# Baseline data on the interactions of a population of white-tailed deer *Odocoileus virginianus*, eastern coyote *Canis latrans* var., and red fox *Vulpes vulpes* inhabiting a barrier beach ecosystem on Cape Cod, Massachusetts

A Senior Honors Thesis Presented

By

Jonathan G. Way

Submitted May 1996

APPROVED

Todd Fuller, Wildlife Conservation

Peter Auger, Biology, Boston College &
Museum of Comparative Zoology, Harvard University

Eric Strauss, Biology, Boston College

## Contents

**Acknowledgments**

I would first like to thank T. Fuller, P. Auger and E. Strauss for being the members of my guidance committee for this honors thesis. Their help, advice and guidance with any questions that I raised were vital towards the successful completion of this project. I would also like to acknowledge The University of Massachusetts at Boston and the National Science Foundation for the grant to make the first study (i.e., chapter 1) possible with funding. I am grateful to E. Strauss for being my sponsor for the first project (chapter 1) and for offering his insight to every question that I asked or for every task that I had to accomplish. I would also like to thank P. Auger for starting this research project and keeping it going so I had the chance to do this study. I also appreciate all of the help and advice that he gave me throughout the completion of the entire study. In addition, I am very fortunate and thankful to have T. Fuller as my Faculty Advisor. His knowledge and explanation of the accepted scientific writing format for journals will ultimately make these two studies publishable. Finally, I am grateful, and lucky, that the Sandy Neck Governing Board supports this project and I hope that they will keep supporting this type of research for as long as there are studies to be done on Sandy Neck Beach.

## Preface

This thesis is broadly titled "Baseline data on the interactions of a population of white-tailed deer *Odocoileus viginianus*, eastern coyote *Canis latrans* var., and red fox *Vulpes vulpes* inhabiting a barrier beach ecosystem on Cape Cod, Massachusetts", but there are two distinct parts with both falling under the general realm of this topic. I intended it to be in this form so both papers could be published individually. It will also aid the reader, because they only have to read the parts that they are interested in.

The field work for the first chapter, "White-tailed deer demographic response to recent range expansion of the eastern coyote on a Cape Cod barrier beach", was completed the summer after my freshman year (1994) at the University of Massachusetts at Amherst. The study was a result of an REU (Research Experience for Undergraduates) grant that I received through UMass-Boston and the National Science Foundation. The project was originally intended to be on white-tailed deer ecology, but my finding of an active eastern coyote den site on the study area enabled me to switch the focus of my study to include this member of the family Canidae. Radio telemetry and direct sightings were the principle means that I used to collect data for this project.

The following summer (1995) I originally planned on quantifying the effects that eastern coyotes were having on white-tailed deer. Unfortunately, coyotes were not as prevalent on the study site as the previous year, so I knew I would not obtain the results that I wanted if I pursued this topic. While I was searching for an active coyote den site, however, I managed to sight red foxes on the study site for the first time in over four years. This sequence of events enabled me to switch the focus of my study to what is represented as the second chapter, "Transect analysis of a population of red fox, eastern coyote, and white-tailed deer inhabiting a barrier beach on Cape Cod". This chapter makes a generalized account of the interactions and spatial dynamics that exists between these three species using track transects as my main method of gathering data. There was no funding for this project but I was able to complete the study on the side while I was also working as a full-time seasonal ranger on Sandy Neck Beach.

## Chapter 1

### White-tailed deer demographic response to recent range expansion of the eastern coyote on a Cape Cod barrier beach

Jonathan G. Way, Department of Forestry and Wildlife Management, University of Massachusetts, Amherst, MA 01003

**Abstract:** As part of both a long-term study of Lyme disease and a hunting management program at the Sandy Neck Barrier Beach system on Cape Cod, Massachusetts, demographic and behavioral data were collected from a small population of white-tailed deer (*Odocoileus virginianus*) during summer 1994. A total of 62 days was spent in the field, during which 392 hours of direct observational data were collected using radio telemetry (n=178), observation from blinds (n=124), tracking (n=49), observation of eastern coyote (*Canis latrans* var.) den sites (n=22), and evening spotlighting (n=19). Ninety-four white-tailed deer and 49 eastern coyotes were sighted on the study area. Population estimates, adult and juvenile movement patterns, and female reproductive success were determined using standard ethological techniques. Deer reproductive success averaged 1.5 fawns/breeding female. Most female deer remained faithful to a specific vegetated patch throughout the study period. Notable exceptions to this pattern occurred when an eastern coyote reproductive group (known to prey on deer) switched den sites and moved into a new vegetated patch on the barrier beach. The resident deer moved out of that patch and avoided the activity area of the coyotes. The resident deer population on the barrier beach was estimated to be 43 deer: 3 adult males, 14

reproductive females, 5 combined male and female yearlings, and 21 fawns. It is important to assess the predation of eastern coyotes on the local deer population before controlled hunting practices are designed and implemented.

**Introduction**

An overall study of a barrier beach ecosystem was initiated in 1975 by Dr. P. J. Auger which focuses on Lyme disease, the sometimes fatal and most common anthropod-borne disease of humans in the United States. The pathogen is a spirochete bacterium (*Borrelia burgdorferi*) which is transmitted in the northeastern United States by the deer tick (*Ixodes scapularis*; Bolen and Robinson, 1995). A maintenance host for the adult deer tick is the white-tailed deer (*Odocoileus virginianus*; Gill et al., 1993; Luckhart, 1992), but there is a paucity of information concerning white-tailed deer distribution, abundance and behavior on barrier beaches (O'Connell, 1989). Since ticks are more prevalent in broken habitat typical of deer country (Magnarelli et al., 1993), this study site makes for an ideal location to conduct this type of research. Basic natural history traits of deer can be examined in order to give insight into white-tailed deer ecology on a barrier beach. As a result, future studies of Lyme disease could possibly relate deer distribution and abundance to the overall disease system.

It is clear that regulating deer populations is likely to control the disease threat associated with Lyme disease. An interesting dilemma is the policy for deer removal (Smith and Coggin, 1984; Ellingwood and Caturano, 1988). Proper management using hunting as a regulating mechanism is complicated in this instance because of the recent addition of a large predator, the eastern coyote (*Canis latrans* var.), to the study site (first documented in 1992). Coyotes, known to prey on deer, were studied in summer 1994 in order to examine the effects that they have on deer and to question whether human-related hunting of deer is needed in such a system.

**Study Area**

The Sandy Neck study site lies in a conservation area owned by the town of Barnstable on Cape Cod, Massachusetts (Figure 1). It is approximately 10 km long and consists of six distinct upland maritime forested areas. The western part of the ecosystem, designated Patch 1, has the oldest plant community on the study site; scrub oak (*Quercus ilicifolia*) dominates the area. Meanwhile, the relatively recent formation of the plant community on the eastern part of the study site (i.e., Patch 6) consists of pitch pine (*Pinus rigida*) and many small-sized (<1 hectare) swamps. The eastern portion of the study site is characterized by large contiguous tracks of forest compared to the more fragmented western end. Redfield (1972) conducted a classic geological ontogeny study of the area, going to great lengths surveying the natural history of this region.

In areas devoid of forest, sand dunes covered with dune grass (*Ammophila breviligulata*) exist. Cranberry bogs (*Vaccinium macrocarpon*) are common in the swale areas of the study site. Shrubs such as northern bayberry (*Myrica pensylvanica*), beach plum (*Prunus maritima*), blueberries (*Vaccinium* spp.), and poison ivy (*Rhus radicans*) are also present in this fragmented landscape.

The study area connects to the mainland at the western end of the barrier beach and via the Great Marsh (an estuary adjoining Barnstable Harbor), which encompasses 32.4 $km^2$. There are many creeks and gullies in the estuary which provide a formidable barrier for land mammals going to the mainland due to extremely irregular terrain and tidal activity.

There is a vehicle trail on the beach front and the marsh edge, of which both run west to east. There also are four dirt vehicle trails that run north to south, which are equidistant from each other, connecting the beachfront and marsh sides of the beach.

**Methodology**

Access to the various areas of the study site was accomplished through the use of a four-wheel-drive vehicle. During previous work on the study site, seven deer were trapped in clover box traps or darted from tree stands and fitted with radiocollars (unpubl. field data). Two of the collared animals were bucks (males) while the remaining five (of which only three gave off signals) were adult does (females). The deer were named to aid individual identification. The two bucks were called Muck and Muff, the three does with functioning collars were called Fring, Pin and Filt and the does with non-functioning collars were Fax and Tack.

Due to the secretiveness of white-tailed deer and eastern coyotes, a variety of techniques were used to collect data in order to describe their activities. Radiomonitoring of the five functioning (seven in all) deer collars enabled marked deer to be located and individually identified by using a 3-element Yagi antenna (Nelson and Mech, 1992; Fuller, 1990). Standard telemetry techniques were followed, as suggested by Bookhout (1994). In order to follow each collared deer's movement over time, a general location, or quadrant was assigned (Figure 1), showing where each deer was at the time of the readings. This was done effectively because a four-wheel-drive vehicle could easily access each part of the beach in order to find a specific deer's location.

In addition, the collared deer were occasionally walked in on (tracked) using the radiotelemetry equipment. This was done in order to see if other animals (e. g., fawns) were present with them.

