ECOLOGY OF CAPE COD COYOTES

(*Canis latrans* var.)

Jonathan G. Way

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Presented by

Jonathan G. Way, B.S.

Major Advisor _____
Isaac M. Ortega

Associate Advisor _____
David B. Schroeder

Associate Advisor _____
Peter J. Auger

University of Connecticut

2000

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Care and use of animal subjects was approved by the University of Connecticut Institutional Animal Care and Use Committee protocol # YEE 0101 and by the Massachusetts Division of Fisheries and Wildlife permit # 038.98LP.

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Abstract

Padded-leg hold traps became illegal to use in 1996 in Massachusetts. Thus, box traps were tested as a capture technique for eastern coyotes (*Canis latrans* var.) in a suburban environment within Barnstable County, Cape Cod, Massachusetts between May 1998 and February 2000. Box traps were in the field for 4,076 trap days resulting in 977 armed trap days. Traps were sprung 253 times resulting in 224 animals, of 11 species, captured. Eleven individual coyotes (7 adults/4 pups) were captured a total of 16 times; three adults were captured twice and one adult was captured three times. The capture efficiency rating for coyotes was 16.4. Coyotes were successfully captured during 10 of the 12 months. Box traps were relatively inefficient in capturing coyotes because of the expense of each trap, the time involved in baiting and conditioning coyotes into traps, the high rate of non-target captures and only one adult coyote (at most) was captured in a social group. I recommend the use of padded leg-hold traps to successfully capture and release coyotes for scientific study in Massachusetts.

I studied home range sizes, movement and activity patterns, and sociality of 11 radio-transmitted eastern coyotes, *Canis latrans* var., inhabiting a heavily suburban area (Cape Cod, Massachusetts) between June 1998 and March 2000. A total of 3,086 radiolocations were obtained, representing 2,973 successful and 113 unsuccessful finds. Home ranges sizes were variable depending on the method used. Average home range for breeding adult coyotes using the 95 % minimum convex polygon vertex edited method was 29.7 $\pm$ 5.3 (SE) km^2. Resident coyote groups showed limited overlap in home ranges. Juvenile coyotes had small home ranges varying from 0.3 – 10.8 km^2. One transient and one associate coyote had the largest home ranges (152.2 km^2 and 100.4 km^2, respectively) in the study. The home range of a reproductive female coyote compared to a non-reproductive one was considerably smaller during the denning season. Resident coyotes typically traveled and lived in social groups of three members. Coyotes were strictly nocturnal with activity generally beginning just after dusk and ending just before dawn. Twenty four-hour movements of coyotes ranged up to 31.9 linear km. Coyote numbers appear to be stable with an estimated 0.08-0.15 coyotes/km^2 (90 % CI) residing on the study area.

CHAPTER 1

Literature Review: Eastern Coyote Research

Introduction

The eastern coyote (*Canis latrans* var.) is believed to be non-native to Cape Cod (Boer, 1992). Habitat changes and unregulated persecution led to the extirpation of the gray wolf (*Canis lupus*) throughout most of the eastern United States by the early 1900's (McIntire, 1996; Mech, 1970). Around the turn of the century, the coyote was observed progressively colonizing land further east (Parker, 1995). With less competition (i.e., wolves) and more second growth habitat, the eastern coyote grew in exponential numbers around the mid-1900's (Parker, 1995). The eastern coyote was first documented as far east as western Massachusetts during the 1950's and subsequently reported on Cape Cod during the 1970's (Parker, 1995; J. Cardoza, pers. comm., Massachusetts Division of Fisheries and Wildlife). Apparently coyotes arrived on Cape Cod by crossing directly over the two bridges connecting Cape Cod to the mainland or by swimming across the Cape Cod Canal.

The eastern coyote has predominately been studied in forested areas in Maine (Harrison, 1992; Harrison et al., 1991; Harrison and Gilbert, 1985; Harrison and Harrison, 1984). Person (1988) and Person and Hirth (1991) studied coyotes in an agricultural region of rural Vermont. In addition, Person (1988) found that little quantitative research has been conducted in coastal plains, hardwoods and urban areas on the eastern coyote. It is important that studies be conducted in various habitat types in the northeast if the impact and ecology of the eastern coyote is to be better understood.

There have been few studies documenting the behavioral and morphological development of the eastern coyote (Silver and Silver, 1969; Parks, 1979). However, no studies have been done in suburban areas. Existing studies in other habitats have demonstrated contrasting results showing the eastern coyote behaving like the western coyote, or the eastern coyote acting more like the gray wolf.

The recent addition of a relatively large predator to Cape Cod may impact potential prey species (i.e., white-tailed deer, *Odocoileus virginianus*). Thus, it is important to understand the relationship that exists between deer and coyote. With a lack of large predators (e.g., wolf and mountain lion, *Felis concolor*) in the northeast, white-tailed deer have become very numerous (Warren, 1997). Previous studies have shown that the coyote can practice cooperative hunting during periods of increased sociality (Bowen, 1981; Gese et al., 1988b; Messier and Barrette, 1982). Cooperative hunting has enabled the coyote to prey on deer (Parker, 1995: Harrison and Harrison, 1984; Nelson and Woolf, 1987; O'Gara and Harris, 1988), but no studies have demonstrated that the coyote can significantly impact overall deer abundance in an area.

Wildlife managers, for years, have speculated about reintroducing the wolf to the northeast (Henshaw, 1982). One suggestion is that it would help in controlling deer overabundance in certain areas (Warren, 1997). However, the eastern coyote on Sandy Neck Beach, Cape Cod, Massachusetts was observed to form packs and hunt deer (Peter Auger, pers. comm., Boston College; Way, 1996). These observations have led to the suggestion that the coyote may be affecting deer abundance in this region. Due to the open, sandy areas, which make it perfect for year round tracking,

Sandy Neck is an ideal place for a predator/prey study. A population of white-tailed deer currently estimated at 45 animals has been studied in the Sandy Neck area (Peter Auger, pers. comm., Boston College; Way, 1996).

The eastern coyote may have developed the behavior to prey on Cape Cod white-tailed deer (and the northeast in general) as a consequence of possible hybridization with the gray wolf (Parker, 1995, Boer, 1992; Schmitz and Lavigne, 1987) or the red wolf (*C. rufus*; Theberge, 1998). Taxonomic classification of the eastern coyote has been widely discussed (Parker, 1995; Schmitz and Lavigne, 1987; Hilton, 1978; Lawrence and Bossert, 1975 and 1969; Silver and Silver, 1969). There are, currently, no studies that have used DNA analysis (Wayne and Lehman, 1992) and/or discriminate analysis (Lawrence and Bossert, 1969) and concurrent radio collaring of the same individuals to study the behavior of the eastern coyote. Parker (1995) noted that it is surprising that some taxonomic identification of the eastern coyote has not been proposed.

No studies have demonstrated the utility of capturing coyotes in box traps. Given that many states (e.g., Massachusetts) have banned the use of leg-hold traps, a new technique, such as box traps, should be tested in order to determine the effectiveness of capturing coyotes.

Coyote General Ecology

Regarding habitat selection, Holzman et al. (1992) found that mature pine plantations in southcentral Georgia might have more potential den sites and consequently coyotes were found there more than in other habitat types in southwestern Oklahoma. Litvaitis and Shaw (1980) found that coyotes were primarily found in savanna habitat. Harrison and Gilbert (1985) examined den site characteristics and behavior of adults and their offspring during the pup rearing periods in mainly coniferous forest habitat in Maine. Adults prepared multiple dens and periodically transferred pups from den to den. They expanded the use of their home range from 11.2 to 46 km^2 as pups became more independent.

Person (1988) and Person and Hirth (1991) studied the eastern coyote in an agricultural region of Vermont. They were found to have smaller average home ranges (18 km^2) than their counterparts in Maine, most likely because they were in more productive habitats. The Vermont coyote preferred forest habitats during winter and spring and open agricultural land during summer and fall. Person (1988) found that little quantitative research has been done in coastal plains, hardwoods and urban areas on the eastern coyote. These are the three main habitats found in Barnstable County, Massachusetts.

Coyotes are well known for being opportunists and therefore extremely adaptable in their choice of food and habitat selection. O'Connell et al. (1992) found that on an insular habitat (Mount Desert Island, Maine) there was a high percentage of raccoon (*Procyon lotor*) and an overall greater dietary diversity in eastern coyote diets despite lower faunal diversity when compared to mainland populations. Gese et

al. (1988a) has even found that juniper berries (*Juniperus* sp.) were a major coyote food source during winter in southeastern Colorado.

Coyote pup survival is low (Silvestro, 1996; Andelt, 1985), but reasons for this are unclear. Gese et al. (1997a) found that canine parvovirus substantially impacts coyote pup survival during the first three months of life. Pup mortality rates can be very high: >68% to year 1 in Alberta; 50% from birth to July in Kansas; 50% to fall in Missouri; up to 72% in Utah; over 90% in Maine (Parker, 1995) and 100% of pups on Cape Cod (Way, 1998). Parker (1995) noted that observations of captive coyotes have shown that the loss of entire litters might occur immediately after whelping, primarily among females that are nutritionally or socially stressed. He concluded that 33% survival of juveniles seems average, given estimates of population structure and an assumed small mortality among very young pups.

Detailed observations of western coyote pups, in the wild, at den sites are rare. Ortega (1988) documented two litters of pups in Arizona interact freely. These litters, produced by two separate females, were found in communal dens. Moreover, Fentress et al. (1987) concluded that observations of captive western coyote pups suggest that within the first three months pups had already developed individual long-term relationships with each adult that transcended specific interactions.

Harrison et al. (1991) and Harrison (1992) studied pre-dispersal and dispersal characteristics of coyotes in Maine. He found that there was no sex-specific differences in pre-dispersal movement patterns observed. He attributed dispersal during the fall and winter following their birth due to greater levels of aggression

among siblings. Harrison (1992) found that dispersal distances by Maine coyotes could be at least 342 km.

The influence of food availability and coyote densities upon reproductive performance and age structure has important implications for efforts to control coyotes through population reductions (Parker, 1995). The majority of coyotes harvested in early winter are juveniles. Juveniles are the most expendable part of a population, because most are dispersers that do not have established territories and experience a high rate of natural mortality (Parker, 1995). Because many juveniles would not have survived the winter anyway, mortality in this age group is considered compensatory to natural mortality factors. In essence, the removal of juveniles during the autumn actually increases reproduction in the older segment of the population, because overall density and predation in an area decreases (Parker, 1995).

In the absence of organized programs of control in areas such as the eastern U. S., more than 70% of prewhelping, and 80% of coyotes in fall populations are 3 years old or less, while less than 5% are over seven years of age (Parker, 1995). Mortality is highest on subadults, and progressively declines with age. Western populations of juvenile coyotes comprise only one-half of the autumn population, because control efforts are often intense (Parker, 1995).

The coyote is an extremely adaptable animal with regard to habitat and food selection. Reproduction is highly variable depending on natural factors and human control pressures. Although juvenile mortality is high, populations have a tremendous potential to rebound to high densities (Parker, 1995). It is important that

studies be conducted in various habitat types in the northeast if the impact and ecology of the eastern coyote is to be better understood.

Coyote/Ungulate Interactions

Coyote predation on fawns can have a direct impact on deer population dynamics. Harrison and Harrison (1984) reported that in eastern Maine, white-tailed deer were the most common animal food eaten by coyotes. The researchers found that, for coyotes, it was much more energy efficient for adults attending pups to kill proportionately more deer (over small mammals) during June and July, because of the nutritional requirements that pups have at this time. The incidence of deer observed in feces was hypothesized to be the result of coyotes feeding on newborn fawns.

Decker (1991) monitored deer fawn survival rates (n=37) in western Massachusetts. Only 6% of the mortality inflicted upon fawns was attributed to predation by coyotes. It was concluded that predation was having little effect on white-tailed deer populations in Massachusetts (Decker, 1993). Conversely, Ballard et al. (1999) found that coyotes were the primary cause of mortality of fawns >= 7 months old in northcentral New Brunswick. The authors concluded that coyotes have replaced gray wolves in northeastern North America, with survival and mortality rates being comparable between New Brunswick and other areas where wolves and coyotes are sympatric.

Springer and Wenger (1981) observed that coyotes killed an estimated 25% of all mule deer, *Odocoileus hemionus*, fawns per year in a 1,200 square mile area in central Wyoming. Coyotes, in that area, actually killed more deer per year than were taken by legal harvest. In addition, Nelson and Woolf (1987) conducted a white-

tailed deer fawn mortality study in southern Illinois and found that coyotes accounted for 69% of the natural mortality (30% overall mortality). Nelson and Woolf (1987) also noted that it is apparent that wherever coyotes and deer are sympatric it is likely that some level of predation on fawns occurs. Hamlin et al. (1984) reported that a minimum of 90% mortality of mule deer fawns was the result of coyote predation in north-central Montana. Hamlin et al. (1984) indicated that coyote predation was the major proximal factor influencing mule deer fawn survival on their study area.

Although coyote predation on fawns can be substantial, coyotes can also reduce deer numbers by preying on juvenile and adult deer. MacCracken (1984) reported that white-tailed deer were the major food of coyotes in the Black Hills, South Dakota, during all seasons. Thus, besides predation on fawns during the summer, coyotes also took adult and juvenile deer during winter. MacCracken (1984) found that coyotes form packs to hunt cooperatively where deer are the primary winter prey, e.g., in the Black Hills and speculated that coyotes are filling a niche that has recently been vacated due to the extirpation of the gray wolf.

Gese and Grothe (1995) directly observed coyote predation attempts on white-tailed deer and elk (*Cervus elaphus*) during winter in Yellowstone National Park, Wyoming. Coyotes were successful in five of nine attempts. It was concluded that two adult coyotes could successfully kill calf and adult elk (and deer) when there was deep snowcover and the prey was in poor nutritional condition.

Furthermore, white-tailed deer constituted the largest proportion of coyote diets among mammalian prey in Texas (Andelt et al., 1987). Deer were readily taken throughout the year, indicating that juveniles and adults were also preyed upon, in

addition to fawns. There was also a significantly greater consumption of deer (especially during the winter) that coincided with a higher deer density, indicating that coyotes concentrated on deer when they were more abundant.

Coursing predators (e.g., coyotes and wolves) are generally expected to take prey in poor condition because their method of hunting is by running down their prey over long distances (O'Gara and Harris, 1988). However, cooperative hunting and cover, which allows a close approach, may predispose all suitable prey, strong or weak, to coyotes. For example, the majority of deer killed by coyotes in western Montana were found to be healthy adults (O'Gara and Harris, 1988). Coyotes made most of their kills when snow was greater than 20 cm deep, because their favorite prey, voles, were not readily available. Data gathered during this study indicated that two or more coyotes could kill deer even when snow depths were negligible.

