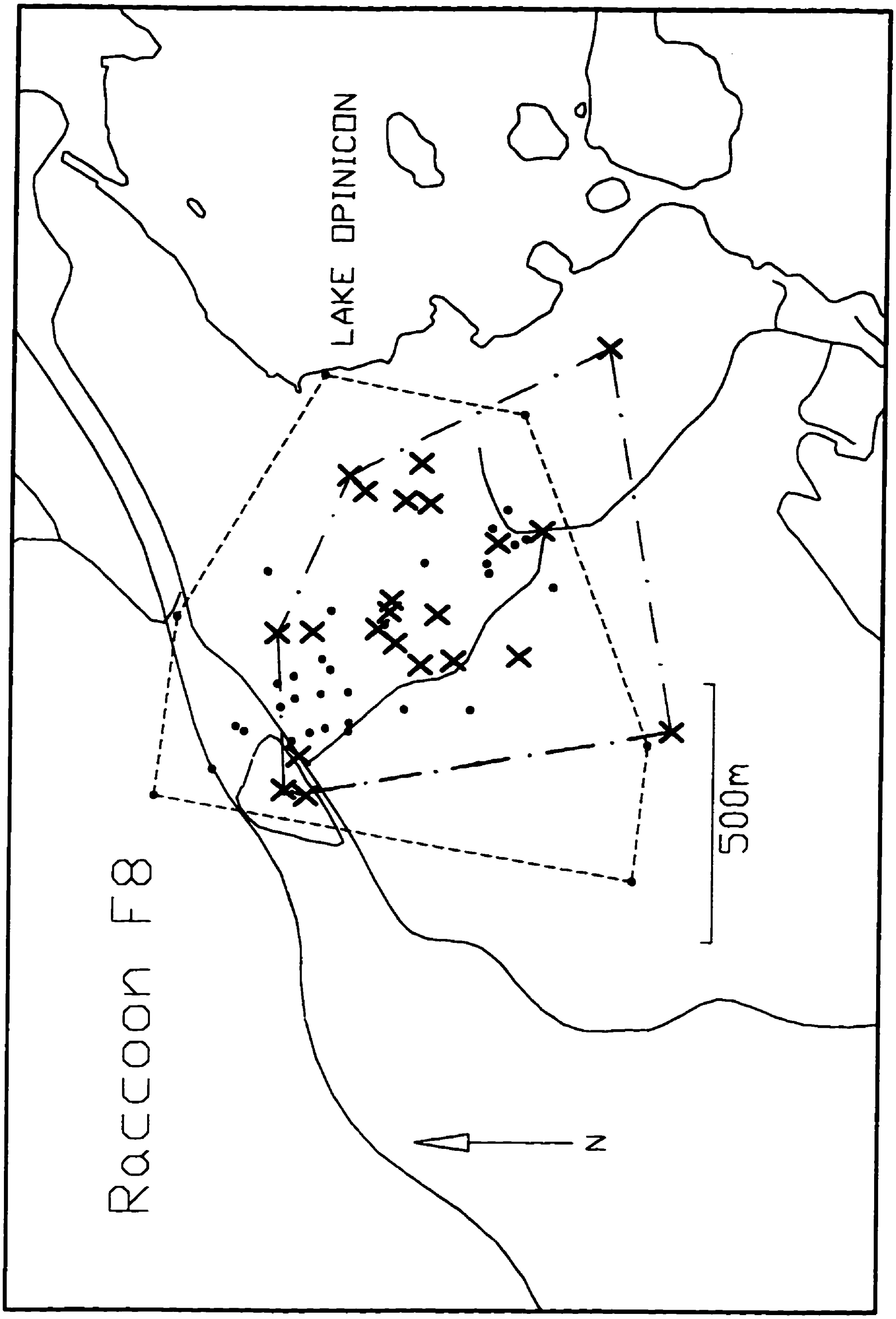

Raccoon F3
INDIAN LAKE
INDIAN LAKE
500m
N


LAKE OPINICON
Raccoon F4
500m
N


Raccoon F5
500m
N


LAKE OPINICON
N
Raccoon F6
500m


Raccoon F7
LAKE OPINICON
500m
N


Raccoon F8
LAKE OPINICON
500m
N