Five blinds (little sheds to sit in and observe the surroundings) were permanently stationed on top of dunes at the edge of patches. They provided the opportunity to directly observe the animals without disturbing them. A few of the sites were baited with apples and water throughout the summer in order to try to influence deer and coyotes to come out into the open more often. A video camcorder and two 35-mm cameras were used to record field observations while sitting in blinds. Since deer and coyotes are primarily crepuscular (active at dawn or dusk), stays in blinds were limited to coincide with these times of the day.

Spotlighting was also used to directly observe coyotes and deer. An intense spotlight (1,000,000 candle power), powered by a vehicle's cigarette lighter, was used effectively, because the vehicle trail system covers a large portion of the study area.

I observed behavior of coyotes at den sites. Using the techniques of tracking (following actual coyote tracks) and howling (once the general location of the coyote den site was known), a directed search was conducted to find coyote dens. Identification of coyote tracks followed descriptions from Stokes (1986). In addition, Gaines et al. (1995) and McCarley (1975) described how to effectively howl to coyotes and gray wolves. Direct observation of coyotes included sitting in a tree or on the ground with a 35-mm camera or a video camcorder and quietly observing the interactions of pups.

A chronological record of activities (e.g., initiation and termination of observations, deer and coyotes sighted, time and location of observation) was kept (Fuller et al., 1995). From these data, the total number of deer and coyotes sighted, estimated deer reproductive output, summer adult deer distribution by patch, and a total deer population estimate on the study site were made.

In order to predict the number of reproductive does and yearlings on the study site, an intense examination of the data from summer 1994 was conducted. The number of collared deer sighted was compared to the total number of deer observed on the study site. A reasonable estimate as to the number of deer per patch was made through the use of the chronological record kept of every individual deer sighted at a particular location during the course of the summer.

The total deer population estimate for Sandy Neck was extrapolated using the information from the patches and the estimate of the mean number of fawns of radiocollared females. That number was then applied (1.5 fawns/female) to the total number of does on the beach assuming that all of the fawns survived (i.e., no coyote predation). It was estimated (from past sighting data) that only three adult males will migrate from the mainland back onto the beach for the mating season.

**Results**

A total of 62 days and 392 hours were spent observing the animals directly or indirectly during summer 1994 (Figure 2), in which 49 eastern coyote and 94 white-tailed deer sightings were made. Many of these sightings were of individuals of both species seen previously. During the summer, a rise in the number of deer sightings in July (Figure 3) was attributed to increased fawn mobility. A sighting with numerous coyotes for a specific day (Figure 4) was the result of sighting the 5 pups that were present at a located den site on the study area.

The reproductive output of radiocollared females averaged 1.5 fawns per female (Table 1). Fax and Tack did not have functioning collars and thus were not positively distinguishable. At least one of them was sighted with two fawns so in order to avoid counting one of them twice they were represented as one deer.

No adult male deer (bucks) were sighted during the entire summer on the study site. Furthermore, the two radiocollared males left the beach for the majority of the summer presumably because of better forage available on the mainland. Previous data indicate that they will come back onto the study area for the mating season during the fall (unpubl. field data).

There was an estimated population of 14 reproductive does and 5 combined male and female yearlings on the study site during summer 1994 (Figure 5). Each radiocollared doe tended to remain faithful to a patch of vegetation throughout the study period. An exception to this pattern occurred when an eastern coyote family moved to Patch 5 on August 4. The resident deer moved out of the patch that the coyotes frequented and no sightings of deer from that area were made during the rest of the study period.

The number of deer by age and sex class was estimated to be 3 adult males, 14 reproductive females, 5 combined male and female yearlings and 21 fawns. Thus, the total population estimate of deer on Sandy Neck was made to be 43 individuals, assuming no deer mortality (Table 2).

**Discussion**

The large amount of data collected using radiotelemetry from the five transmitting deer was used merely to individually identify deer. This made it possible to use the ratio of collared deer observed to the total number of deer observed in order to come up with approximate population estimates. Mark Buckler (a graduate student at UMass-Boston) is working on a GIS program and will incorporate the home range data collected from this study into his project.

It should be stressed that the estimated population sizes for white-tailed deer were maximum estimates. For example, although Pin was almost always seen alone, she was sighted once with a fawn. Although coyotes could have killed her fawn, it was still included in the estimate. In addition, the deer estimate per patch and for the entire study area could be high. Deer are very mobile and though the radiocollared does generally remained faithful to a particular patch, some could have easily moved into different patches. For instance, although Filt mostly inhabited Patch 6 she was located in Patch 5 several times.

The reason for the low number of yearlings on the study area is twofold. First, they may leave the beach, as do the bucks. With more forage on the mainland, yearlings may obtain the nutrition that they need during the summer on the mainland. Second, and most importantly, coyotes have preyed heavily on fawns and yearlings, presumably because they are, on average, easier to kill than adults. The past winter (1993-94) was very harsh and coyotes may have culled the less fit individuals from the herd.

Noticeable increases of deer occurred from 1982 to 1988 (Figure 6) because there was no controlled human hunting on the study site. The next year deer were rarer on the study area because of a regulated harvest that occurred. The number gradually increased to about 32 in 1993 and once the population is stable (i.e., before next breeding season) I predict that it will number about 30. This includes taking the predation of coyotes on juvenile and adult deer into account, because since 1992, when coyotes first were documented on the study area, the deer population has remained stable even without human hunting.

It was surprising how few deer there actually were on the study site. Given the growth potential of a population of non-hunted deer (Gotelli, 1995), the population was expected to increase much quicker than it has in the past six years.

The literature indicates that coyotes are known to prey on deer fawns (Harrison and Harrison, 1984; Nelson and Woolf, 1987; Hamlin et al., 1984). MacCracken (1984), Andelt et al. (1987), O'Gara and Harris (1988), and Toweill and Anthony (1988) found that coyotes can, and will, prey on juvenile and adult deer under appropriate conditions. In addition, Springer and Wenger (1981) noted that coyote population levels can affect the amount of predation on deer. Nothing, however, has been published on eastern coyote/white-tailed deer interactions on a coastal environment like Cape Cod. I feel that this is an important area for more study of coyote/deer interactions because the open, fragmented habitat, typical of this type of ecosystem, appears to make deer vulnerable to coyote predation.

In other habitats, coyotes may not effect deer numbers as much as they do on this study area. We have reason to believe that they cooperatively hunt deer. Track analysis in the sand and snow has shown instances of two or more coyotes bringing down deer (unpubl. data). Furthermore, no deer were sighted coming out of Patch 5 when the coyote family moved there on August 4. It was clear from this event that deer apparently were avoiding coyotes. In addition, a direct sighting was made of a coyote chasing an adult deer out of Patch 5 before the coyotes settled in there. No direct observations were made of coyotes killing deer during the summer of 1994, and thus, it was not clear as to how much predation coyotes were actually inflicting on deer. However, five deer carcasses were found during fall 1992 - spring 1994 and were presumed to have been killed by coyotes based on track and scat analysis.

**Conclusions**

It is important to more empirically assess the predation of coyotes on the local deer population on the study site before any human hunting is allowed. If padded leg-hold traps are legalized in Massachusetts, coyotes could be captured and subsequently radiocollared. With the general public concerned that eastern coyotes now populate all of Cape Cod and are dangerous to humans, there has never been a better time to shed light on an important predator species that lives in close proximity with humans. In addition, the results from these studies could be valuable for the Massachusetts Department of Fish and Wildlife. It will enable them to base their models for deer hunting quotas with empirical evidence of natural predation (i.e., not human caused) on deer. This will hopefully help them more accurately reach their desired level of deer harvested in each management zone throughout the state.

**Literature Cited**

Andelt, W. F. 1987. Variation in coyote diets associated with season and successional changes in vegetation. J. Wildl. Manage. 51: 273-277.

Bolen, E. G. and W. L. Robinson. Wildlife ecology and management. Third ed. Prentice Hall, Englewood Cliffs, New Jersey. 620pp.

Bookhout, T.A., Editor. 1994. Research and management techniques for wildlife and habitats. Fifth ed. The Wildlife Society, Bethesda, Md. 740pp.

Ellingwood, M. R. and S. L. Caturano. 1988. An evaluation of deer management options. New England Chapter of the Wildlife Society. 12pp.

Fuller, T. K. 1990. Dynamics of a declining white-tailed deer population in north-central Minnesota. Wildl. Monogr. 110: 1-37.

Fuller, T. K., T. H. Nicholls and P. W. Kat. 1995. Prey and estimated food consumption of African wild dogs in Kenya. S. Afr. J. Wildl. Res. 25: 106-110.

Gaines, W. L., G. K. Neale and R. H. Naney. 1995. Response of coyotes and gray wolves to simulated howling in north-central Washington. Northwest Science. 69: 217-222.

Gill, J. S., R. C. Johnson, M. K. Sinclair and A. R. Weisbrod. 1993. Prevelence of the Lyme disease spirochete, *Borrelia bungdorferi*, in deer ticks (*Ixodes Dammini*) collected from white-tailed deer (*Odocoileus virginianus*) in Saint Croix State Park, Minnesota. J. Wildl. Dis. 29: 74-72.

Gotelli, N. F. 1995. A primer of ecology. Sinauer Associates. 206pp.

Hamlin, K. L., et al. 1984. Relationships among mule deer fawn mortality, coyotes, and alternate prey species during summer. J. Wildl. Manage. 48: 489-499.

Harrison, D. J. and J. A. Harrison. 1984. Foods of adult Maine coyotes and their known-aged pups. J. Wildl. Manage. 48: 922-926.

Luckhart, S., G. R. Mullen, L. A. Durden and J. C. Wright. 1992. *Borrelia* sp. in ticks recovered from white-tailed deer in Alabama. J. Wildl. Dis. 28: 449-452.