Evidence of black-tailed deer found in coyote diets in Oregon was bimodal (24% occurrence in all coyote scats), with a peak during fall and winter when most adult and juvenile deer were taken. Early summer, when mostly fawns were killed, was the other peak in the occurrence of deer in coyote diets (Toweill and Anthony, 1988).

Parker (1995) speculated about the potential impact that the eastern coyote could have on deer during the winter, especially in inland-forested wilderness areas in the northeastern United States and southeastern Canada. Data from Parker (1995) suggest that the coyote preys heavily on white-tailed deer in central and northern New Brunswick. Parker (1995) attributed a greater coyote predation effect on deer herds in the north due to: 1) an absence of severe winters in the south does not concentrate

deer, restrict movements and limit access to variable food sources; 2) there is an availability of more abundant and diverse source of prey where the weather is favorable; and 3) different behavioral patterns because of differences in environmental and food availability. Parker also notes the majority of coyote predation on deer in the south is of young fawns. In highly productive deer populations, a moderate loss of fawns to coyote predation would prove insignificant to overall herd dynamics.

It is well known that the coyote preys on all age-classes of deer. Other studies, such as Ballard's et al. (1999), should be conducted in the northeast to try and demonstrate that the eastern coyote can limit deer numbers and keep them close to natural carrying capacity with their environment like the gray wolf (Fuller, 1990; Nelson and Mech, 1981).

Coyote Social Behavior

Coyote social behavior has been shown to be extremely plastic. Research has shown that the coyote will increase pack size in order to defend carcasses, hunt cooperatively or help raise young.

Bekoff and Wells (1980) noted that pack living represents an adaptation to large, clumped food resources such as ungulate carrion. Group hunting by one or more coyotes was found to be a rare and generally unsuccessful undertaking. Instead, groups were found to defend certain food resources (i.e., carcasses; Bekoff and Wells, 1980). One of the advantages of pack living may be that a breeding female receives help in caring for her young and gets additional rest (Bekoff and Wells, 1980).

Andelt (1985) found that habitat saturation delayed dispersal of coyotes on the Welder Wildlife Refuge (WWR) in south Texas. The reason for staying on a parent's territory was improved fitness; dispersal occurred only after getting experience and competitive ability. Group size on WWR was not related to the average seasonal group home range size indicating that food was not the major reason for delayed dispersal (Andelt, 1985).

Messier and Barrette (1982) found that group living in the coyote is favored at higher latitudes since delayed maturity can mean delayed dispersal, especially at high population densities (i.e., lack of vacant territories). The existence of groups larger than a breeding pair of coyotes unlikely evolved as a result of cooperative foraging benefits, but instead increased survival rates of juveniles by staying on their natal territory for an additional year or more in order to gain more experience (Messier and Barrette, 1982).

Den area supernumeraries in the north-central Montana coyote were more prevalent when predation on deer was highest, which may have been the consequence of delayed dispersal (Pyrah, 1984). During food shortages, it was found that juveniles might remain with their parents or den adults to help in hunting.

In addition, Bowen (1981) found that packs were more successful than pairs or single coyotes in catching mule deer. The variation in the average size of prey eaten was indicative of group size and structure of coyote social units. Group foraging increased the feeding efficiency of the coyote with higher rates of deer captured and greater amounts of carcasses available per individual coyote.

Gese et al. (1988b) also found that the formation of coyote packs appears to be an advantage for finding, acquiring, and defending food, and for the care and survival of pups. During winter, coyotes were found in larger groups and most coyote predation on adult pronghorn antelope occurred after heavy snowfalls. A rise in sociality among pack members during the breeding season caused an increase in coyote group size. Larger coyote groups presented an opportunity for coyotes to be more successful at hunting for large prey.

Gese and Ruff (1997b) observed coyotes in Yellowstone National Park to behave markedly similar to gray wolves (Mech, 1970), because of the large packs and high rate of scent marking displayed by the alpha pairs of coyotes. The authors concluded that scent marking is an important strategy for coyote packs to enhance the defense of territorial boundaries. Gese et al. (1996) examined dispersal patterns of coyotes in Yellowstone National Park, Wyoming. They concluded that philopatric individuals that remained in a pack were more dominant and high-ranking than coyotes that dispersed.

Coyote social behavior is a result of many factors. When food is clumped and abundant (e.g., ungulate carcasses) coyotes tend to form packs to defend food resources. When population densities are high, juvenile coyote remain on their natal territory to gain more experience and increase survival probabilities. Finally, when food is limited, coyotes may form groups in order to successfully capture live prey.

Capture and Immobilization

Hunting and trapping has become a very controversial issue nationwide. In Massachusetts, padded-leg hold traps became illegal in 1996 (J. Cardoza, pers.

comm., Massachusetts Division of Fisheries and Wildlife). Thus, a detailed literature search on the subject of capture and immobilization is appropriate, in order to examine leg-hold trap capture efficiency and alternate means of capture of coyotes.

Capture Techniques

Sillero-Zubiri (1996) used No. 3 leg-hold rubber jawed traps to capture an endangered population (<500 adults remaining) of Ethopian wolves, *Canis simensis,* endemic to the Ethiopian highlands. Body size of the Ethopian wolf averaged 16.2 and 12.8 kg for males and females, respectively (Sillero-Zubiri, 1996). These figures are lower than weights reported for the eastern coyote in Vermont and New Hampshire (Person, 1988; Silver and Silver, 1969). The Ethopian wolf was captured with a 100% success rate, in which all wolves were captured safely and unharmed from the padded leg-hold traps (Sillero-Zubiri, 1996). In addition, Phillips and Mullis (1996) and Linhart and Dasch (1992) also found that padded traps (Woodstream Corp, Lititz, Pa) were just as effective as other unpadded traps under a variety of trapping conditions and were very safe, causing no harm to the captured animal.

Turkowski et al. (1984) tested modifying pan tension devices in order to try to specifically focus on the capture of coyotes, thus avoiding incidental catch. They found that the modified traps occasionally failed to capture coyote, but by excluding many nontarget animals, more traps remained set and operable for taking coyote. Overall, coyote captures should therefore increase through the use of trap pan tension devices.

Windberg and Knowlton (1990) noted that Carman's Canine Call Lure (CCCL) was the best olfactory attractant used to attract coyotes to a trapping site.

Leg-hold traps were most effective to capture coyotes over other capturing devices using CCCL as a lure, but it was still difficult to capture adults in core areas of use by any means (Windbert and Knowlton, 1990). Andelt et al. (1985) also found that, even using the best methods to capture coyotes (i.e., leg-hold traps), they were seldom retrapped after initial capture. Significant lower visitation rates to trap sites occurred on the study area because an estimated 80% of coyotes had prior trap experience.

Nellis (1968) described other methods of capturing coyotes alive. Snares, although cheaper, were generally less effective than leg-hold traps even when set on well-used wildlife trails. In addition, snares would have to be questioned as an acceptable management tool if the general public is already opposed to leg-hold traps. Nellis (1968) found that autoboggans (archaic snowmobiles) would chase coyotes in the open until they tired, then the operator of the vehicle could jump on and capture the exhausted animal. This technique would have to be questioned in a heavily forested ecosystem and low snowfall yield area such as Cape Cod, Massachusetts.

Mech and Gese (1992) tested capture collars (telemetry collar with anesthetic darts) on a population of wolves. They found that if used within two months (the battery life) it was very successful (86%) at recapturing animals safely.

Andelt (1980) used a helicopter and tranquilize darting with a modified capture gun to capture coyotes. He found that it was most cost effective given all variables considered, required much less capture time, had a greater selectivity for target coyotes, and had no impact on non-target species. This technique would also

have to be questioned in a forested, suburban area (i.e., Cape Cod), where animals are rarely seen.

The factors associated with limb restraint were found to directly contribute to the trauma experience by trapped red fox in a captive enclosure (White et al., 1991). Foxes that were caught in box traps, however, underwent less trauma than foxes that were restrained by a limb in a padded - or unpadded - jaw foothold trap.

There are, however, no published studies that have documented the efficiency of capturing coyotes in box traps in either captive or wild circumstances. However, The Department of Animal Control in Los Angeles County, CA has captured 545 coyote in box traps (D. Kroeplin, pers. comm.). Using 152.4 cm x 50.8 cm x 66.0 cm Tomahawk box traps, coyotes of all ages and of both sexes, including lactating females, have been captured during all seasons. Bait consisted of dead, but whole, feathered chickens wired to the top back of the cage. With leg-hold traps now illegal in an increasing number of places and other capture attempts futile in heavily forested areas, the use of box traps is one of the only legal ways remaining to capture coyotes alive in Massachusetts.

Immobilization Techniques

Early methods used ketamine and xylazine hydrochloride to chemically restrain large carnivores (Cornely, 1979; Kreeger and Seal, 1986). It was preferred at the time because there was a wide margin of safety, and a smooth induction and recovery time (Cornely, 1979). However, there was also a prolonged induction period and an extended recovery time (Kreeger, 1996).

Person (1988) chemically restrained the first two coyotes that he captured with an intramuscular injection of ketamine HCl and xylazine HCl. Because of long recovery times, an alternate method in handling trapped coyotes was developed, in which the coyote's legs were tied together and a muzzle was put over the animal's mouth resulting in the animal not being anesthetized at all.

Ballard et al. (1991) tested telazol (a combination of tiletamine hydrochloride and zolazepam hydrochloride) on gray wolves and found it to be very effective. Tiletamine HCl when used alone caused convulsive seizures and zolazepam HCl, alone, caused belligerency. The undesirable characteristics of each drug used individually are eliminated when the drugs are combined. Telazol is characterized by retention of cranial, spinal, laryngeal, and pharyngeal reflexes. Eyes usually remain open.

Ballard et al. (1991) found that telazol was a preferred restraining drug because phencyclidine HCl was no longer commercially available, etorphine was expensive, and ketamine has resulted in cardiac abnormalties and prolonged induction times. Telazol had a low cost, lower human toxicity, and rapid induction times. The only disadvantage was that there was no antagonist. In addition, Kreeger (1996) claimed that, of all drugs used in wildlife research, telazol was the best agent to immobilize carnivores.

Sillero-Zubiri (1996) used telazol with 100% success to immobilize 49 Ethopian wolves. He found telazol advantageous because it was prepared in powdered form allowing easy transport, with small volume dose requirements, a lack of adverse side effects during immobilization and recovery, and wide safety margins.

The disadvantages found were short shelf life once reconstituted, a long recovery time and a lack of reversing agent.

B. Crabtree (pers. comm., Yellowstone Ecosystem Studies) used telazol/xylazine or ketamine/xylazine intramuscularly in order to restrain and anesthetize coyote pups so that surgery could be performed to implant abdominal radio transmitters. Using either group of restraining drugs, pups were only handled for an average of 14 minutes.

In summary, padded leg-hold traps have been shown to be very effective and safe in capturing coyotes, but currently are not legal to use in Massachusetts, even for research purposes. Box traps have not been demonstrated to capture coyotes. More research needs to be done in order to document if this capture technique is effective. Telazol has proven to be very good at successfully immobilizing and recovering carnivores and should be used to ensure a safe anesthetized period for captured coyotes.

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CHAPTER 2

Box trapping: A new technique to capture eastern coyotes

Introduction

Hunting and trapping has become a very controversial issue nationwide. In Massachusetts, padded-leg hold traps became illegal in 1996 (J. Cardoza, pers. comm., Massachusetts Division of Fisheries and Wildlife). Leg-hold traps are typically used to capture wild canids. Sillero-Zubiri (1996) has used the traps with a 100% success rate (meaning no injuries reported) to capture the endangered Ethopian wolf (*Canis simensis*). Furthermore, research has demonstrated that padded-leg hold traps cause minimal injury to captured animals (Onderka et al. 1990) and are effective in catching coyotes (Phillips and Mullis, 1996; Skinner and Todd, 1990; Linhard and Dasch, 1992).

However, it has been shown that the factors associated with limb restraint directly contribute to the trauma experienced by trapped red fox (*Vulpes vulpes*) in a captive enclosure (White et al., 1991). Foxes that were caught in box traps underwent less trauma than foxes that were restrained by a limb in a padded, or unpadded, jaw foothold trap.

Box traps have been shown to be effective in capturing raccoons (Gehrt and Fritzell, 1996). In fact, Gehrt and Fritzell believed that all adult raccoons (*Procyon lotor*) residing on their core study area were captured during the study. American martens (*Martes americana*) were captured in live traps in relatively comparable numbers to Conibear 120 traps (Naylor and Novak, 1994). However, these authors did not recommend the use of box traps because of the difficulty of transport and the

high cost associated with live traps. Mowat et al. (1994) used box traps to capture lynx (*Lynx canadensis*). Although box traps caused fewer injuries than foothold traps and foot snares they were not recommended because they were expensive, cumbersome to transport and had low capture efficiency. Fuller et al. (1995) captured 15 bobcats (*Lynx rufus)* in wire box traps for purposes of a radio telemetry study in western Massachusetts. No data were given, however, on trapping success or methods.

There are no published studies that have documented the efficiency of capturing large canids in box traps in either captive or wild circumstances. However, The Department of Animal Control in Los Angeles County, CA has reportedly captured 545 coyotes in box traps for control purposes (D. Kroeplin, pers. comm.). Using 152.4 cm x 50.8 cm x 66.0 cm Tomahawk box traps, coyotes of all ages and of box sexes, including lactating females, have been reported to been captured during all seasons. Bait consisted of dead, but whole, feathered chickens wired to the top back of the cage.

With leg-hold traps now illegal in an increasing number of states and other capture attempts, such as helicopter netting, futile in heavily forested or suburban areas (Gese et al., 1987), the use of box traps is one of the only legal ways remaining to capture coyotes alive in areas like Massachusetts. In this chapter, I describe the technique and success in capturing eastern coyotes in box traps in a heavily suburban area between May 1998 and February 2000.

Study Area

Research was conducted within Barnstable County, Cape Cod, Massachusetts (approx. area 250 km^2), with a concentration in the Town of Barnstable (land area = 155.5 km^2). The estimated human population density in the Town of Barnstable was 290 people/km^2, while the entire Barnstable County averaged 203 people/km^2 (U.S. Census Bureau, 1998 estimates). The highest density was found in Hyannis with 556 people/km^2. Road density, defined as centerline km of roadway per km^2, were 4.66 for the town of Barnstable and 3.97 for Barnstable County (Cape Cod Commission, 1996, Barnstable, MA).

Cape Cod (Barnstable County) is a peninsula (1025 km^2) connected to the rest of Massachusetts by two bridges each approx. 1 km in length. The Town of Barnstable is located within 15 km of the bridges, or the west part of the peninsula. The region is classified as coastal; inland areas consist of maritime forests dominated by scrub oak (*Quercus ilicifolia*) and pitch pine (*Pinus rigida*).