MacCrachen, J. G. 1984. Coyote foods in the Black Hills, South Dakota. J. Wildl. Manage. 48: 1420-1423.

Magnarelli, L. A., J. F. Anderson and M. L. Cartter. 1993. Geographic distribution of white-tailed deer with ticks and antibodies to *Borrelia burgdorferi* in Connecticut. Yale J. Biol. Med. 66: 19-26.

McCarley, H. 1975. Long distance vocalizations of coyotes (*Canis latrans*). J. Mamm. 56: 847-856.

Nelson, M. E. and L. D. Mech. 1992. Dispersal in female white-tailed deer. J. Mamm. 73: 891-894.

Nelson, T. A. and A. Woolf. 1987. Mortality of white-tailed deer fawns in southern Illinois. J. Wildl. Mange. 51: 326-329.

O'Connell, A. F., Jr. 1989. Population dynamics, habitat relationships, physiological parameters, Lyme disease, and management of a barrier island white-tailed deer population. Ph.D. Dissertation, Univ. Mass. 179pp.

O'Gara, B. W. and R. B. Harris. 1988. Age and condition of deer killed by predators and automobiles. J. Wild. Mange. 52: 316-320.

Redfield, A. C. 1972. Development of a New England salt marsh. Ecol. Monographs. 42: 201-237.

Smith, R. L. and J. L. Coggin. 1984. White-tailed deer ecology and management: Basis and role of management. Stackpole Books. Chapter 35.

Springer, J. T. and C. R. Wenger. 1981. Interactions between and some ecological aspects of coyotes and mule deer in central Wyoming. Wyoming Game and Fish Department: Wildlife Technical Report. 162 pp.

Stokes, D. W. and L. Q. Stokes. 1986. Animal tracking and behavior. Little, Brown and Company, Boston, MA. pg 266-275.

Toweill, D. E. and R. G. Anthony. 1988. Coyote foods in a coniferous forest in Oregon. J. Wildl. Manage. 52: 507-512.

Figure 1. Location of the Sandy Neck study site, Barnstable, Massachusetts showing the four trails and the six main maritime forest patches. Patch 6 is divided into vector quadrants to show how radiocollared white-tailed deer were given a general distribution in the patch that they inhabited at the time of a reading.

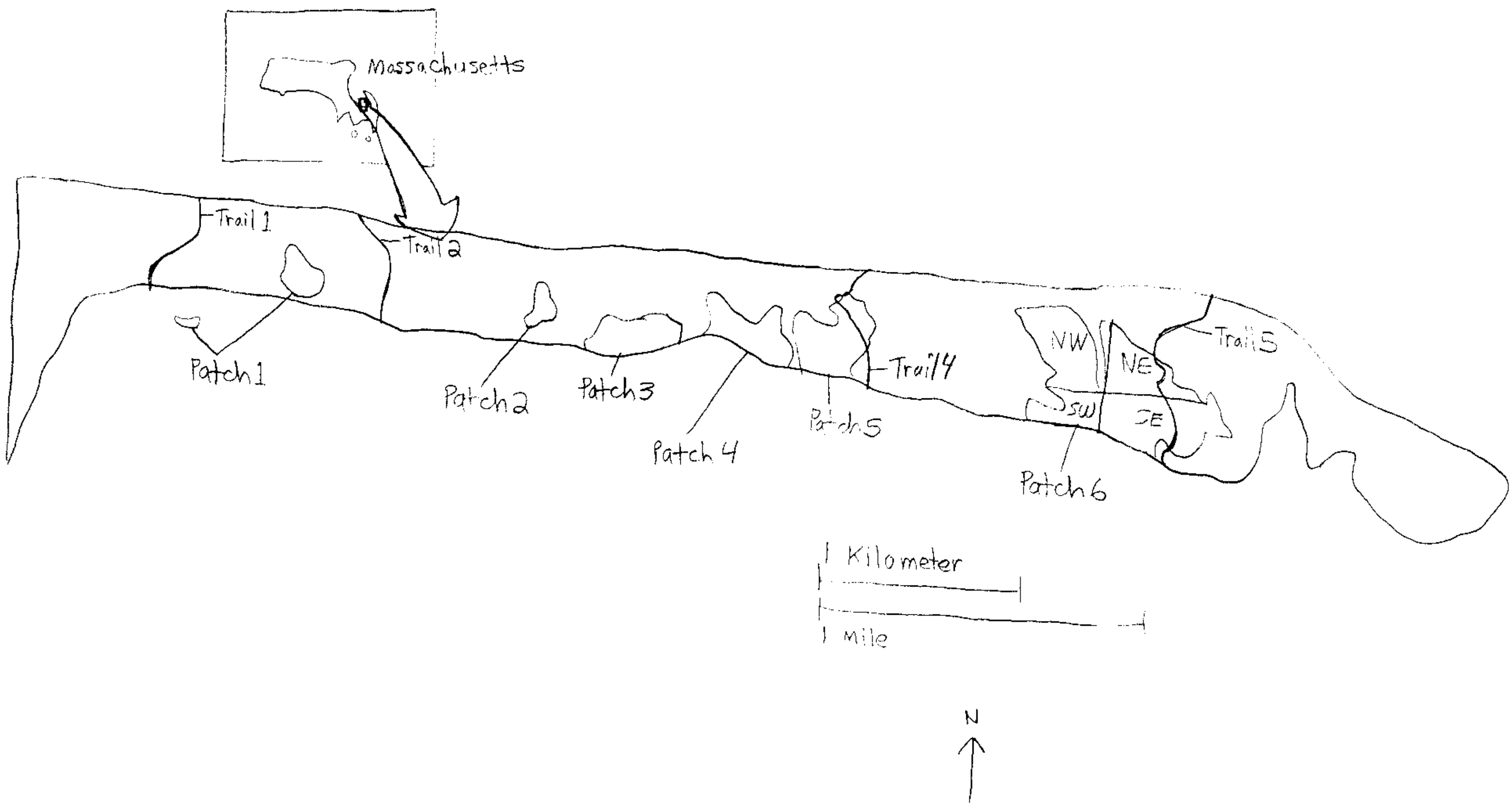


Figure 2. Number of hours spent observing white-tailed deer and eastern coyotes by various methods during 62 days in summer 1994 on Sandy Neck Beach, Barnstable, Massachusetts

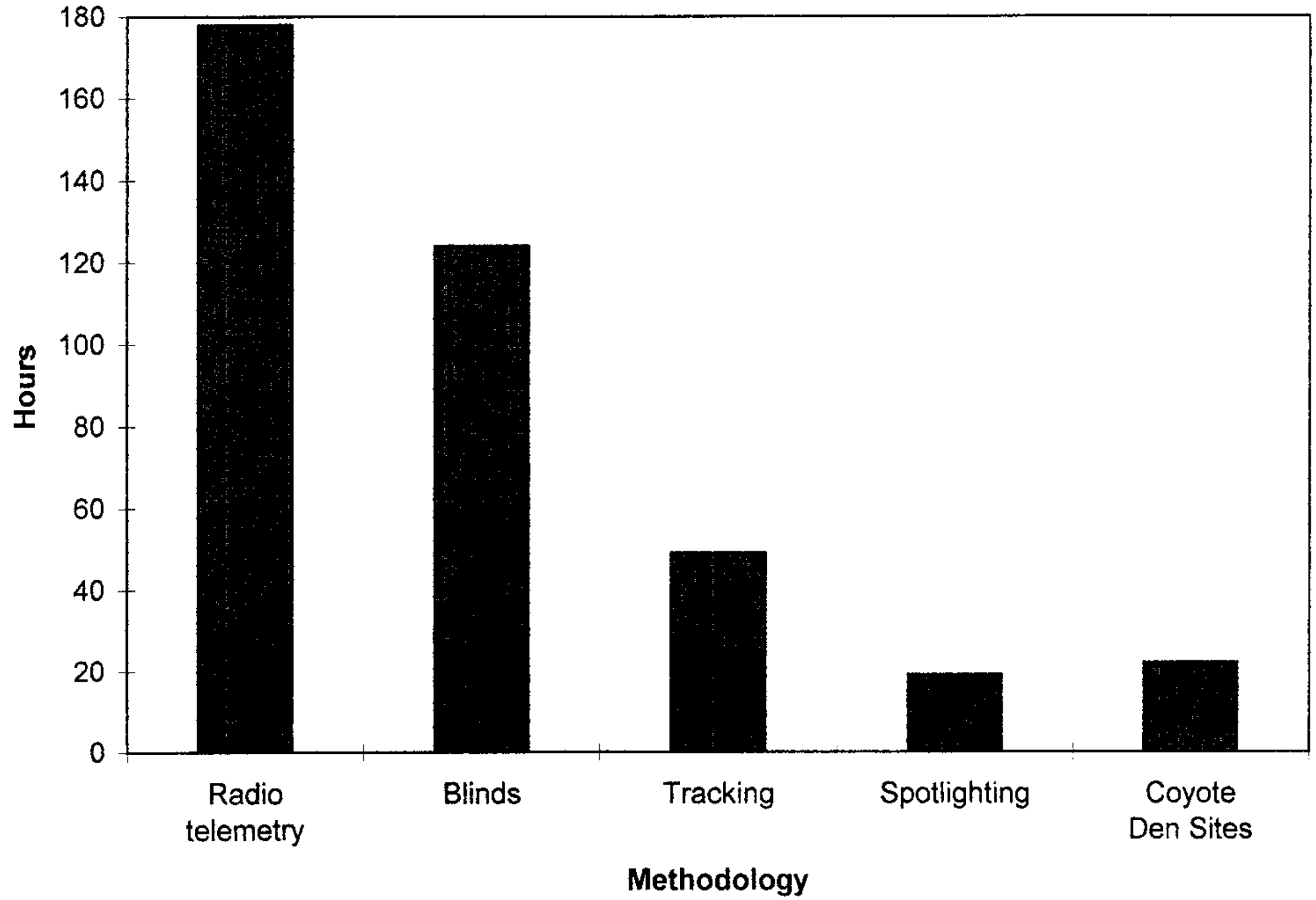


Figure 3. Summer white-tailed deer sightings (n=94), with and without radiotelemetry equipment, made on Sandy Neck Beach, Barnstable, Massachusetts during 1994

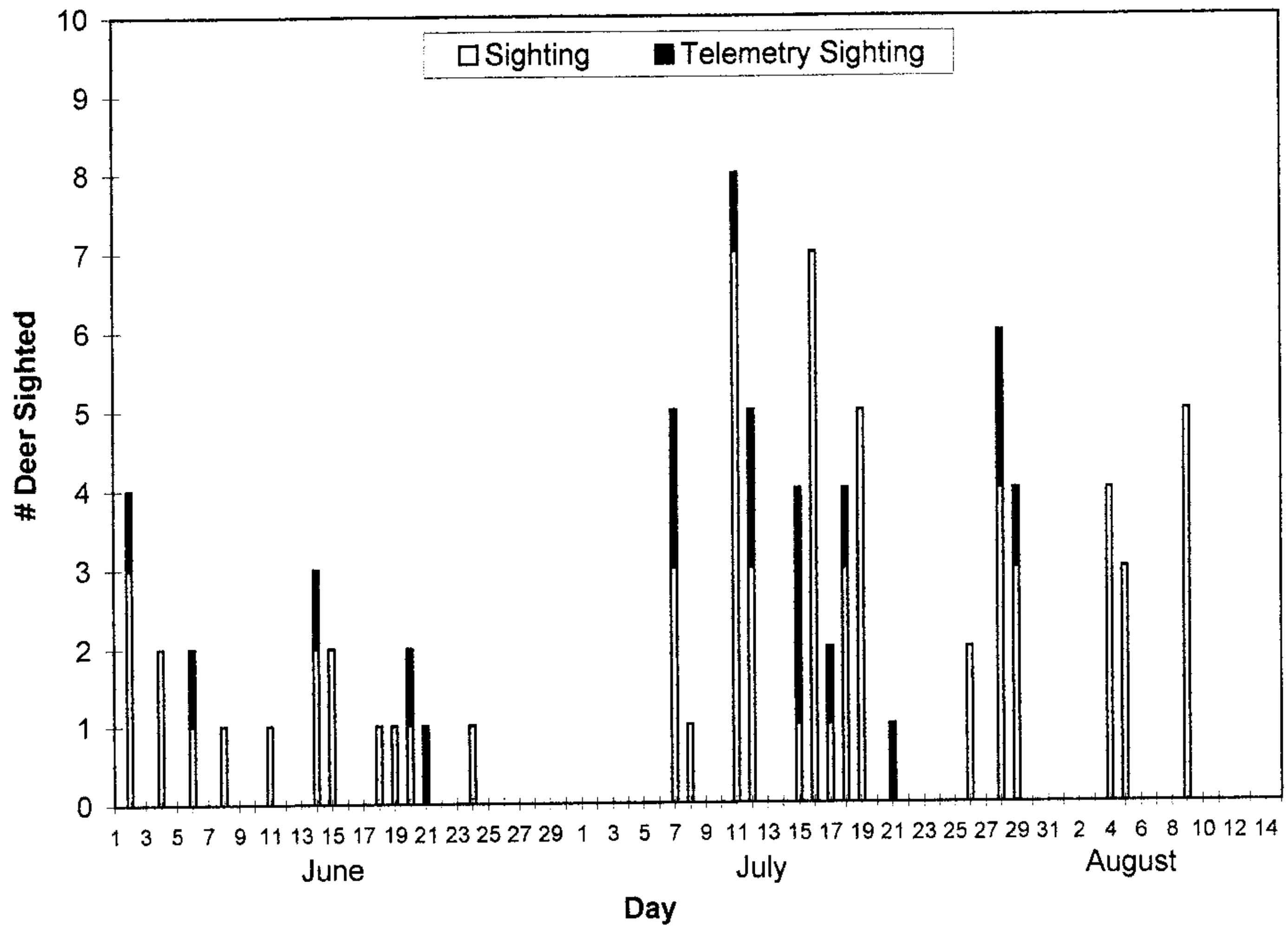


Figure 4. Summer sightings (n=49) of adult and pup eastern coyotes made on Sandy Neck Beach, Barnstable, Massachusetts during 1994

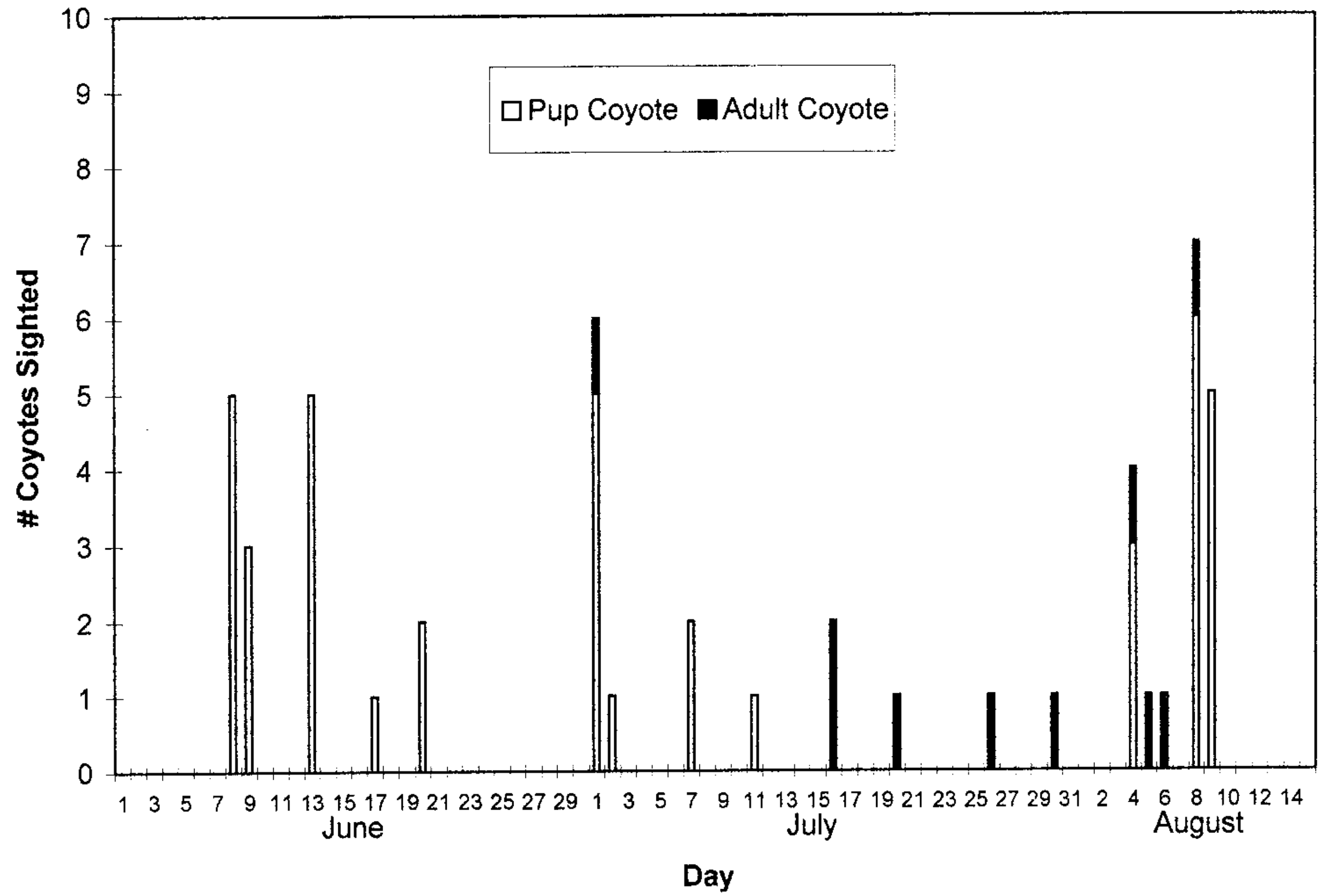


Table 1. Reproductive output of radiocollared female white-tailed deer tallied by means of direct observation of fawns with collared females inhabiting Sandy Neck Beach, Barnstable, Massachusetts during summer 1994

| Female | Fawns Produced |
|---|---|
| Fring | 1 |
| Filt | 2 |
| Pin | 1 |
| Fax/Tack | 2 |
| Total | 6 |
| Mean | 1.5 |

Figure 5. Summer distribution by patch of reproductive does and yearling white-tailed deer, with location of patch inhabited by collared does included, on Sandy Neck Beach, Barnstable, Massachusetts, 1994