Methods

Coyotes were captured in box traps (models 610A, 121.9 cm x 50.8 cm x 66.0 cm, 610B, 152.4 cm x 50.8 cm x 66.0 cm, and 610C, 182.9 cm x 50.8 cm x 66.0 cm, Tomahawk Live Trap Co., Tomahawk, WI). Traps were typically deployed in immediate areas of lower human density, such as in small watersheds, in back of cemeteries, off railroad tracks and powerlines, in conservation areas or in other predicted areas of coyote movements/activities. However, traps were spaced evenly throughout the study area, including Hyannis, the most urban part of Cape Cod. These areas were chosen because of recent coyote activity through reported public

sightings or direct documented activity. Prebaiting was often attempted in an area before traps were initially deployed. Once coyote activity was noticed, traps were deployed. Trap sites were usually spaced a minimum of 4-5 km away in an attempt to capture different coyote social groups.

The bottoms of the box traps were bedded down with material that naturally occurred in the immediate area of the deployed trap: soil, leaves, pine needles, grass, mulch and/or snow. Trap bottoms were always covered up because coyotes never approached the front of a trap when the bare metal was exposed on the ground. However, the sides and top of the trap were left exposed (i.e., wire metal visible) with the idea of keeping the trap as open in appearance as possible. Trap doors were wired open until it was decided to arm them for capture. Signs, alerting the public to this study, were placed on traps (on index cards, covered in a small plastic bag) or on nearby trees.

Bait consisted of supermarket meat scraps. Bait was placed outside the traps until it was determined that coyotes were taking the scraps; then bait was gradually placed inside the trap. Typically, when all of the bait was gone, including bones, I felt that coyotes were taking the bait. I did not document any other species that consumed all of the bait. Efforts were usually made to not arm traps until I was confident that coyotes were consistently taking the bait from the back of the trap. Generally, traps were checked every two days and baited for 2-3 months (conditioning period) until it was decided to arm them for capture.

Traps were armed during all seasons and weather conditions. Traps were checked twice daily when armed. Once as close to dawn as possible, and the second time just before dusk to ensure that non-target animals (e.g., pets) were released.

Non-coyote captures were immediately released from the traps when checked. Captured coyotes were given an intramuscular injection of telazol (a combination of tiletamine hydrochloride and zolazepan hydrochloride; Sillero-Zubiri, 1996; Ballard et al., 1991). Dr. L. Venezia of the Hyannis Animal Hospital determined the dosage amount of 8 mg/kg to be sufficient for eastern coyotes. Chemically restrained coyotes were weighed, measured, sexed and given either an implant radio-transmitter (IMP/300/L, Telonics Inc., Mesa, AZ) or a radio-collar (MOD-225 and 335, Telonics Inc.) depending on the size of the animal. All animals over one year of age, based on body size and dentition, were classified as adults (Bekoff and Jamieson, 1975).

After the handling procedure was finished (Appendix I), coyotes were put back in the box traps to recover from the sedatives. Traps were covered with blankets at all times in an attempt to calm the coyotes. Coyotes were not released from traps until fully recovered and alert. Usually this occurred approximately 12 hours after the capture and handling process. All animals were released within 24 hours in the exact place of capture, with the exception of one juvenile that had mange. It was rehabilitated (WildCare, Brewster, MA) for six weeks then released in the same place as its original capture location.

A capture was defined as an instance in which an animal was trapped and held until the next trap check (Skinner and Todd, 1990). A trap day occurred when one trap was armed for capture for one night; however, it included a 24-hour span per

trap. Thus any night captures were recorded the next day, because that is when traps were checked (i.e., even if an animal was technically captured during the previous evening it was counted the next day). Capture efficiency was defined as the number of captures/1,000 armed trap nights (Skinner and Todd, 1990).

I used the chi-square goodness-of-fit test to detect differences in the number of coyote captures/month (Ott, 1993). The most appropriate significance level was chosen based on the outcome of the test.

Results

A total of 8 traps or fewer were in the field for a total of 4,076 trap days. One trap was stolen and one was inoperable because it was too short (Tomahawk model 610A) to effectively capture coyotes; thus five/six traps were used on average at any one time during the study. Traps were wired open for 3,099 days and were armed for capture for 977 days. A total of 224 animals (efficiency = 229.3) were captured from a total of 253 sprung traps; 40 times (4% of armed trap nights; efficiency = 40.9) nothing was found in the trap but the door was shut.

The 224 animals captured (Fig. 2.1) consisted of 69 raccoons (efficiency = 70.6), 43 American crows (*Corvus brachyrhynchos*; 44.0), 35 opossums (*Didelphis marsupialis*; 35.8), 17 domestic dogs (*Canis familiaris*; 17.4), 16 eastern coyotes (16.4), 16 feral/house cats (*Felis catus*; 16.4), 13 striped skunks (*Mephitis mephitis*; 13.3), 8 red foxes (8.2), 4 gulls (*Larus* sp.; 4.1), 2 Northern harriers, *Circus cyaneus*; 2.0), and 1 muskrat (*Ondatra zibethica*; 1.0). Five pairs of crows and 3 raccoons (a mother and 2 juveniles) were captured together in the same trap. Turkey vultures

(*Cathartes aura*) and red-tailed hawks (*Buteo jamaicensis*) were commonly noted in close proximity to traps but were never captured.

A total of 11 individual coyotes (7 adults/4 pups) were captured a total of 16 times (12 adults/4 pups) during the study; one adult was captured three times, and three adults were captured twice (Table 2.1; Fig. 2.2). All recaptures involved adults. All coyotes were captured at night. Of the 4 coyote pups captured, 3 were during the summer and 1 was during the fall. Coyotes were captured throughout the year, with the exception of August and September (Table 2.2; Fig. 2.3 and 2.4). There were no significance differences in the number of captures per month (χ^2=8.02, 11 df, P>0.1).

No major injuries were reported for coyotes captured in box traps, although judging from fresh blood on two of the adult coyotes mouth's, one coyote lost half of a lower canine and an entire incisor from biting on the trap and another coyote chipped its two lower canines to the gum line (Table 2.1). Two of the three puppies captured in the summer appeared to chip off some of their deciduous teeth from biting on the traps. This was not considered as severe as the adults because they would eventually get permanent teeth. One adult had superficial cuts on one paw; it was seen running without a problem the night of its release and for the rest of the study period. Although these injuries were relatively minor compared to reported limb damage from foothold traps (Onderka et al., 1990) it should be taken into account that coyotes have the potential to injure themselves, especially their teeth and mouth, when caught in box traps.

Discussion

Adult coyotes captured during this study were some of the largest reported in the literature (Parker, 1995) but were similar in size to New Hampshire (Silver and Silver, 1969) and Vermont coyotes (Person, 1988). It is significant that the largest coyotes are all reported in the northeastern United States because it is theorized that the eastern coyote may be a hybrid between the coyote and the gray or red wolf (*Canis lupus* and *rufus*, respectively; Parker, 1995; Theberge, 1998).

For practicality, I recommend the use of Tomahawk's model 610B trap. It is long enough to capture coyotes effectively, and is much easier to transport in the bed of a pickup truck than the 610C trap. Almost an equal number of coyotes (nine in 610C and seven in 610B traps) were captured in each trap (610C traps, n=4; 610B traps, n=3). The model 610A trap is not recommended because it was too short for eastern coyotes and there was a small amount of room to put bait between the trap pan and the rear door.

Quantification of the number of times a trap was approached and avoided by coyotes (Skinner and Todd, 1990; Mowat et al., 1994) was not done because I tried to keep the surrounding areas of the traps as natural as possible. Tracks were not consistently found near a trap unless there was snow on the ground or coyotes dug at the trap site. Most of the time it was known that coyotes visited the trap site by the amount of bait remaining. Coyotes were the only species in this study area that would consume all of the meat scraps (including the bones). Domestic dogs occasionally hauled bones away but were not documented to consume all bait at a

site. I usually waited for all of the bait to consistently be consumed behind the trap pan before arming the traps for capture.

In addition, I did not record the number of potential captures (as defined by Skinner and Todd, 1990), because I had no way of knowing every time an animal came in contact with a trap. However, a couple of instances were documented in which coyotes left tracks on the trap pan, but were not captured (they did not spring the trap in both instances). A coyote was never captured at two of these geographically distinct sites (i.e., 4-5 km away from other traps; Fig. 2.2).

Although the capture efficiency rate (or catch per unit effort) for eastern coyotes (see Table 2.2) is considerably higher than Skinner and Todd's (1990) success in capturing coyotes using padded and unpadded leg-hold traps and footsnares, the numbers can be misleading. Despite spending nearly two straight years of box trapping during this study, traps were only armed for 977 trap days. They had over 6,600 trap days for each of four trap types used during their study. While I spent a large amount of time (usually over two months) repeatedly driving to traps (on average three times per week) to condition coyotes to unarmed and open traps, multiple foothold and snare traps could have been deployed and set to capture animals in an area. The entire conditioning periods for each trap site used in my study was not counted as trapping effort in the efficiency ratings. For this reason, I feel that these results are much less efficient than they initially appear.

As stated, once a location was selected, a box trap was typically not moved for months at a time. When coupled with the low number of traps (n=5-8), I was

severely limited in my efforts to capture a large sample size of coyotes. Rather, I focused on capturing specific animals in specific areas.

Coyotes were captured during 10 of the 12 calendar months of data collecting. Although the summer data (June and July; Fig. 2.3 and 2.4) appears successful in coyote captures (n=5 animals), 3 of the animals were pups, 1 of the adults was conditioned to the trap from March – June before the traps were finally armed for capture, and the 5th coyote captured during June/July was a recapture (Table 2.1; *Casper*); prior trap experience may have influenced her capture. It seems that adult coyotes can be captured during any time of the year except late summer.

Late fall/early winter and the middle of the summer appear to be the best periods to capture coyotes in box traps. Food is often less available during fall and winter. Pups appear to be vulnerable in June/July because they are making the transition from living in a den to partly foraging on their own (Parker, 1995). However, pups appeared to also become wary of the traps. Once a pup was captured in an area, the other pups in the litter seemed to stay away from the traps. In addition, one adult female that was recaptured (*Mizz*) clearly avoided box traps after that incident. Furthermore, a trap was placed near her known den of five pups. I expected to immediately capture one of the pups because of their known locations (via sightings) near the trap site. It took from May to October to finally catch one of the pups in that trap. This pup had mange (*Hap*) and appeared to be very close to death. It remains unclear as to why it was so difficult to capture this litter of 5 pups. It seems probable that adults have some way to communicate the danger of the traps to their offspring. Andelt et al. (1985) found that coyotes were seldom retrapped after initial

capture. A significant lower visitation rate on their study area seems to suggest that trap shy adults relayed this information to group members.

I did not gather enough data to statistically compare capture efficiencies between the months. For example, the highest success rate came in March but traps were armed for only five days during that month. Future, more long term, studies should collect sufficient data per month in order to accurately assess whether certain months are better times to capture coyotes.

The recapture rate of 4 of the adult coyotes (n=5) was not expected. However, all of the animals were anesthetized during their original capture. It seems possible that sedated coyotes may have forgot what happened or could have been confused by the whole event, especially since they were able to get out of the trap (i.e., when released). On two of the four recaptures, however, coyotes were let out of the trap without being handled. One animal did not enter a trap after this period but was seen eating bait immediately next to the trap site (*Mizz*). However, the second coyote that was recaptured and released from the box trap unhandled was captured a third time, four and a half months after the second capture (Table 2.1; *Casper*). Possibly some animals are behaviorally predisposed to repeatedly enter traps because of the food reward associated with the traps.

I did not capture a second adult coyote in an existing social group. It appeared that once a coyote social group (consisting of typically three members; see Chapter 3 and Appendix II) saw one of its members get captured in a box trap the rest of the animals stayed away from the traps. Towards the end of the study, it appeared that all

of the coyotes in the study area were aware of the traps because of past events (i.e., coyotes captures). It seemed that the only way to catch more coyotes was to significantly increase the study area. However, with limited time and funding and concurrently conducting the radio telemetry portion of the study (Chapter 3), moving to new areas was not desirable. I feel strongly that it is not possible to use box traps to capture and radio-tag coyotes with the purpose of capturing as many coyotes as possible in a small area in order to study interactions among coyotes. Once one coyote from a specific group was captured, it was impossible to capture another member of the group. It did appear possible to catch one coyote from a certain area, given that traps were in that area for a considerable amount of time (i.e., three or four months) and an effort was made to repeatedly check the trap. However, some of the traps never captured coyotes in certain areas despite known coyote activity around and in certain trap sites (Fig. 2.2).

Incidental captures were another problem with the box traps. Capturing non-target animals (Fig. 2.1) obviously eliminated the chance of capturing a target animal (e.g., coyote) on a given day. Furthermore, it seemed that coyotes would also shy away from the traps for extended periods of time when they saw a non-target animal captured and held inside the trap. On repeated instances, coyotes were known to enter wired open traps because scats left near the trap, tracks around and inside the trap and the general pattern of how the bait disappeared were consistent with coyote activity. When those traps were armed for capture, often times, incidental animals were quickly captured. It was very typical in a situation like that to observe massive amounts of digging (with fresh coyote tracks or scat at the trap) around the trap. In

that scenario, coyotes approached the trap when an incidental animal was already captured and held inside the trap. It was rare to capture a coyote in a trap after that happened.

It was very difficult to avoid capturing raccoon and opossum on Cape Cod. Although I am not aware of any studies that have taken place on either species in the area, they appeared to be abundant. By general appearance, some individual raccoon seemed to be recaptured multiple times in certain areas. However, because raccoons were not marked, I had no way of knowing if they were the same individuals. The only solution to problem raccoons (i.e., repeat captures) was to move traps to new sites with the hope that raccoons were not as bold in the new trapping areas.

Crows were about the only species of animals captured that I believed could be consistently not seen by coyotes. Crows were always captured during the day and they could be released before dusk. I appeared to capture a disproportionate number of crows when bait was wired up in the top rear part of the trap. It seemed that crows would put enough pressure on the trap pan by jumping up and down causing the door to fire shut. Throughout the study period, most bait was put on the ground behind the trap pan with the purpose of discouraging crows from springing the traps. Even so, many crows were still captured with bait on the ground in the back of the trap.

Domestic dogs and cats were very predictable in their capture. All dogs and cats were caught in traps that were <0.5 km and approx. 1 km, respectively, from houses. Individual dogs were repeatedly captured much like some raccoons. The only solution most of the time was to move the traps.

Although it was reported that there was nothing inside a sprung trap on 40 occasions, I have reason to believe that many, if not most, of these instances were of humans letting their pet dogs out of the box traps. In addition, many instances of shut doors could simply be attributed to human vandalism. Occasionally, signs were accidentally removed from traps (e.g., during bad weather). That seemed to be when most vandalism occurred, possibly because people did not realize the traps were there for research purposes.