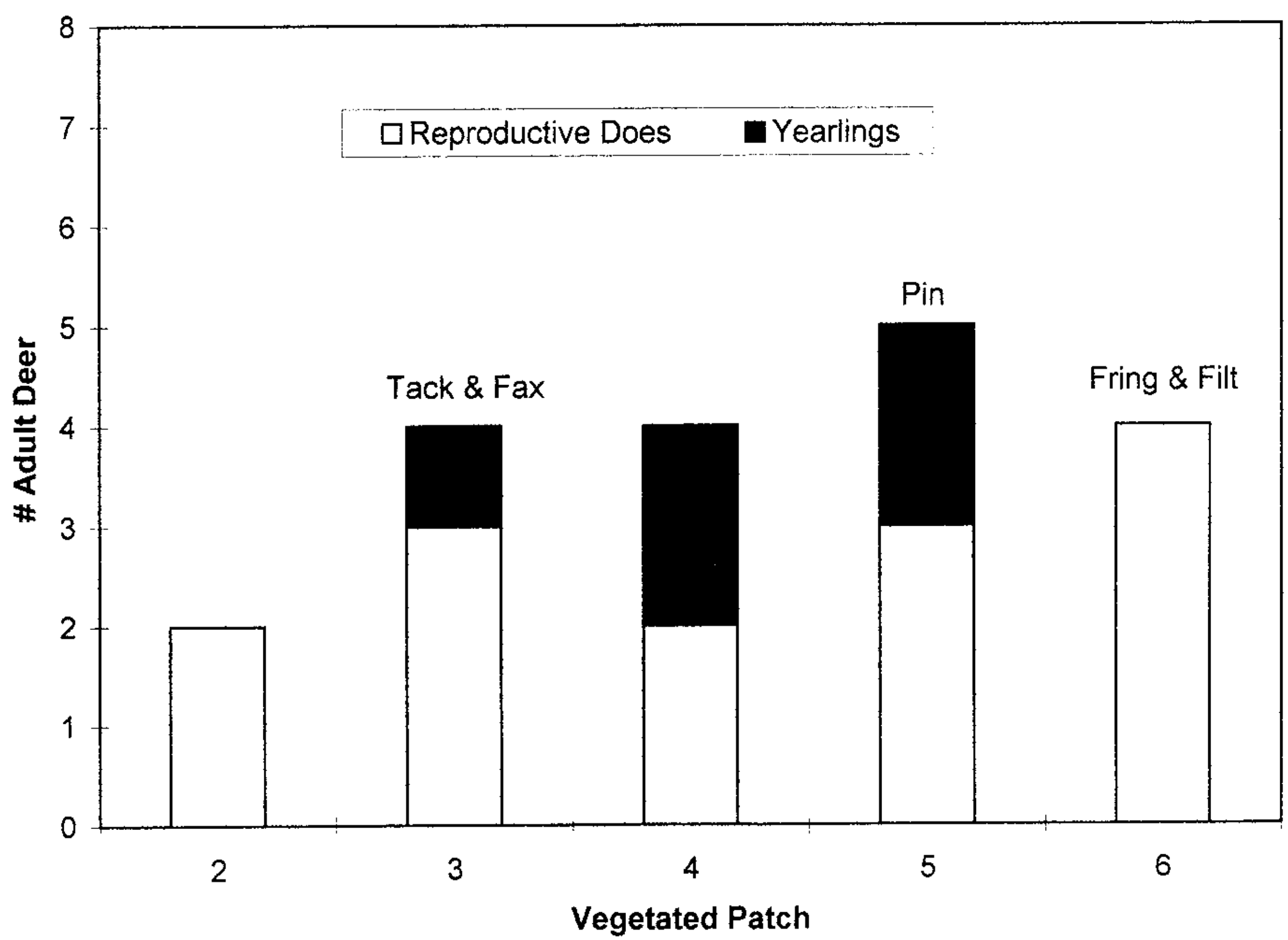
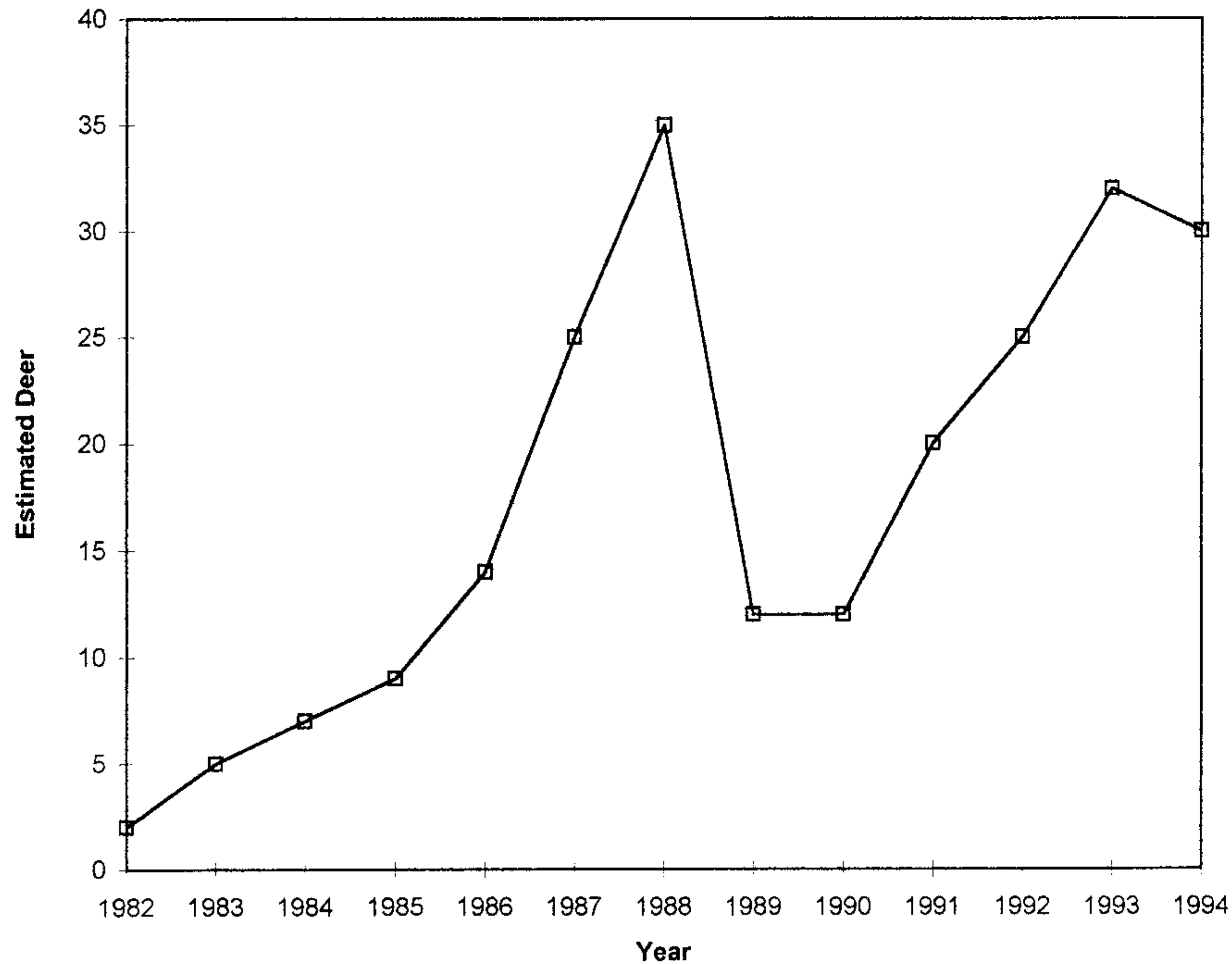


Table 2. Total white-tailed deer population estimate made by direct observation of collared and uncollared individuals for Sandy Neck Beach, Barnstable, Massachusetts, summer 1994

| Age and Sex Class | Number of Individuals |
|---|---|
| Adult Females (Does) | 14 |
| Yearlings | 5 |
| Fawns[1] | 21 |
| Adult Males (Bucks) | 3 |
| Total | 43 |

[1]Total number of fawns estimated from mean of radiocollared reproductive females multiplied by the total number of adult does present on the study area

Figure 6. White-tailed deer annual population estimates on Sandy Neck Beach, Barnstable, Massachusetts from 1982-1994



## Chapter 2

# Transect analysis of a population of red fox, eastern coyote, and white-tailed deer inhabiting a barrier beach on Cape Cod

Jonathan G. Way, Department of Forestry and Wildlife Management, University of Massachusetts, Amherst, MA, 01003

**Abstract**: The spatial dynamics of sympatric populations of red fox (*Vulpes vulpes*), eastern coyote (*Canis latrans* var.), and white-tailed deer (*Odocoileus virginianus*) on Sandy Neck Beach, Cape Cod, Massachusetts, were documented using transect analysis during the summer of 1995. Deer were most abundant towards the eastern end of the study site, presumably due to forage type variation and reduced human disturbance as observed by relative abundances of foot traffic. Eastern coyotes were less common on the study site during the summer of 1995 than in previous years (no active den sites were documented). There was no strong correlation between deer and coyote densities. A stronger correlation existed between fox and coyote track abundance. Coyote and fox tracks suggested the possibility of interference competition through inverse relative abundance. Instances of interspecific indifference displayed between the species also were observed. Future attempts must be made to capture and radiocollar fox and coyotes to more accurately understand the complex relationship that exists between these canids and white-tailed deer.