There were specific instances where I was confident that coyotes managed to escape from the traps. Mainly, this occurred when traps were checked in the dark, when people were generally less active, and the next morning there was apparent fresh coyote activity near the traps. Two possible reasons for a shut door and coyotes "escaping" from the trap may be: 1) Two animals went into a trap and one coyote fired the trap door onto another coyotes back and they both managed to escape; 2) They kicked at the outside of the trap and caused the door to shut without even entering the trap. Predictably, coyotes seemed to stay away from the box traps when a sprung trap and fresh coyote activity nearby was noted.

Little effort was made to cover the top and sides of the traps. I felt that any covering of the traps would be less "attractive" to coyotes, because it would tend to enclose the area. Uncovered traps appeared to be bigger and more open in appearance because animals inside of the trap could see around them. O'Farrell et al. (1994) concluded that it was easier to capture rodents using an open trap (mesh) that could be seen through rather than an enclosed box (Sherman traps). However, additional research should investigate the effects of covered box traps in order to

analyze the success of capturing coyotes under a variety of circumstances. Also, efforts to design a trap as big as possible, e.g., as wide and tall (1.5 m is plenty long for a trap), should be attempted. Logically, it seems that the bigger an opening is the more likely an animal as wary as the coyote will be to enter the trap.

All eight of the red fox captured during the study were at the edge of existing coyote group home ranges (see Chapter 3; Fig. 2.2) or in areas where coyotes were not successfully captured. Major and Sherburne (1987), Harrison et al. (1989) and Theberge and Wedeles (1989) have described interference competition that was inferred from spatial and temporal segregation displayed by foxes avoiding coyotes. Future studies should include a suburban, coastal, and relatively restricted area (a peninsula) such as Cape Cod to examine fox distribution relative to coyotes.

Management Implications

Although it has been demonstrated that it is possible to capture coyotes using box traps they are relatively impractical because:

- They are very expensive (>$250/trap),
- It is very difficult to capture additional adults in a coyote social group,
- They are very cumbersome,
- They are very time intensive to check and must remain in a specific area for a long period of time (months) in order to condition local coyotes into the trap, and
- There is a high incidental catch of non-target species.

I suspect that padded leg-hold traps would be more efficient in capturing a greater number of coyotes in a relatively small area, especially multiple coyotes in a social

group. In addition, the money saved using leg-hold traps instead of box traps as the capture technique, could divert valuable funds into the monitoring of free ranging radio-collared coyotes. Strictly for research purposes, I recommend the use of padded leg-hold traps in order to capture and release coyotes for scientific study in Massachusetts.

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Table 2.1. Data from eastern coyotes captured in box traps between June 1998 and February 2000 within the Town of Barnstable, Cape Cod, Massachusetts.

ID	Date	Sex	Age	Weight (kg)	Length (cm)	Comments	Injuries whil in trap	Fate
Pon	6-8-98	M	P	6.7	98	Implant given	Chipped dec-iduous teeth	killed by car (10/6/98)-wt=15.9 kg
Poo	6-17-98	M	P	6.9	98	Implant given	None	killed by car (9/13/98)-wt=12.3 kg
Snix	6-19-98	F	Y/A	14.5	130	Healthy/thin	1 chipped can-ine appeared unrelated to capture	see below
Casper	11-30-98	F	A	23.2	149	Robust	None	see below
Kett	12-16-98	M	A	19.3	150	Sinewy	Superficial cuts on paw (minor)	see below
Mizz	2-25-99	F	A	13.6	122	small/silver color	None	see below
Casper	3-6-99	NT	A	NT	NT	Recapture # 1	Broken canine missing inciso –fresh blood on mouth	see below
Mizz	4-22-99	NT	A	NT	NT	Recapture # 1	None	alive as of 2-20-00
Sly	5-15-99	M	Y/A	17.6	141	Scent used at trap	Both lower canines were broken to gum line. Blood on mouth.	alive as of 2-20-00
Cup	7-11-99	F	P	7.3	103	Implant given	Chipped decid uous teeth	contact lost 1-8-00 – Dispersed
Casper	7-26-99	F	A	19.5	140	Recapture#2-thin[1]	None	alive as of 2-20-00
Hap	10-1-99	M	P	8.2/ 12.7[2]	118	Had Mange	None	alive as of 2-20-00
Kett	11-5-99	M	A	20	146	Recapture#1	None	alive as of 2-20-00
Glope	1-14-00	M	A	20.4	152	tan/distinct eye rings	None	contact lost 2-16-00 – Dispersed?
Sill	1-18-00	M	Y/A	16.8	138	silver striped shoulders	None	alive as of 2-20-00
Snix	1-19-00	F	A	14.5	135	howled in trap for 10 min.	None	died 1-28-00 -Glomerulo-nephritis

P=Pup; A=Adult; Y/A = Possibly a yearling coyote, but treated as an adult in the text.
NT = Measurements not taken; animal was released from the trap without being handled.
[1]Appeared to have whelped a litter based on body condition.
[2]Estimate of 8.2 kg on 10-1-99; 12.7 kg after rehabilitation on 11-23-99; Released to wild 11-24-99.

Table 2.2. Monthly and total capture efficiencies of eastern coyotes captured in box traps during 977 armed trap days between June 1998 and February 2000 within Barnstable County, Cape Cod, Massachusetts.

Month	Armed trap days	Coyotes captured	Efficiency[1]
January	135	3	22.2
February	85	1	11.8
March	5	1	200.0
April	87	1	11.5
May	83	1	12.0
June	148	3	20.3
July	135	2	14.8
August	99	0	0
September	19	0	0
October	50	1	20
November	66	2	30.3
December	65	1	15.4
Total	**977**	**16**	**16.4**

[1]Captures/1,000 armed trap nights

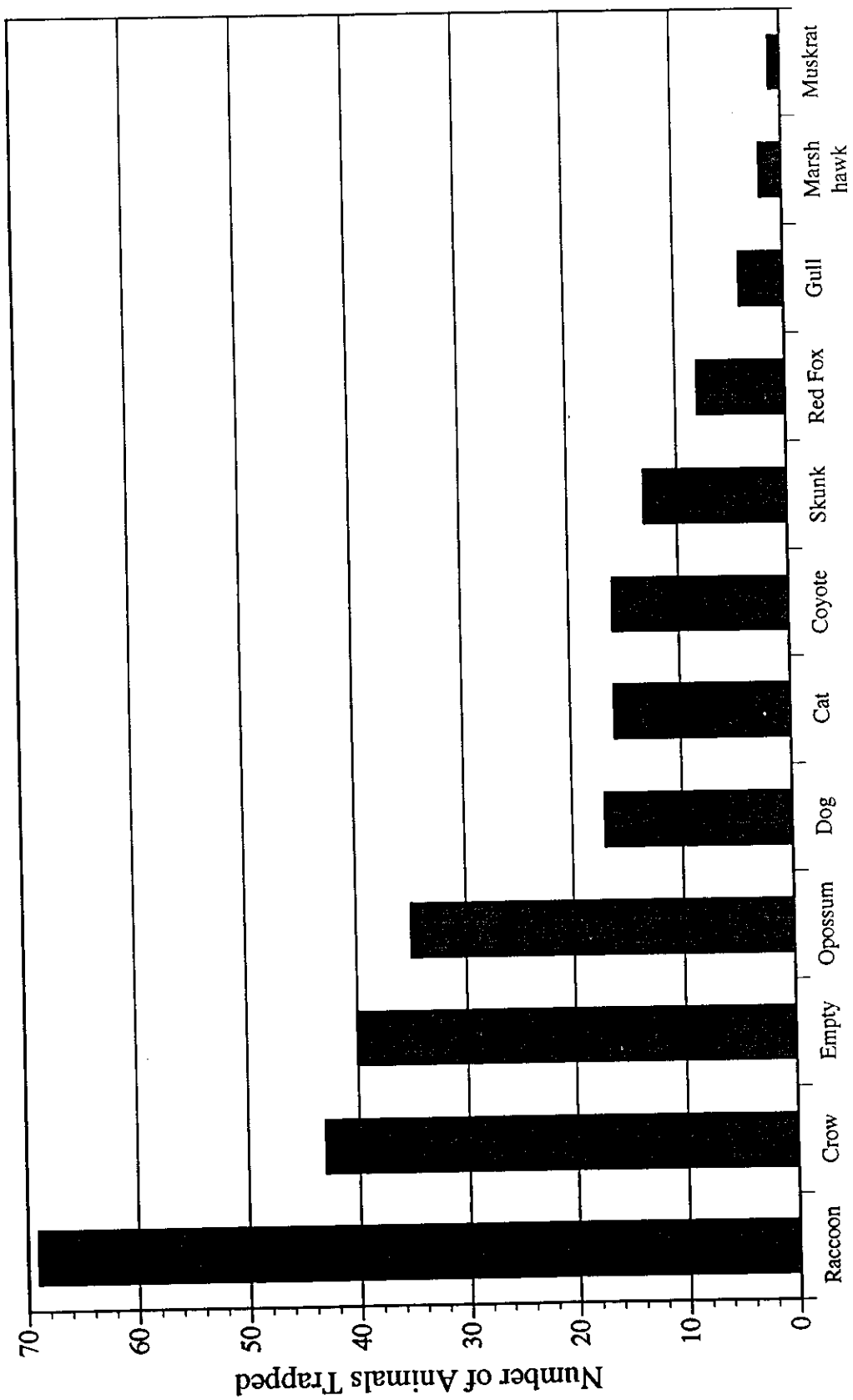

Figure 2.1. Diversity of species and number of animals captured using box traps during 977 armed trap days between May 1998 and February 2000 within BarnstableCounty, Cape Cod, Massachusetts.

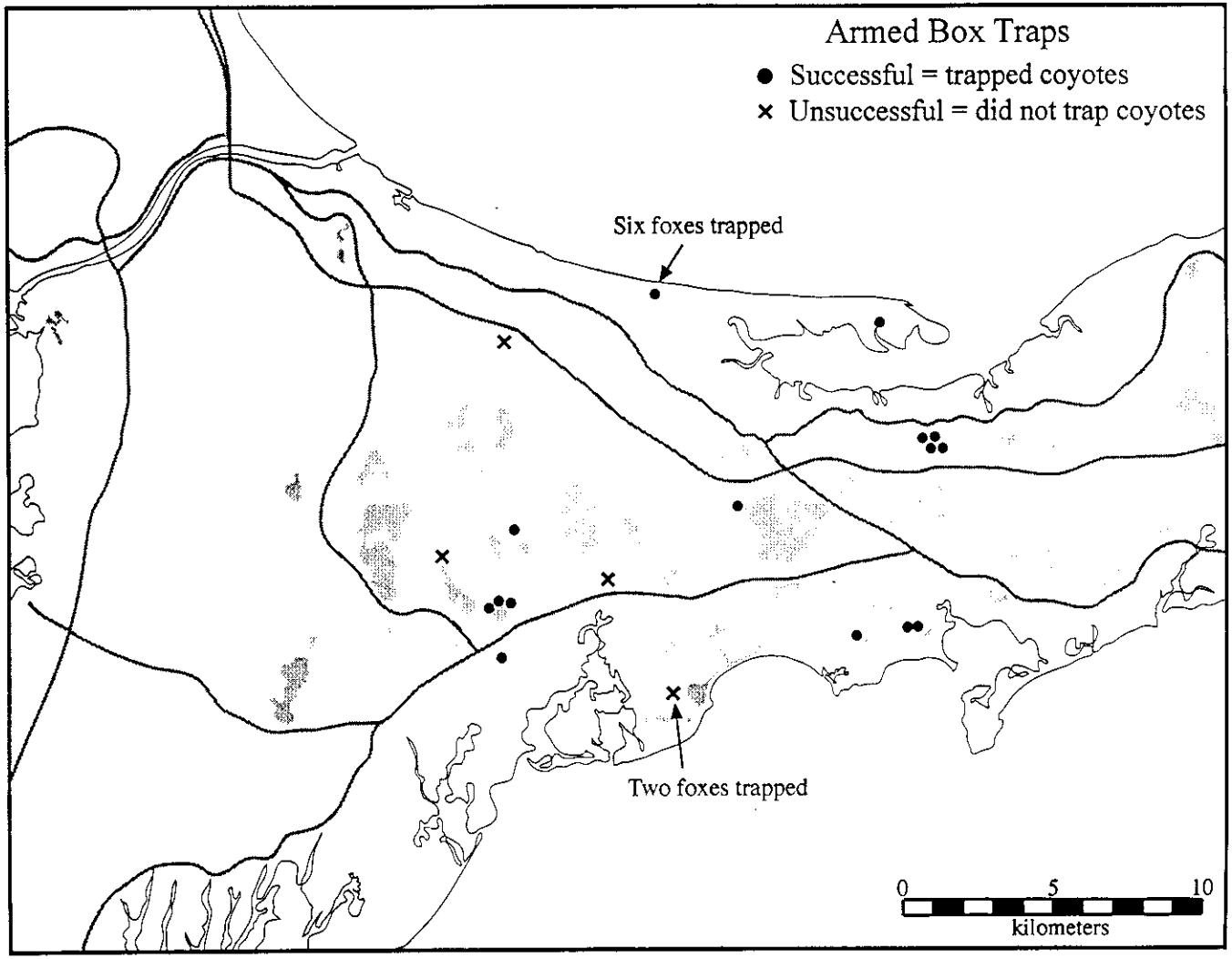

Figure 2.2. Armed box traps showing where coyotes and red foxes were captured on Cape Cod, MA., between May 1998 - February 2000.