## Introduction

Eastern coyotes (*Canis latrans* var.) were not originally native to Cape Cod. However, with the extirpation of the gray wolf (*Canis lupus*) throughout most of the eastern United States by the early 1900's, a niche was opened up and coyotes quickly filled it. They were first documented in western Massachusetts during the 1950's and were found on Cape Cod during the 1970's (Parker, 1995). The recent addition of a large predator back to Cape Cod will inevitably impact its prey (i.e., white-tailed deer - *Odocoileus virginianus*) and competitors (i.e., red fox - *Vulpes vulpes*). Thus, it is important to understand the relationship that exists between these species and coyotes.

Coyotes prey on deer (Parker, 1995, chapter 8; Harrison and Harrison, 1984; Nelson and Woolf, 1987; O'Gara and Harris, 1988) and the results from this study may have important management implications with regard to relative abundance of deer and coyote found in an area. Their numbers may be regulated based on the public's desire to manipulate deer densities in specific areas. Under natural conditions (i.e., no human-hunting) high local deer densities should indicate relatively low coyote numbers or activity and low deer occurrence may reflect high coyote numbers or activity. In addition, interference competition causes foxes to establish home ranges outside of coyote territories, thus limiting the available habitat for red foxes (Dekker, 1983; Sargeant and Allen, 1989; Voigt and Earle, 1983). Therefore, where coyotes are found, foxes should not become well-established.

I conducted research during the summer of 1995 in an attempt to quantify spatial dynamics displayed between eastern coyote, red fox, and white-tailed deer. By taking transects across set trails I counted the frequency of tracks that co-occurred between these species.

**Study Area**

The Sandy Neck study site lies in a conservation area owned by the town of Barnstable on Cape Cod, Massachusetts (Figure 1). It is approximately 10 km long and consists of six distinct upland maritime forested areas. The western part of the ecosystem, designated Patch 1, has the oldest plant community on the study site; scrub oak (*Quercus ilicifolia*) dominates the area. Meanwhile, the relatively recent formation of the plant community on the eastern part of the study site (i.e., Patch 6) consists of pitch pine (*Pinus rigida*) and many small-sized (<1 hectare) swamps. The eastern portion of the study site is characterized by large contiguous tracks of forest compared to the more fragmented western end. Redfield (1972) conducted a classic geological ontogeny study of the area, going to great lengths surveying the natural history of this region.

In areas devoid of forest, sand dunes covered with dune grass (*Ammophila breviligulata*) exist. Cranberry bogs (*Vaccinium macrocarpon*) are common in the swale areas of the study site. Shrubs such as northern bayberry (*Myrica pensylvanica*), beach plum (*Prunus maritima*), blueberries (*Vaccinium* spp.), and poison ivy (*Rhus radicans*) are also present in this fragmented landscape.

The study area connects to the mainland at the western end of the barrier beach and via the Great Marsh (an estuary adjoining Barnstable Harbor), which encompasses 32.4 $km^2$. There are many creeks and gullies in the estuary which provide a formidable barrier for land mammals going to the mainland due to extremely irregular terrain and tidal activity.

There is a vehicle trail on the beach front and the marsh edge, of which both run west to east. There also are four dirt vehicle trails that run north to south, which are equidistant from each other, connecting the beachfront and marsh sides of the beach.

**Methodology**

Access to the various areas of the study site was accomplished through the use of a four-wheel-drive vehicle. The four vehicle trails were used to obtain track indices. Trail 1 (0.625 km in length) is close to Patch 1, Trail 2 (0.6 km) is west of Patch 2, Trail 4 (0.7 km) runs through Patch 5 and Trail 5 (1.25 km) meanders through the eastern region of Patch 6.

For this study three important issues examined regarding transect analysis were: (1) movement patterns relative to temporal and environmental factors - comparing movement patterns versus weather, season, time of day, week, or month would likely indicate a trend in activity by the noticeable differences in relative abundance of tracks during different conditions; (2) relative index of track counts - the number of track counts could directly correlate to abundance of a species; by comparing existing data, the difference in track counts would presumably correspond to changes in estimated abundance of animals; to avoid bias, there is a need to control for instances of same animal recrossings of transects vs. specific transect, and (3) general directions of movement and activity patterns - by examining shifts in patches or immigration/emigration on and off the study site, relative activity at various spots on the study area (e.g., west or east end) can be investigated.

Tracks of white-tailed deer, red fox and eastern coyote were identified on site (Stokes, 1986). The larger front track of a fox is about 2 ½ inches long and is rounder than the 2 inch long hind track. Fox tracks can be hard to distinguish from those of a small dog or coyote. However, a fox straddle measures 4 inches or less, while the heavier coyote has a larger straddle of 4 to 6 inches. The larger front track of a coyote is 2 ¼ to 2 ¾ inches long in adults. Interestingly, front track measurements of one large eastern coyote on the study area measured an astonishing 3 ½ inches long, far larger than fox or what any field guide describes for coyotes, making it easy to differentiate between smaller canids (unpubl. field data).

Track transects were recorded along the four dirt (vehicle) trails located on the study site (Bookhout, 1994). These trails varied from 0.6 km to 1.25 km in length. As suggested by Cavallini (1994), transects were located on dirt trails because of their similar width. This avoided the bias from nonrandom patterns in identifying tracks. Trails were on relatively sandy areas which made tracks easy to locate.

Track transects were taken by driving a four-wheel-drive vehicle from one end of the trail to the other end. Tracks were recorded for all three species within 150-250 meter intervals along trails in order to note the general area of movement on the study site (Figure 2). The direction of an animal's movement and the number of animals traveling together were recorded on each data sheet. Once recorded, each track was swept clean. Data was entered into Lotus Spreadsheet form (Program: Symphony). Information was sorted by trails which revealed patterns of spatial dynamics displayed by the animals. Totals for each transect were standardized into a mean number of tracks/kilometer (Table 1). More generally, mean values for tracks/km were taken for the western and eastern end of the study site.

**Results**

During the course of summer 1995 Trail 1 was searched 5 times, 8 times for Trail 2, 10 for Trail 4 and 9 for Trail 5 (Figure 3; Table 1). White-tailed deer varied greatly in their use of the four trails, ranging from 0.0 tracks/km at Trail 1 to 21.86 tracks/km at Trail 4. Deer were more abundant on the eastern half of the study area (15.02 tracks/km) compared to the western side (0.21 tracks/km).

Red fox tracks were most abundant towards the west end of the study site (2.56 tracks/km at Trail 1) and progressively decreased towards the east end (0.30 tracks/km at Trail 5). Furthermore, the mean number of fox tracks on the western part of the study area averaged 2.32 tracks/km while only being 0.65 on the eastern side.

Coyotes were notably more abundant on the eastern end of the study site (mean=0.77 tracks/km) but were also present on the western portion (mean=0.48 tracks/km). No tracks of coyotes were observed crossing Trail 2.

**Discussion**

The trend in white-tailed deer abundance correlates with the sighting data that has been collected over the past two summers. For example, most deer sign found was near Trails 4 and 5, presumably due to better forage type and cover (e.g., blueberries, northern bayberry, hardwoods, cranberry bogs) coupled with minimal disturbance from humans because of the remoteness and contiguous tracks of forest associated with the eastern end of the study area. Conversely, at the western end of the study site (Trails 1 and 2) there is less cover and human activity was far more substantial (as indicated by changes in relative abundance of foot traffic on the various trails) than that at the eastern end. Furthermore, the forest that Trail 4 transverses offers more suitable habitat for white-tailed deer during the summer than the Trail 5 area does. This is due to a difference in vegetation types; Trail 4 is dominated by blueberries, *Vaccinium* spp., and hardwood species that are preferred foods for deer in the summer where Trail 5 is comprised mainly of softwood species which are more utilized by deer during the winter (e.g., Atlantic white cedar - *Chamaecyparis thyoides*).

It was apparent that coyotes used the study area during the summer of 1995 significantly less than the previous summer. The data from the 1994 field season showed that coyotes were more prevalent on the beach due to a relatively high number of tracks/km per trail. This was associated with a den site located between Trails 4 and 5 (unpubl. data). An intensive coyote den search was conducted from May 24 - June 23 on the study site but no den was located. Coyote sign was commonly found in the study area (e.g., tracks, scat, digging) coupled with occasional sightings, but it was assumed that there were no denning coyotes in the area. No strong correlation could be made between deer and coyote interactions due to an insufficient track count sample size.

There were a number of possible reasons a coyote den was not located on the study site: (1) they were unsuccessful in producing a litter; (2) the pregnant female was killed and the territory was void of female immigrants, and (3) coyotes simply found a more suitable den off the parameters of the study site. Stokes (1986) indicates that the home range of coyotes can be 25 square miles. This value is significantly greater than the entire size of the study area, especially given the poor habitat quality.

Despite the lack of a high abundance of coyotes on the study site during summer 1995, a strong correlation still existed between coyote and red fox tracks. Foxes were documented on the study area for the first time since coyotes colonized the site in 1992. Numerous studies (Dekker,1983; Sargent and Allen, 1989; Voigt and Earle, 1983; Major and Sherburne, 1987; Harrison et al.,1989; Theberge and Wedeles, 1989), have documented the interactions between red foxes and coyotes. Throughout the study, the trend in relative activity suggested that fox were found less frequently in areas used by coyotes. Fox sign was most often found at the west end of the beach where there were more scavenging opportunities via human campers. Coyotes were most frequently seen towards the east end of the beach where they were afforded more cover due to vegetation type.

There were also accounts from the past summer, however, that suggested the possibility of interspecific indifference (Sargeant and Allen, 1989). For example, a fox was sighted one evening from a blind just west of Trail 5. The next night a coyote was called into the same place using a fawn bleat call. This sequence of sightings appeared to indicate that the two canids were using common areas of activity or, at the very least, one or two of the species were passing through the area. In addition, tracks of both species were found along Trails 4 and 5 throughout the summer even though the literature strongly indicates that fox spatially segregate themselves from local coyote activity.

A factor that was not included in the results was the fact that coyotes and foxes could emigrate/immigrate from or into the study site by traveling the beachfront or the marsh. The data could be skewed if these tracks were not counted, because the total number of tracks would be much lower than what actually crossed by a particular trail. This could be the reason why no coyote tracks were observed crossing Trail 2.

Fox and coyote tracks were sometimes indistinguishable in the soft sand on the study site. To safeguard against bias, if one species could not be positively identified, they were not counted. Weather also caused a problem leading to inaccurate track counts. Environmental factors either contributed or withdrew from the success of track identification. For example, after it rained it was much easier to identify tracks than after a drought. In addition, when part of the study site was opened to the public, the influx of various tracks made it difficult to count the number of deer tracks crossing Trails 4 and 5. Pet dogs compounded the problem as it was sometimes difficult to distinguish between dog and coyote tracks.

The vehicle used to collect transect data caused another bias to the data. When ATVs were used, tracks were very easy to see, while it was more difficult using a standard vehicle. The time of day was important to the collection of accurate data. It was much easier to drive by older tracks at night than earlier in the day. The observer doing the transect is also important because their vision and experience identifying tracks can affect the reliability of data produced. For this reason, it is important to standardize transects before they are actually taken in order to avoid potential biases.

Furthermore, data were not collected at regular temporal intervals so only the trend in the populations of fox, coyotes and deer could be examined. If transects were done in a systematic fashion, such as suggested by Bookhout (1994), further data analysis could take place (e.g., time of activity - diurnal, nocturnal, crepuscular).

## Conclusions

The original focus of this study was to quantify deer/coyote spatial dynamics. It was altered due to an invasion of red fox onto the study site. For this reason, the topic changed to encompass the interactions of all three species.

Currently, the literature does not describe the interactions of foxes, coyotes and deer. I found that coyotes appear to influence the spatial dynamics of red fox. Coyotes did not affect deer abundance during summer 1995, but data from summer 1994 suggests the possibility that coyotes can influence deer spatial dynamics when coyotes are found at relatively high densities. To understand the population dynamics and interactions of these animals it is important that a more comprehensive study be conducted. For this reason, future attempts must be made to capture and radiocollar coyotes and foxes, as well as taking continued track transects with controls, in an attempt to empirically understand the complex relationship that exists between these canids and white-tailed deer.

## Literature cited


Bookhout, T. A., Editor. 1994. Research and management techniques for wildlife and habitats. Fifth ed. The Wildlife Society, Bethesda, Md. 740pp.

Cavallini, P. 1994. Faeces count as an index of fox abundance. Acta theriol. 39: 417-424.

Dekker, D. 1983. Denning and foraging habits of red foxes, *Vulpes vulpes*, and their interaction with coyotes, *Canis latrans*, in central Alberta, 1972-1981. Canadian Field-Naturalist. 97: 303-306.

Harrison, D. J., J. A. Bissonette, and J. A. Sherburne. 1989. Spatial relationships between coyotes and red foxes in eastern Maine. J. Wildl. Manage. 53: 181-185.

_____, and J. A. Harrison. 1984. Foods of adult Maine coyotes and their known-aged pups. J. Wildl. Manage. 48: 922-926.

Major, J. T. and J. A. Sherburne. 1987. Interspecific relationships of coyotes, bobcats, and red foxes in western Maine. 51: 606-616.

Nelson, T. A. and A. Woolf. 1987. Mortality of white-tailed deer fawns in southern Illinois. J. Wildl. Mange. 51: 326-329.

O'Gara, B. W. and R. B. Harris. 1988. Age and condition of deer killed by predators and automobiles. J. Wild. Mange. 52: 316-320.

Parker, G. 1995. Eastern coyote: The story of its success. Nimbus Publishing, Halifax, Nova Scotia. 254 pp.

Redfield, A. C. 1972. Development of a New England salt marsh. Ecol. Monographs. 42: 201-237.

Sargeant, A. B. and S. H. Allen. 1989. Observed interactions between coyotes and red foxes. 70: 631-633.

Stokes, D. W. and L. Q. Stokes. 1986. Animal tracking and behavior. Little, Brown and Company, Boston, MA. pg 266-275.

Theberge, J. B. and C. H. R. Wedeles. 1989. Prey selection and habitat partitioning in sympatric coyote and red fox populations, southwest Yukon. Can. J. Zool. 67: 1285-1290.

Voigt, D. R. and B. D. Earle. 1983. Avoidance of coyotes by red fox families. J. Wildl. Manage. 47: 852-857.

Figure 1. Location of the Sandy Neck study site, Barnstable, Massachusetts showing the four trails and the six main maritime forest patches