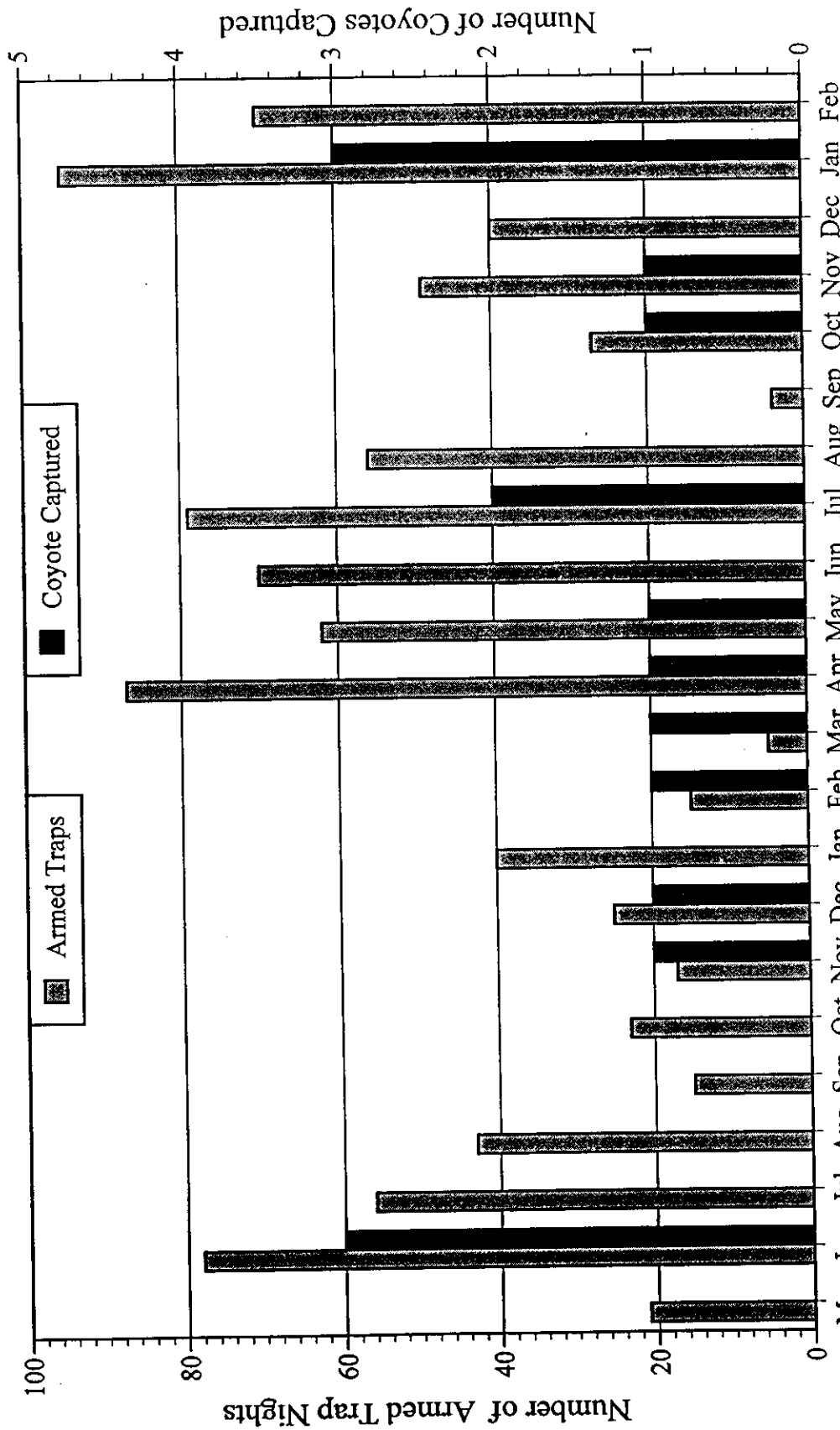

Figure 2.3. Number of monthly armed traps and eastern coyotes captured between May 1998 and February 2000 on Cape Cod, Barnstable County, Massachusetts.

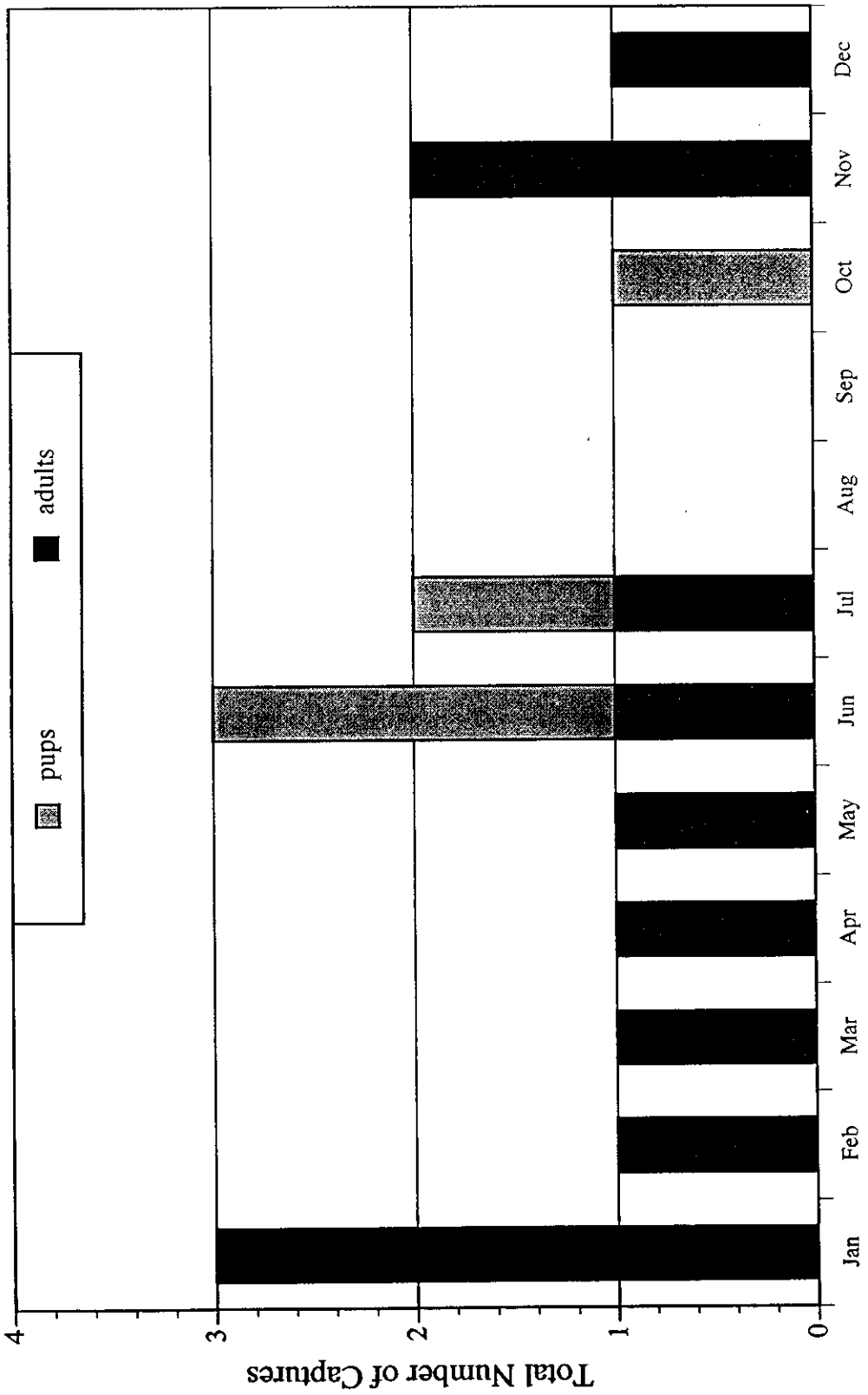

Figure 2.4. Total number of pup and adult eastern coyotes captured in box traps per month between May 1998 and February 2000 on Cape Cod, Barnstable County, Massachusetts.

CHAPTER 3

Home range, movement, activity patterns, and sociality of Cape Cod coyotes

Introduction

Numerous studies have described home range, movement patterns, activity patterns and/or habitat use of coyotes, *Canis latrans*, throughout North America (Andelt, 1985; Gese et al., 1988; Litvaitis and Shaw, 1980; Bowen, 1982; Holzman et al., 1992; Springer, 1982; Windberg et al., 1997; Parker and Maxwell, 1989; Knowlton et al., 1999; Laundre and Keller, 1981), and, specifically in New England (Person and Hirth, 1991; Person, 1988; Harrison and Gilbert, 1985; Harrison et al., 1989). Home range and habitat use has been shown to be highly variable depending on geographical location. Coyotes are thought to be mostly nocturnal (Atkinson and Shackleton, 1991) with more limited daytime movements (Andelt, 1985). Sociality is reported to be very variable in coyotes, ranging from coyotes living in packs much like gray wolves, *Canis lupus* (Gese and Ruff, 1997; Andelt, 1985), to the mated pair as the main group size (Harrison, 1992).

However, few studies have been conducted on coyotes inhabiting suburban or rural areas (Atkinson and Shackleton, 1991). No studies of eastern coyotes, *Canis latrans* var., residing in heavily developed areas have been conducted.

Studies have shown that coyotes (Atkinson and Shackleton, 1991; Person and Hirth, 1991), raccoons, *Procyon lotor* (Riley et al., 1998), and red foxes, *Vulpes vulpes* (Baker et al., 1998), inhabiting agricultural, suburban or urban areas tend to have smaller home ranges and exist in higher densities than in more rural, wooded

areas. Increased productivity and a greater availability of resources are believed to be the primary reasons these species exist in greater numbers in human dominated areas.

Eastern coyotes are believed to be a relative newcomer to New England (Parker, 1995). Coyotes are thought to have arrived in western Massachusetts during 1957-58 and were first documented on Cape Cod during the late 1970's (J. Cardoza, pers. comm., Massachusetts Division of Fisheries and Wildlife). There remains a lack of scientific knowledge on the ecology and impact of eastern coyotes existing in recently colonized suburban and urban habitats. In order to better understand the biology of this species, I studied home range sizes, movement and activity patterns, and sociality of eastern coyotes existing in a heavily suburban area (Cape Cod, Massachusetts) between June 1998 and March 2000.

Study Area

Research was conducted within Barnstable County, Cape Cod, Massachusetts (approx. area 250 km^2), with a concentration in the Town of Barnstable (land area = 155.5 km^2; Fig. 3.1). The estimated human population density in the Town of Barnstable was 290 people/km^2, while the entire Barnstable County averaged 203 people/km^2 (U.S. Census Bureau, 1998 estimates). The highest and lowest densities of people were found in Hyannis with 556 and West Barnstable with 89 people/km^2 (Fig. 3.2). Housing units varied from 328.3/km^2 in Hyannis to 39.3/km^2 in West Barnstable. Road density, defined as centerline km of roadway per km^2, were 4.66 for the town of Barnstable and 3.97 for Barnstable County (Cape Cod Commission, 1996, Barnstable, MA).

Cape Cod (Barnstable County) is a peninsula (1,025 km^2) connected to the rest of Massachusetts by two bridges each approx. 1 km in length. The Town of Barnstable is located within 15 km of the bridges, or the west part of the peninsula. The region is classified as coastal; inland areas consist of maritime forests dominated by scrub oak (*Quercus ilicifolia*) and pitch pine (*Pinus rigida*).

Methods

Eastern coyotes were captured in model 610B & 610C Tomahawk box traps (Tomahawk Live Trap Co., Tomahawk, WI; see Chapter 2). Traps were checked two times a day. Non-coyote captures were immediately released from the traps when checked. Captured coyotes were given an intramuscular injection of telazol (a 50 percent combination of tiletamine hydrochloride and zolazepan hydrochloride; Sillero-Zubiri, 1996; Ballard et al., 1991). Dr. L. Venezia of the Hyannis Animal Hospital determined the dosage amount of 8 mg/kg to be sufficient for eastern coyotes. Chemically restrained coyotes were weighed, measured, sexed and given either an implant radio-transmitter (IMP/300/L, Telonics Inc., Mesa, AZ) or a radio-collar (MOD-225 and 335, Telonics Inc.) depending on the size of the animal. All animals over one year of age, based on body size and dentition, were classified as adults (Bekoff and Jamieson, 1975).

Coyotes were classified as breeding residents, resident associates, juveniles, and transients (Andelt, 1985). *Breeding residents* were adult animals that had established home ranges and exhibited breeding behavior (e.g., pair bonding or denning; Person and Hirth, 1991). *Resident associates* were adults/subadults with home ranges that overlapped extensively with those of resident breeders and were

directly observed interacting with breeding residents. A coyote that was captured between January and March and was determined to be a probable *pup* of the year was classified as a *subadult*. Offspring of the year (*pups*) were classified as *juveniles*. *Transient coyotes* were adults with large, poorly defined home ranges (Person and Hirth, 1991).

Telemetry Techniques

Portable receivers (Custom Electronics, Urbana, IL) and hand-held 3 element Yagi antennas were used to radiotrack coyotes. Typically, antennas were wedged into (thus, hanging outside) a moving vehicle's closed window until a signal was received. Once a signal was obtained, the researcher would remove the antenna from the window and take a hand held fix in order to determine the direction of the signal. This process was repeated until the animals were pinpointed by using the loudest-signal method (Springer, 1979). Due to the suburban environment and the associated high density of roads, once a signal was obtained for a given coyote I was confident that these successful radio-fixes were recorded as known coyote locations (i.e., within 50 m of their actual locations). I was not always able to find a specific coyote (i.e., no radio-signal obtained) during a tracking bout; this resulted in an unsuccessful radiolocation.

Conducting two controlled experiments tested precision and accuracy. First, radio collars were placed in the field. A second person radio-located the collar and recorded its location on a map. Both technicians mapped locations, and then compared results. Second, two observers would independently radio-locate a bedded coyote and record its location. Both experiments were repeated 30 times. From these

two experiments and the actual tracking of collared coyotes in the field, it was believed that >80% of telemetry fixes were accurate to within an area of 50 m^2.

An attempt was made to locate each coyote daily throughout the study. Consistent efforts were made to locate coyotes approximately evenly during all hours of a 24-hour period. In order to avoid geographical and serial autocorrelation between successive relocations (June 1998 – January 1999) individual coyotes were initially located by point sampling no sooner than every eight hours (Laundre and Keller, 1984; Person and Hirth, 1991; Harris et al., 1990; Swihart and Slade, 1985a&b). However, realizing the benefit of collecting sequential locations (Gese et al., 1990; Reynolds and Laundre, 1990; Laundre and Keller, 1984), coyotes were tracked as often as possible from February 1999 - March 2000 in an attempt to accurately understand actual movement patterns and areas used by each coyote during a 24-hour time span (Andelt, 1985).

Animal activity was determined by signal modulation and activity was recorded as either resting or active (Person and Hirth, 1991). I used the chi-square goodness-of-fit test to detect differences in daily activity patterns (Ott, 1993). The most appropriate significance level was chosen based on the outcome of the test.

Universal Transverse Mercator (UTM) X and Y coordinates from each recovered telemetry find were determined by using a digitized mapping program (Terrain Navigator, Maptech, Greenland, NH). Locations were recorded in a spreadsheet for analysis.

Radio collared coyotes and companions were often sighted during night tracking efforts. Occasionally I positioned my vehicle in predicted areas of coyote

travel (e.g., railroad tracks, powerlines) and sighted coyotes cross (undisturbed) in front of my turned-off vehicle. Spotlighting, however, was the most common technique to observe coyotes. Areas were scanned for approximately 4-8 seconds each time a coyote was believed to be close to my vehicle. Because the coyotes ran away from the spotlights on >90 % of the sightings I tried to keep the spotlights on for no more than 8 seconds per social group per tracking session to try to reduce altering their behavior. If an individual or group was successfully sighted via spotlighting I typically left the area for >1 hour and went to find a new coyote group. This was done to reduce altering their behavior by continuingly following them. If I was able to see an individual or group of coyotes without spotlighting then I continued to follow them with the belief that I had not influenced their behavior. Based on observed coyote movements (via telemetry) before and after sightings it quickly became apparent when I was altering their behavior. For instance, if a group of coyotes was moving on a corridor (e.g., powerlines) for 2-3 km and all of a sudden they changed their course of travel when I sighted them, then I typically would leave the area realizing that I most likely caused them to move in a direction that it did not appear that they were heading.

A detailed description was kept on group size and characteristics of each coyote, especially uncollared animals, in an attempt to aid in individual identification (see Appendix II). Collared coyotes were considered together if they were <300 m apart (Harrison and Gilbert, 1985) and there were no roads separating them.

Home Range Analysis

Home ranges were calculated by using the minimum convex polygon (MCP; Mohr, 1947) and the vertex edit methods in the animal movement analysis Arc View extension program (Hooge and Eichenlaub, 1997). Coyote radiolocations were overlaid on a topographical map (Terrain Navigator) that was imported and rectified into the program animal movement in Arc View. For each method 100% and 95% of the most tightly clustered data points were used. Harmonic mean outliers were used to calculate and delete the outer 5% of data. After each 100% and 95% MCP was drawn, I subjectively modified each polygon in the vertex edit mode to include only areas that were most likely used by each coyote. Therefore, parts of the polygons that included major bodies of water, urban areas believed not to be used by coyotes and any other similar areas were deleted. Sample movement patterns were mapped and distances calculated by creating polylines from point files in the animal movement analysis Arc View extension program (Hooge and Eichenlaub, 1997).

I grouped animal locations into yearly home ranges but also compared the denning movements (Person and Hirth, 1991) of a female coyote determined to be reproductive (*Mizz*) in 1999 with a female determined to be nonreproductive (*Snix*). April was selected as the denning month (Parker, 1995) and was predicted to be the least a female coyote will move during the year. Denning movements were compared to overall yearly home ranges.

I used the *separate-variance t test* to compare juvenile and adult and male and female home range sizes (Ott, 1993). The most appropriate significance level was chosen based on the outcome of the tests.

Results

Eleven coyotes (6 adults: 3 males and 3 females; 1 subadult male; 4 pups: 3 males and 1 female) were captured a total of 16 times. All recaptures (n=4 animals a total of 5 times) involved adults (see Chapter 2). A total of 3,086 radiolocations, representing 2,973 successful and 113 unsuccessful finds, were obtained between June 1998 and March 2000 (Table 3.1).

Home ranges sizes were variable depending on the method used (Table 3.2). Average home range for breeding adult coyotes using the 95 % MCP vertex edited method was 29.7 $\pm$ 5.3 (SE) km^2. Resident male home ranges (39.1 $\pm$ 0.3 (SE) km^2) were larger than resident females (23.6 $\pm$ 6.7 (SE) km^2; $t=7.83$, 6 df, $P<0.001$). Resident coyote groups showed limited overlap in home ranges after the outer 5% of data were deleted and the polygons were adjusted to correlate with actual, known movement and location patterns (95% MCP vertex method; Fig. 3.3).

Juvenile coyotes had small home ranges varying from 0.3 – 10.8 km^2 depending on method of data analysis used and individual animal (Table 3.2). They were significantly smaller than resident adult home ranges ($t=4.7$, 4 df, $P<0.005$). Conversely, one transient and one associate had the largest home ranges (152.2 km^2 and 100.4 km^2, respectively) in the study. While the transient appeared to be a nomad with no discernable center of activity, the associate made multiple trips outside of its apparent natal home range (Fig. 3.4).

The home range of *Mizz*, a reproductive coyote, during the denning season (April 1999) was 16% of her yearly home range (2.0 km^2 versus 12.4 km^2 using the

95 MCP vertex edit method). Conversely, *Snix*, a non-reproductive, resident coyote maintained a yearly home range of 22.8 km^2 (95 vertex); during the denning season her range was 14.3 km^2, or 63% of her annual home range (Fig. 3.5).

Sightings during the study period (n=230) indicated that resident coyotes typically lived in groups of three members (Tables 3.3 and 3.4). It appeared that by late-fall (November) all pups either died or dispersed because tagged animals were believed to be traveling with the same coyotes based on individual markings (see Appendix II). Only two observations, not including summertime observations (Table 3.5), consisted of four coyotes (Table 3.4). *Snix*'s group was the only group that was not documented in a group of three: however, she was never determined to be reproductive (summers 1998 and 1999), even though she did appear to be pair bonded and was frequently (n=21) observed with a second coyote. Possibly *Snix*'s lack of successful reproduction precluded additional members (i.e., pups of the year) from joining that group. Collared adults were often sighted alone (n=121); however they were frequently sighted with other coyotes before and after these sightings suggesting that additionally animals were likely nearby or that group members occasionally hunted and/or traveled alone but regularly rejoined each other.

Coyotes were noticeably nocturnal with activity generally beginning just after dusk and ending just before dawn (χ^2=748, 11 df, P<0.001; Table 3.6; Fig. 3.6), except when adults were tending pups (e.g., mid-spring – mid-summer) and during the winter. However, daytime activity was associated with short distance movements (<2 km). All large-scale movements (>2 km) were documented during the night. One exception occurred when a radio-collared coyote (*Snix*) was moved (by a

researcher) approx. 2 ½ km during the day. However, this event took place on the largest conservation area in the Town of Barnstable (Sandy Neck Beach), which is approximately 10 km long x 1 km wide in area.

Cape Cod coyotes regularly traveled long distances (Table 3.7). *Sill*, an associate coyote, regularly left his natal home range on predispersal forays (Harrison et al., 1991) then returned under the cover of darkness (Fig. 3.4). *Glope* regularly traveled nomadically around the study area with no apparent direction (Fig. 3.7). *Sly, Casper* and *Kett* regularly traveled throughout their established home ranges (Fig. 3.8).

Discussion

Home Range Analysis

I believed that it was important to include unsuccessful radio-fixes in the results. Because automobiles were used to track coyotes (i.e., not airplanes), each unsuccessful find of a coyote during a tracking bout could possibly result in an underestimate of actual home ranges displayed by the coyotes in this study. It usually took a month of tracking in order to understand which areas individual coyotes were using; after this time, search patterns maximized the efficiency of repeatedly being able to locate radio-collared coyotes.

Not surprisingly, the coyote with the most unsuccessful finds (*Cup*) was the coyote that dispersed (in January) during the study. Harrison (1992) did not document any December-January coyote dispersals on his Maine study site. However, Person (1988) did document coyotes that dispersed during January (n=3) in Vermont.

Additionally, this coyote (*Cup*) used only 10 % (95 MCP vector edited) of her probable mother's (*Casper*) home range before dispersing (Fig 3.3). There is a lack of published data describing how juvenile/transient coyotes set up home ranges in new areas (Person and Hirth, 1991). However, it is of particular interest that this juvenile used a fraction of its parent's home range before dispersing.

All juvenile coyote home ranges were significantly smaller than adults in this study (Table 3.2; Fig. 3.3). These agree with findings from Person and Hirth (1991) and Harrison et al. (1991). The very small home range of one juvenile coyote in particular (*Hap*) was very peculiar, especially considering that he was monitored until March. However, this pup was infected with mange when originally captured and was rehabilitated for six weeks before being released. Perhaps the animal passed a critical stage in its learning and developmental process when it was either sick in the wild or while held in captivity. Following release, *Mizz* and two other coyotes frequently passed through the area but *Hap* was never observed traveling with them. Although *Hap* did survive the winter existing in a small woodlot (<0.5 km^2) bordered by houses and roads on all sides, he was considered to be aberrant to normal juvenile movements during winter (Harrison, 1992). Future research should investigate the success of releasing rehabilitated animals of all ages into the wild. (Note: Just as the study concluded, 20 Mar. 2000, *Hap* was documented to disperse and leave the study area. Based on conversations with people who lived in the area, *Hap* apparently was not observed for the four months that he inhabited the small woodlot prior to his dispersal.)

Future research should attempt to document how coyotes establish new home ranges after dispersing (Harrison, 1992). Capturing coyotes when they are young juveniles and monitoring them to adulthood will help resolve behavioral questions such as how much is innate or learned when coyotes disperse and establish themselves in a new area.

Because of the suburban, fragmented nature of the study area, I believe that modifying a MCP in the vertex edit mode is the best technique to successfully map coyote home ranges and actual areas used. With many unsuccessful radio finds (Table 3.1) for each coyote, coupled with deleting 5% of the known outlying data, I felt that the 95% MCP vertex edited polygon produced the most accurate description of each coyotes' actual home range area. Each coyote was radio located frequently during the course of the study (Table 3.1); therefore, I elected to use the vertex edit technique because it was believed that actual areas used by each coyote were known (Fig. 3.9). For example, a breeding female (*Snix*) inhabited a barrier beach (Fig. 3.10). The 100 (55.6 km^2) and 95 (32.4 km^2) MCPs included a large salt marsh as part of her range. However, she was never documented using that area. The resulting 100 (38.1 km^2) and 95 (22.8 km^2) vertex-edited home ranges were noticeably smaller than the original MCP estimates (Table 3.2).

I do not believe that any existing studies have recovered more data/coyote in the same time span as this study (20 months). Although I am aware of no studies using this technique, I recommend the 95% vertex edit method to accurately map coyote home ranges in fragmented areas or areas where it is obvious that coyotes are not using part of a standard polygon's area, especially if there is a large dataset with

which to accurately make your modifications. Although the harmonic mean method traditionally has been a popular technique to determine home range sizes (Dixon and Chapman, 1980; Person and Hirth, 1991) I did not use this technique because of the many problems associated with its home range calculations (Hooge and Eichenlaub, 1997; White and Garrott, 1990).

Home range sizes of adult resident coyotes on Cape Cod appeared to be within the range of the literature for eastern coyotes (Table 3.8). Although Person and Hirth (1991) documented a 75% reduction of home range size in more urban areas of Vermont all adult coyotes in my study maintained large ranges while inhabiting a highly suburban environment. Interestingly, however, *Mizz*, who resided in the most urban part of Cape Cod (Hyannis) with a population density of 560 people per km^2 and a housing density of 330 per km^2, had the smallest home range of all of the breeding coyotes. However, she regularly traveled throughout this area and was not observed making forays beyond her established home range. Most of the adult coyotes occasionally left their normal area of activity; *Mizz* was the exception.

Although males and females had different home range sizes on Cape Cod, I suspect that the opposite is actually true (Person and Hirth, 1991). Because Cape Cod coyotes appear to be territorial, I believe that similar home range sizes would exist between the two sexes if there was a higher sample size of each sex and 2-3 adults of each social group under study were radio-collared. All resident adults used regular, well-defined home ranges and appeared to travel with the same coyotes (Appendix II).

Person and Hirth (1991) documented that coyotes have smaller home ranges during the denning season. Furthermore, Mech et al. (1998) noted that non-reproductive wolves maintain their approximate annual home range during the denning season. *Snix* (nonreproductive) appeared to maintain the majority of her home range, while *Mizz* (reproductive) used a fragment of her yearly range during the denning season (Fig. 3.5). This is consistent with the published literature.

Not surprisingly, *Glope*, a transient, had the largest home range and was frequently documented traveling in and out of existing resident coyote social groups much in the same way as described by Person and Hirth (1991) (Fig. 3.7). *Sill*, an associate coyote, focused the majority of his movements in his natal range but made a few long distance trips. These movements greatly increased the overall area of his range when 100% vs. 95% of the data were used (Fig. 3.11).

Territoriality

Cape Cod coyotes appeared to be territorial by maintaining mutually exclusive home ranges. This is consistent with the literature (Andelt, 1985; Bekoff and Wells, 1986; Person and Hirth, 1991; Sacks et al., 1999). The 95% MCP vertex method used in this study appears to correlate with the 75% harmonic mean method used in Person and Hirth's (1991) study. Both studies showed limited overlap of adjacent coyote groups (Fig. 3.3). Although transients (e.g., *Glope*) and even adults, traveled through existing resident coyote's home ranges they spent little time in these areas (maximum = 3 days in one home range) and adults never left their established home ranges (95% MCP Vertex) for more than one night (Fig. 3.3).

Besides the observed spatial segregation from adjacent groups (radio telemetry data) I directly observed territorialism. On 29 Dec. 1999 *Snix* was located within *Casper* and *Sly*'s group's home range (believed to be three members). At 11:15 PM *Casper* and *Sly* were >5 km away from *Snix*. However, at 11:45 PM *Casper* and *Sly* were located very close to *Snix* (<200 m). At 11:59 PM, *Snix* was directly observed running along the edge of a major road under a lighted part of the street. At 12:53 AM on 30 Dec. 1999 *Snix* was observed with a second coyote back in her normal, resident home range approximately 7 km from her encounter with *Casper* and *Sly*.

The second incident took place on 9 Feb. 2000 at 7:40 AM; this was one of the few daytime observations of coyotes that were witnessed. *Mizz* and two coyotes that were regularly seen traveling with *Mizz* were in the center of their home range on a golf course. At 7:50 AM, the three coyotes split up. *Glope*, a transient coyote, (whose signal was obtained on the same golf course during the initial sighting of *Mizz* et al.) immediately chased and pinned one of the coyotes (it was thought that the pinned coyote was a female that *Glope* was attempting to pair bond). When the pinned coyote made a loud whining and audible sound, *Mizz* and the second coyote (assumed to be the breeding male) ran straight to the scene. The uncollared coyote chased *Glope* for >1 km. After *Glope* was chased, he left the golf course and crossed a major road during the daytime. The next day, *Glope* was located at the edge of Mizz's group's home range. He was sighted three days later and appeared to be uninjured. Although wolves have been documented to kill other wolves (Mech et al., 1998), I am not aware of any studies that have shown coyotes killing other coyotes.

Perhaps direct chases such as the two observed during this study, coupled with howling (Lehner, 1978) and scent marking (Gese and Ruff, 1997) are enough to keep coyotes from separate groups from regularly meeting and killing each other.

Sociality

The data in Table 3.3 only revealed the winter and spring group size of adults, because observations of pups/juveniles would have over inflated the estimates for resident group sizes. The five largest group sightings involved pups. One group involved seven coyotes: three adults and four pups during July 1999; four other groups involved one adult and five pups (all during June). Table 3.5 lists the number of pups and associated adults observed from various litters on Cape Cod. However, the dispersal and mortality of juveniles makes them meaningless in coyote social group estimates. Population estimates should focus during the winter and spring when coyote population levels are theoretically and practically at their lowest points during a given year (Parker, 1995).

It should also be noted that the sighting data (Table 3.3) are highly biased to sightings of collared animals. Animals were located using radio telemetry as a technique, thus collared animals were disproportionately observed the most often. Although there were many single sightings (n=121) during the study there is a good chance that there were nearby animals associated with collared animals that simply were not observed (85% of the sightings were made during the night).

Resident coyotes on Cape Cod appeared to be very social and maintain cohesive, but small, groups. Individual identification of non-collared coyotes was recorded (Appendix II) and it was highly suspected that the same adults were

repeatedly seen with radio-collared coyotes on multiple occasions. Furthermore, *Casper* and *Sly* maintained separate home ranges before first being located together (0 of 253 paired observations); however from December 1999 to March 2000 they were located together on 87 % of paired observations (n=109/126). From December – March their home ranges encompassed the majority of both of their respective original ranges; that they were pair bonded for the 2000 breeding season (see Appendix II).