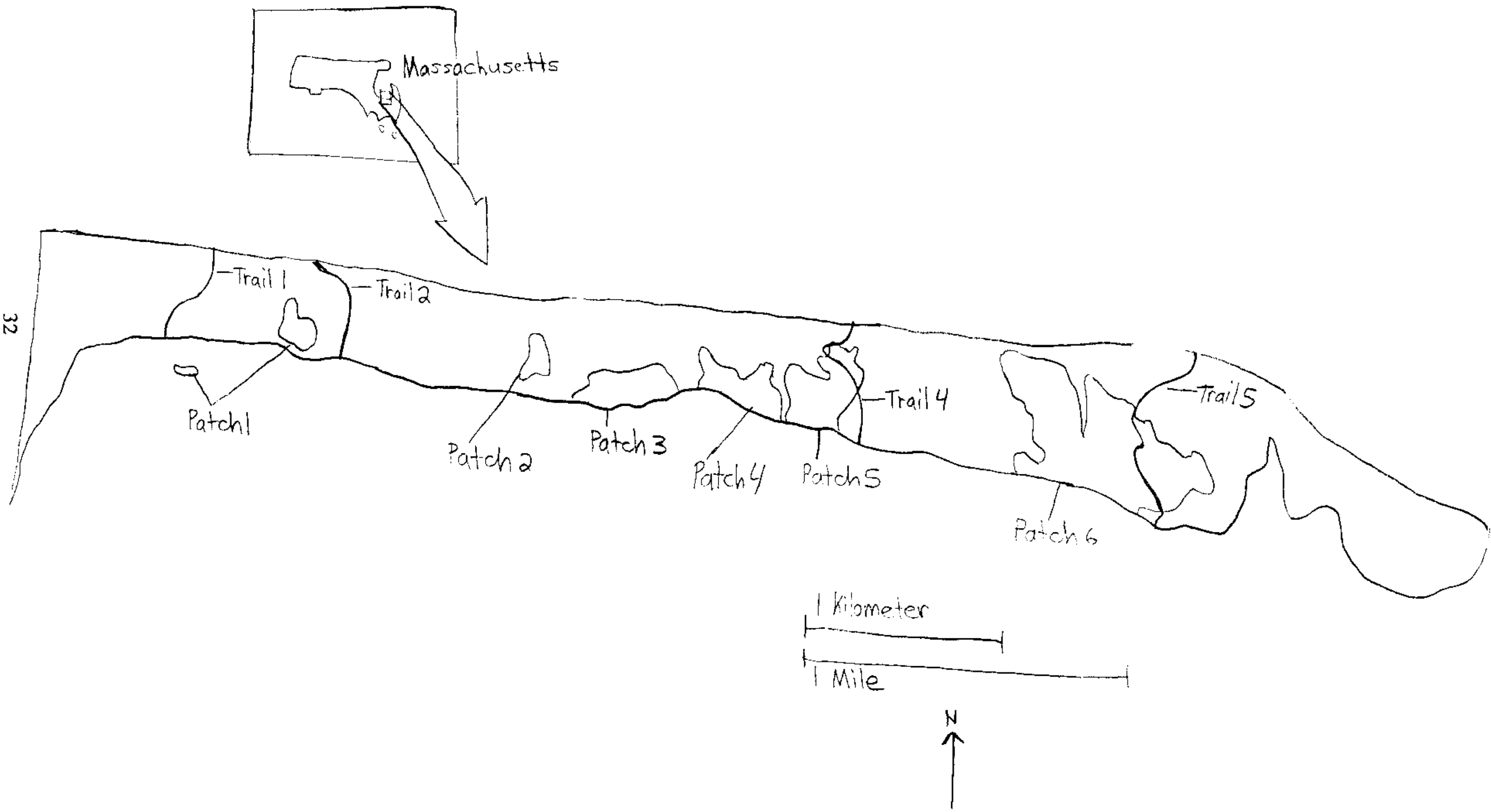


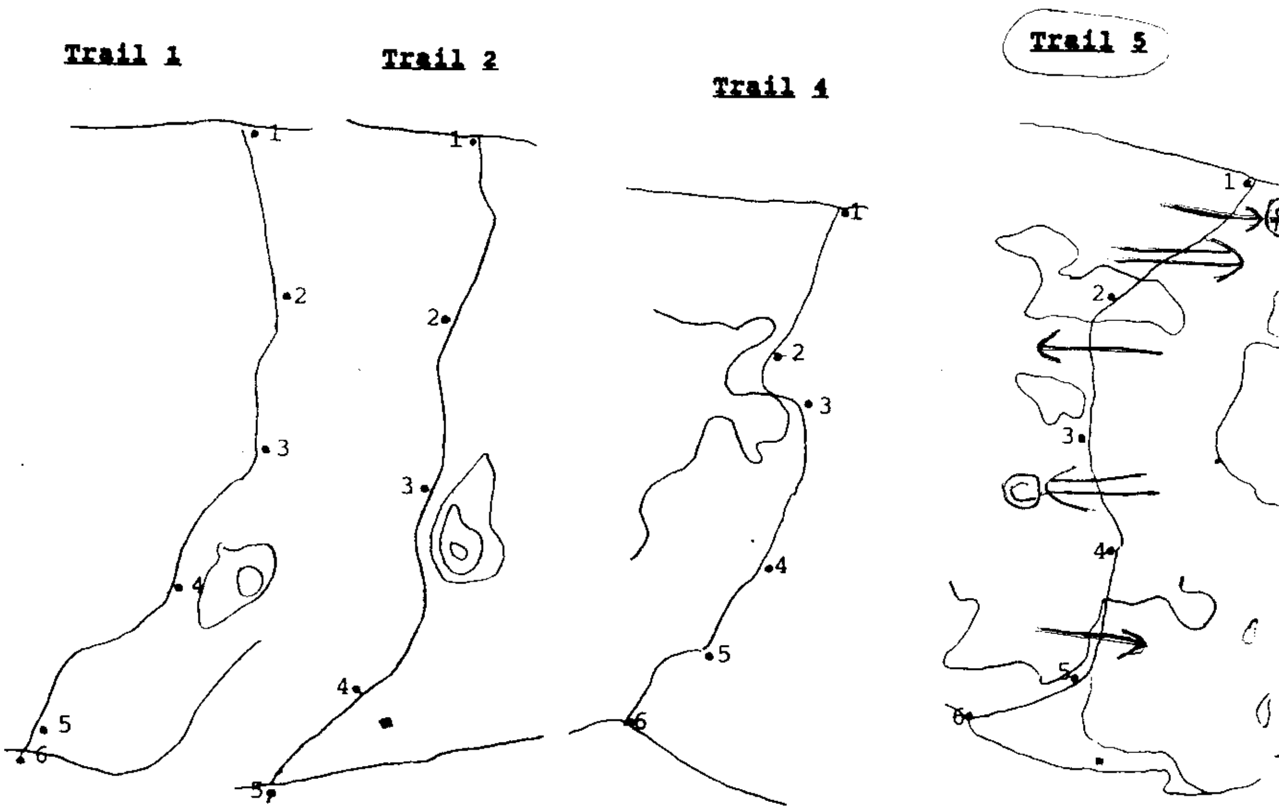
Figure 2. Sample data sheet for driven track transects across trails 1 (0.625 km), 2 (0.600 km), 4 (.700 km) and 5 (1.250 km) on Sandy Neck Beach, Barnstable, Massachusetts, summer 1995 recording the number of deer, coyote and fox tracks observed

Transect T5
Date x/x/95
Observor(s) JW
Beg. Time 9:00 AM
Tot. Time 10 minutes
Sighting N
Weather Sunny, Hot
Prev. Weather Rain

**SANDY NECK BEACH**
**TRANSECT DATA**
**1995**
**Driven Trails**

Sheet # 9500X

**USE A NEW DATA SHEET FOR EACH INDIVIDUAL TRANSECT**




**White-tailed Deer**
*Odocoileus virginianus*

| Tracks (sets) | | Dir. 1 (W) | | Dir. 2 (E) | | Group (L-S) | |
|---|---|---|---|---|---|---|---|
| 1 | 2 | D1a | 0 | D1b | 2 | G | 2 |
| 2 | 1 | D2a | 1 | D2b | 0 | G | 1 |
| 3 | 0 | D3a | 0 | D3b | 0 | G | 0 |
| 4 | 1 | D4a | 0 | D4b | 1 | G | 1 |
| 5 | 0 | D5a | 0 | D5b | 0 | G | 0 |
| 6 | | D6a | | D6b | | G | |
| 7 | | D7a | | D7b | | G | |

Total 4 Total a 1 Total b 3

Coyote/Fox

| Tracks (sets) | | Dir. 1 (W) | | Dir. 2 (E) | |
|---|---|---|---|---|---|
| 1 | 0/1 | D1a | 0/0 | D1b | 0/1 |
| 2 | 0/0 | D2a | 2/0 | D2b | 2/0 |
| 3 | 2/0 | D3a | 2/0 | D3b | 0/0 |
| 4 | 2/0 | D4a | 0/0 | D4b | 0/0 |
| 5 | 2/0 | D5a | 0/0 | D5b | 0/0 |
| 6 | | D6a | | D6b | |
| 7 | | D7a | | D7b | |

Total 2/1 Total a 2/0 Total b 0/1

Figure 3. Mean number of tracks/km per trail for white-tailed deer, eastern coyote, and red fox taken on Sandy Neck Beach, Barnstable, Massachusetts during summer 1995

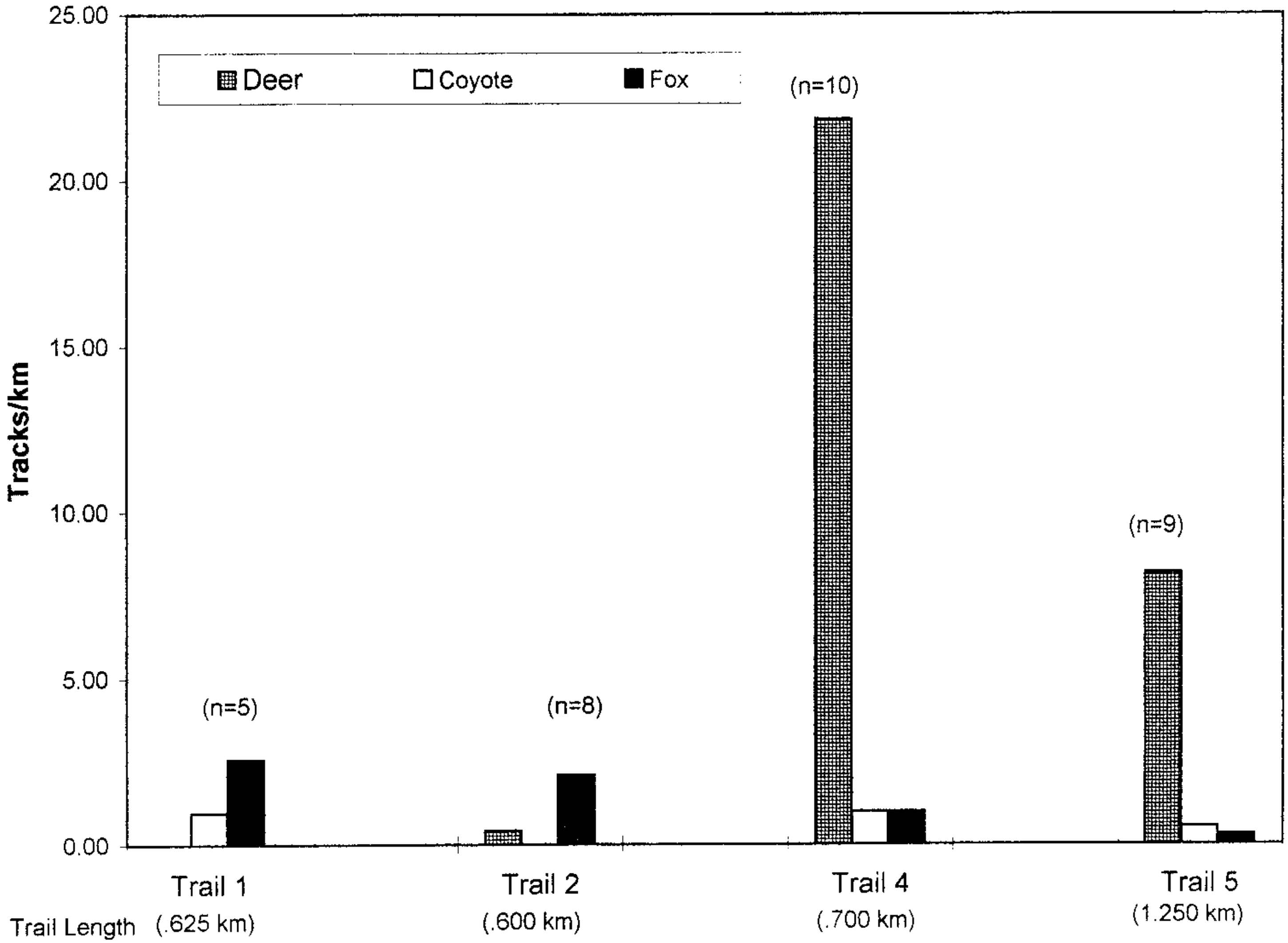


Table 1. Mean number of tracks/km per trail for white-tailed deer, eastern coyote, and red fox taken on Sandy Neck Beach, Barnstable, Massachusetts during summer 1995

| | west end | | | east end | | |
|---|---|---|---|---|---|---|
| | (n=5) | (n=8) | | (n=10) | (n=9) | |
| | Trail 1 | Trail 2 | Mean | Trail 4 | Trail 5 | Mean |
| Deer | 0.00 | 0.42 | 0.21 | 21.86 | 8.18 | 15.02 |
| Coyote | 0.96 | 0.00 | 0.48 | 1.00 | 0.53 | 0.77 |
| Fox | 2.56 | 2.08 | 2.32 | 1.00 | 0.30 | 0.65 |