Kett and *Sill* (breeder and associate, respectively) were located together on 35 of 60 observations (58%) from mid-January 2000 – March 2000. They were not always located together and this might explain why there were many sightings of single, collared animals. Based on *Sill*'s activity near *Kett* and a third coyote (most likely a breeding female), it seems that resident coyote groups consist of a breeding male and female and a resident associate that probably is a pup of the year. They appear to regularly separate and rejoin each other on a daily basis, thus sightings of collared animals can be highly biased depending on when the sighting is made (e.g., when they are alone or together).

Dispersal and/or mortality are perhaps the two single greatest reasons for small group sizes (Harrison, 1992). Although food does not appear to be limiting on Cape Cod for coyotes, the group sizes observed were relatively small when compared to the literature on coyote social ecology (Andelt, 1985; Gese and Ruff, 1997), but seemed to be consistent with coyotes from Maine (Harrison, 1992) and Vermont (Person and Hirth, 1991) and almost exactly as described for California coyotes in an agricultural area (Sacks et al., 1999).

For example, *Casper* (breeding female) and *Cup* (juvenile) were located together 33% of the time (n=90 paired observations) between July and October 1999. However, they were not documented together from November 1999 – January 2000 (n=56), when *Cup* dispersed (although she was always documented in *Casper*'s home range before dispersal). Additionally, two juveniles (*Pon* and *Poo*) were located together 69% of the time (n=100 observations), however, they were only located together 50% of the time in September and appeared to be spending less time together up until *Poo* was struck and killed by a car.

Research should continue to investigate group size dynamics and the sociality of eastern coyotes residing on suburban Cape Cod. Focusing on juvenile coyotes and dispersal patterns will give insight into the population growth potential and survival rates of coyotes inhabiting Cape Cod.

Activity and Movement Patterns

The high rate of nocturnal activity of Cape Cod coyotes was very similar to other studies (Andelt, 1985; Laundre and Keller, 1981; Atkinson and Shackleton, 1991). However, little daytime activity was recorded (Andelt, 1985; Fig. 3.6). This was not surprising however given the suburban environment in which this work was conducted. While coyotes appeared to generally avoid residential areas during day, they commonly traveled and were sighted in yards and on streets during the night. Apparently, coyotes were comfortable in residential areas when it was dark and it was presumed that they spent a good deal of time foraging (based on nighttime telemetry locations) in these areas.

The majority of daytime activity was associated with adult coyotes coming and going from den and summer rendezvous sites (Mech, 1970). The nutritional demands of pups presumably made the adults spend more time foraging. However, most of these movements were relatively localized with residential areas being generally avoided until nighttime. Occasional daytime activity occurred during the winter, when human activity was lower. However, these movements were also short in distance and were usually correlated with dawn and dusk periods.

Although standard 24-hour activity budgets were not taken (Andelt, 1985; Laundre and Keller, 1984), movements by several coyotes were greater than previously documented. Andelt (1985) found that adult males and females averaged 8.1 km and 7.8 km during 24-hour activity budgets. Twenty-four hour travel distances of 10.48, 12.01 and 14.45 km for resident breeding adults were documented during this study. However, these estimates are considered to be the very minimum of actual distances traveled and in one case involved only three location points (i.e., *Kett* =12.01 km). Based on day-to-day radio tracking data these movements seemed to be representative of typical daily (or aptly, nightly) distances traveled by Cape Cod coyotes. In fact, the extreme distances moved by *Sill* (31.89 km) and *Glope* (22.93 km, Table 3.7; Fig. 3.4) were close to descriptions of wolf pack movements (Mech, 1970: 160; Mech et al., 1998; Vila et al., 1995). Vila et al. found that the mean minimum distance traveled was 13.0 km/day for Iberian wolves.

The nightly coyote movements documented during this study were especially surprising given the low number of sample/location points that were recovered during most of the tracking bouts (Table 3.7, range = 3-13 locations). Resources and funding

simply did not allow more than one person to track coyotes on a day-to-day basis. Although some of the tracking movements were taken in over a 24-hour span (e.g., *Sill* and *Glope*), I strongly believed that these distances were still representative of 24-hour movement rates because little activity and movement was found to occur during the day (Fig. 3.6). I suspect that when standardized 24-hour activity budgets on Cape Cod coyotes are conducted, even greater movements will be revealed.

Suburbanization appeared to have little effect on adult coyote movements. When extensive travels by coyotes were documented, usually powerlines, dirt roads, railroad tracks, golf courses and even residential streets were the principle means of coyote travel routes. I could sometimes predict and directly observe coyote movements by realizing that they were traveling on these pathways. Coyotes traveling through neighborhoods were usually very hard to follow because they were traveling at a high rate of speed and there were many roads, thus making it difficult to accurately pinpoint and intersect a coyote's location.

Resident coyotes could potentially be located anywhere in their home range at any given time; i.e., even if they were in one part of their home range they had the potential to show up within minutes at the opposite end of their range (sometimes >10 km away) under the cover of night. These regular, nightly long distance movements of Cape Cod coyotes led the general public to believe that coyotes were becoming very numerous. However, these research findings show that just a few coyotes (typically 3 in a given area coupled with dispersing coyotes traveling in and out of these areas) can be seen in a relatively large area indicating that the local density of coyotes is not as great as previously believed (Fig. 3.8).

Although it appeared that coyotes had little trouble traveling through a highly suburban environment, the results can be misleading. Of 13 dead coyotes recovered during the study (including 3 radio-tagged coyotes), 9 (69%) were known to have been hit and killed by cars, and two more (11 total = 85%) were suspected to have died in the same way (Table 3.9). Although the data may be biased because it would be difficult to find dead coyotes other than road kills in the field, it does appear that there is a critical time period when coyotes must learn how to avoid cars. Furthermore, of the three radio-tagged coyotes that were recovered during the study, cars killed two.

Management Implications

Population Status

It is strongly suspected that coyote numbers are stable in the study area. Resident coyotes inhabiting a suburban setting seem to be able to maintain mutually exclusive territories through chance encounters with conspecifics and spatial avoidance of bordering coyote groups. All resident coyotes regularly traveled throughout their respective home ranges and appeared to travel with the same individuals. No doubt, there are numerous transient coyotes that sporadically travel throughout the home ranges of resident coyote groups but these animals appear to have a much lower survival rate than resident adults (Harrison, 1992) and would seem to only be important if they are able to join or create a resident group. Managers should recognize the described ecology of suburban Cape Cod coyotes when explaining coyote biology to a suburban human population.

Based on the observed territory sizes of 29.7 ± 5.28 (SE) km^2 and group sizes of three for radio-collared resident coyote social groups on Cape Cod, I estimate a density of 0.08-0.15 coyotes/km^2 (90% CI) residing in the study area.

Habitat Protection and Improvement

Despite the adult coyote's apparent ability to thrive and move through a highly fragmented and suburban setting such as Cape Cod, there was one exception to this trend: the denning season. All den sites were found within 0.5 km of water and in areas of coyote home ranges with a low housing density around the immediate area of the den sites (see Table 3.10; Fig. 3.12). It seems that coyote groups use wooded areas mainly in the spring and summer to protect and hide their pups of the year. Future efforts should continue to preserve and expand the wooded areas on Cape Cod to ensure that coyote reproduction is not affected in certain areas. Ideally, connecting wooded areas to other forested places will ensure that large moving animals such as coyotes will have potential places to reproduce throughout Cape Cod.

Resident coyotes were documented to travel extensively on powerlines, railroad tracks and old fire roads. An effort should be made to keep these narrow corridors (Meffe and Carroll, 1994) intact even in highly populated areas. Apparently these areas allow coyotes to cross through highly developed areas. It is strongly suspected that dispersing coyotes disproportionately travel along these paths to colonize new areas.

Future research should attempt to document at what age coyotes become most (and least) vulnerable to cars. It seems that once coyotes are able to get through their first winter, their survival rate increases dramatically (as no adult coyotes were killed

by cars in this study). By radio transmitting and monitoring a sufficient number of juvenile coyotes in a suburban area, this question can surely be answered. Meanwhile, efforts should be made to avoid potential vehicle accidents with coyotes by educating the public on coyote life history requirements (i.e., large home ranges). Construction of under and over-passes along major roads should be experimented with and tested for the potential improvements of coyote (and other wide-ranging animal's) survival rates.

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Table 3.1. Radio-telemetry data for 11 eastern coyotes captured in box traps and monitored between June 1998 and March 2000 within Barnstable County, Cape Cod, Massachusetts.

						No.radiolocations		
ID	Sex	Age	Date Captured	Date last signal	Days transmitting	S[1]	U[2]	Total
Pon[3]	M	P	6-8-98	10-6-98	120	136	6	142
Poo[3]	M	P	6-17-98	9-13-98	88	103	1	104
Snix[4]	F	A	6-19-98	1-27-00	587	504	12	516
Casper	F	A	11-30-98	3-16-00	472	523	12	535
Kett	M	A	12-16-98	3-16-00	456	438	5	443
Mizz	F	A	2-25-99	3-16-00	386	446	1	447
Sly	M	A	5-15-99	3-16-00	306	413	3	416
Cup[5]	F	P	7-11-99	1-6-00	179	127	57	184
Hap[6]	M	P	10-1-99	3-16-00	113[6]	124	0	124
Glope	M	A	1-14-00	3-16-00	63	91	11	102
Sill	M	S	1-18-00	3-16-00	59	68	5	73
Total					**2829**	**2973**	**113**	**3086**

P=Pup; A=Adult; S = Subadult.
[1]represents successful finds of each coyote.
[2]represents unsuccessful finds of each coyote.
____=Animal that died during the study; [3]Killed by car; [4]Died from Glomerulonephritis.
[5] Dispersed during the study.
[6] Had mange when caught on 10-1-99; was released on 11-24-99 after being rehabilitated.

Table 3.2. Home range sizes (km^2) of male and female eastern coyotes within Barnstable County, Cape Cod, Massachusetts between June 1998 and March 2000 based on 2973 successful radiolocations.

			Methods used to estimate home ranges (see text for details)			
Social status	ID	Sex	100 MCP	100 Vertex	95 MCP	95 Vertex
Breeder	*Snix* (504)[1]	F	55.6	32.4	38.1	22.8
	Casper(523)[2]	F	59.3	49.6	40.1	35.5
	Kett (438)[2]	M	77.6	62.7	45.4	38.8
	Mizz (446)[2]	F	16.6	14.6	13.5	12.4
	Sly (413)[3]	M	55.2	50.4	43.5	39.3
Mean	Breeders only		52.9	41.9	36.1	29.7
Associate	*Sill* (68)	M	100.4	72.3	59.7	51.6
Juvenile	*Pon* (136)	M	10.8	9.0	7.4	7.3
	Poo (103)	M	6.0	5.7	5.4	4.8
	Cup (127)	F	5.4	4.6	3.8	3.4
	Hap (124)[4]	M	0.4	0.3	0.4	0.3
Mean	Juveniles only		5.7	4.9	4.2	3.9
Transient	*Glope* (91)	M	152.2	100.2	114.9	89.8

Note: #s in parentheses represent total successful radio-fixes per individual animal.
[1]*Snix* was pair bonded for two breeding seasons but was never determined to successfully raise pups.
[2]Known to successfully raise (or help raise) pups during 1999.
[3]*Sly* displayed two separate home ranges: one with an uncollared coyote (no pups observed during 1999 season) and the second with Casper. Casper and Sly are believed to be pair bonded during the 2000 breeding season.
[4]*Hap* was documented to greatly expand his home range on 3-20-00. He left the study area on 3-23-00.

Table 3.3. Group sizes of eastern coyotes within Barnstable County, Cape Cod, Massachusetts observed between November and April, 1999 and 2000.[1]

Group Size	Number of sightings
1	121 (52.6 %)
2	68 (29.6 %)
3	39 (17.0 %)
4	2 (0.9 %)
Total	**230**

[1]Biased to sighting collared animals.

Table 3.4. Coyote social groups monitored between June 1998 and March 2000 within Barnstable County, Cape Cod, Massachusetts.[1]

Social Group	Member(s)	Adult Group Size	Successful Reproduction
West Barnstable	*Snix*	2	No (1998 & 1999)
Centerville	*Sly*	2-3[2]	?????
Cummaquid	*Casper, Sly*[3]	3	Yes (1999)
Mashpee	*Kett, Sill*	3[4]	Yes (1999)
Hyannis	*Mizz*	3[4]	Yes (1999)

[1]Included at least one radio collared adult coyote in each group.
[2]*Sly* was regularly seen with two different looking adults, but was never found in a group of three while inhabiting Centerville.
[3]First was documented with this group during December 1999. Membership of this group seemed to change (except for *Casper*) during fall 1999 but remained at a constant 3 members (see Appendix II).
[4]Both groups were sighted with four adults on one occasion.

Table 3.5. Coyote litter sizes observed and associated adults involved in raising litters within Barnstable County, Cape Cod, Massachusetts.

Date	Observed litter size	Known adults involved in raising litters[1]
June 1994[2]	5	2
May/June 1996[2]	5	2
June 1997[2]	5	2
June 1998[3]	5	2
May 1999[4]	5	2
June 1999[5]	1 (3-5)	2-3
July 1999[6]	4	3

[1]Minimum estimates.
[2]Before radio telemetry study began. Data based from random observations of pups and adults.
[3]Two pups implanted with radio-transmitters; no adults transmitted
[4]Adult female radiocollared; one pup captured 10/1/99
[5]Adult male collared; one pup observed; 3-5 strongly suspected
[6]Adult female collared; one pup captured and radio-implanted July 1999

Table 3.6. Number of successful radiolocations obtained and percent of time estimated to be active by daily time period for 11 eastern coyotes on Cape Cod, Massachusetts between June 1998 and March 2000.

Hours	Number of radiolocations per daily time period[1]	Number of radiolocations active per daily time period	Percent of radiolocations active
2400-0200	155 (5)	147	95
0200-0400	120 (4)	113	94
0400-0600	196 (7)	151	77
0600-0800	449 (15)	220	49
0800-1000	585 (20)	82	14
1000-1200	335 (11)	37	11
1200-1400	152 (5)	18	12
1400-1600	137 (5)	11	9
1600-1800	207 (7)	85	41
1800-2000	169 (6)	127	75
2000-2200	228 (8)	221	97
2200-2400	240 (8)	226	94
Total	**2973**	**1395**	**47**

[1]Numbers in parentheses refer to percentages of total fixes per daily time period.

Table 3.7. Examples of distances (km) traveled by eastern coyotes within Barnstable County, Cape Cod, Massachusetts.

			Time			
ID	**Status**	**n (total # of fixes taken)**	**Begin**	**End**	**Total time (hours)**	**Distance traveled (km)**
Sill	Associate	9	2/15/00 8 AM	2/16/00 10 AM	26	31.89
Glope	Transient	13	1/15/00 10 PM	1/16/00 10:10PM	25	22.93
Sly	Breeder	11	8/3/99 1 PM	8/4/99 5 AM	16	14.45
Kett	Breeder	3[1]	12/4/99 8 AM	12/5/99 9 AM	25	12.01
Casper	Breeder	5	8/17/99 10 AM	8/18/99 9 AM	23	10.48
Average Breeder		7			21	12.31

[1]Just one night fix was taken.

Table 3.8. Sizes of home ranges (km^2) of adult coyotes reported in this and other studies in the northeastern United States.

		Mean home range size			
Area	**Environment**	*Males*	*Females*	**Method**	**Source**
Vermont	Rural/farm	18.7	17.1	Harmonic mean	Person and Hirth, 1991
Maine	Coniferous forest	44.0	49.7	MCP deleting outliers >3 km from nearest location	Harrison and Gilbert, 1985
Cape Cod, Massachusetts	Suburban	39.1[1]	23.6[1]	95% MCP vertex edited	This study

MCP = minimum convex polygon
[1]Resident adults only

Table 3.9. Dead coyotes recovered and probable cause of death within Barnstable County, Cape Cod, Massachusetts.

Date	Age	Cause of death
7-29-98	pup	vehicle
9-13-98[1]	pup	vehicle
10-6-98[1]	pup	vehicle
11-3-98	juvenile	vehicle
11-22-98	unknown	drowned while attempting to swim the Cape Cod Canal
2-3-99	juvenile	unknown; possibly hit by vehicle; possible disease[2]
11-8-99	juvenile	vehicle
11-22-99	unknown	vehicle
12-1-99	unknown	vehicle
12-16-99	unknown	vehicle
12-18-99	adult	vehicle
1-28-00[1]	adult	Glomerulonephritis
2-10-00	unknown	most likely a vehicle

[1]Radio-tagged coyote monitored during this study (see Table 3.1).
[2]Was recovered in a front yard five meters from a house.

Table 3.10. Location of coyote den and rendezvous sites found within suburban Barnstable County, Cape Cod, Massachusetts.[1]

Date	Area den was found	Population density (/km^2) in the general area	Housing units in the general area (/km^2)	Description of immediate area around den or rendezvous site
Summer 1994 & 1996	West Barnstable	89	39	Large conservation area (10 km^2). Den was 8 km from nearest house.
Summer 1997	Marstons Mills	230	101	A lot of open land consisting of multiple cranberry bogs
Summer 1998	Marstons Mills	230	101	Same as above; also another site was found in a large conservation area (approx. 5-6 km^2).
May 1999	Hyannis	556	330	In a wooded area on a golf course.
Summer 1999	Hyannis	556	330	In a watershed (<1 km^2) surrounded by houses.
Summer 1999	Mashpee	130	115	Two sites: one in a wooded area that is part of a wildlife refuge, the other was in a large swamp on a golf course.
Summer 1999	Cummaquid /Barnstable Village	164	87	Two sites: one on a large conservation area (~8 km^2), the second one was around a County Farm.

[1]All sites were located within 0.5 km of water.

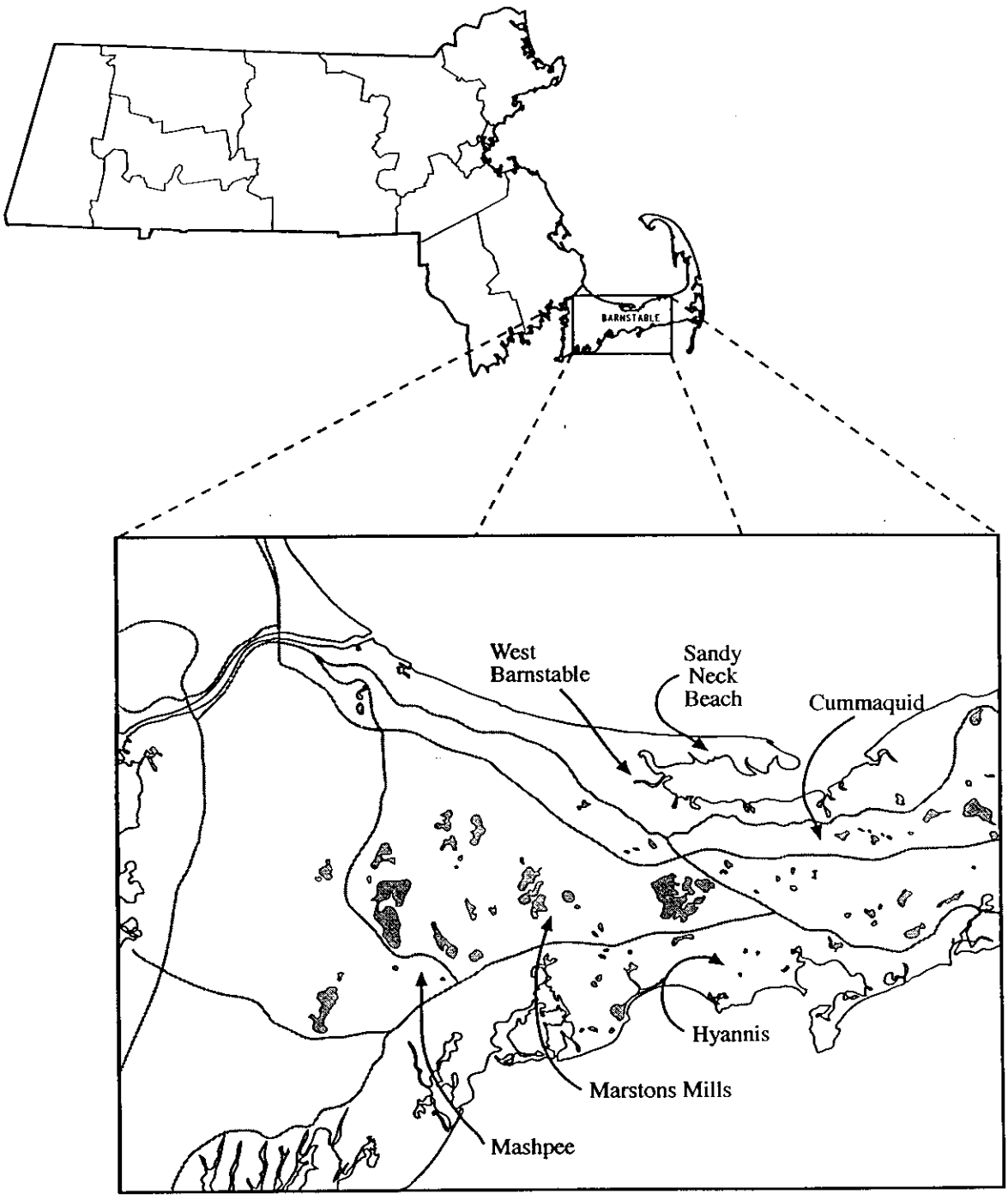

Figure 3.1. Study site showing principal locations and main roads within Barnstable County, Cape Cod, Massachusetts.

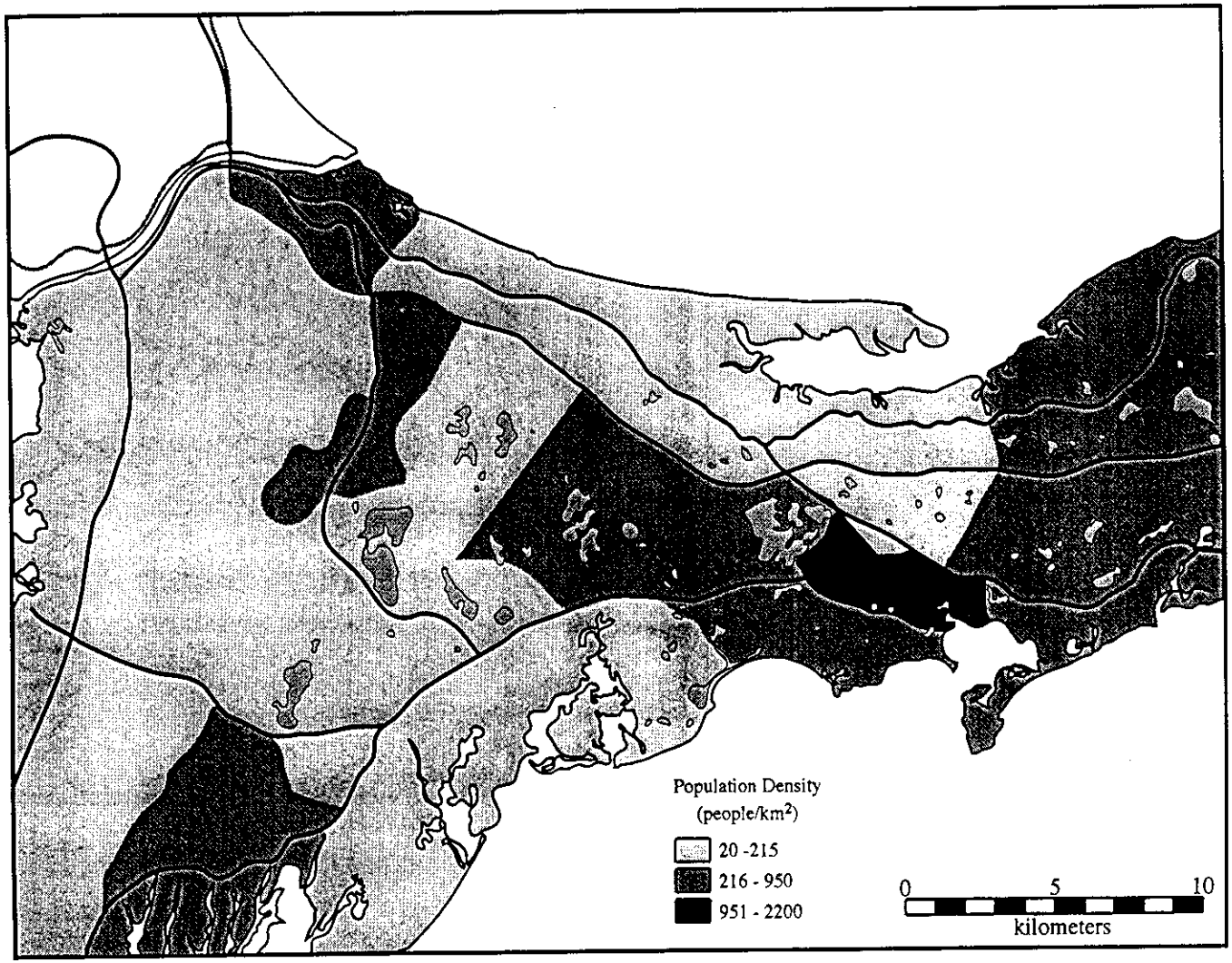

Figure 3.2. Local human population density and major roads in Barnstable and bordering towns, MA. Source: U.S. Census Bureau.

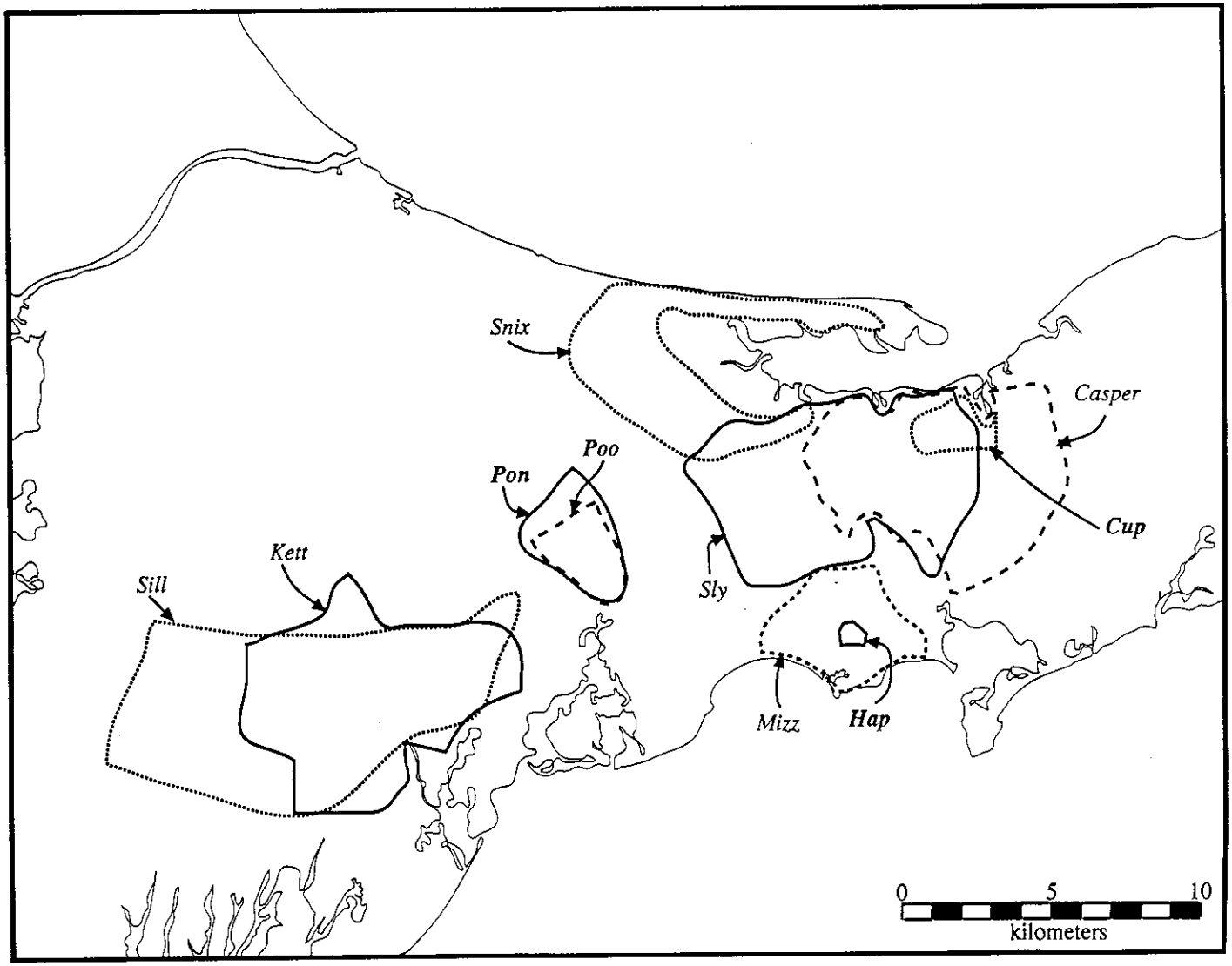

Figure 3.3. Coyote 95% MCP vertex edited home ranges within Barnstable County, MA. *Glope* (a transient coyote) is excluded because of a large undefined home range. Coyote pups are in bold letters.

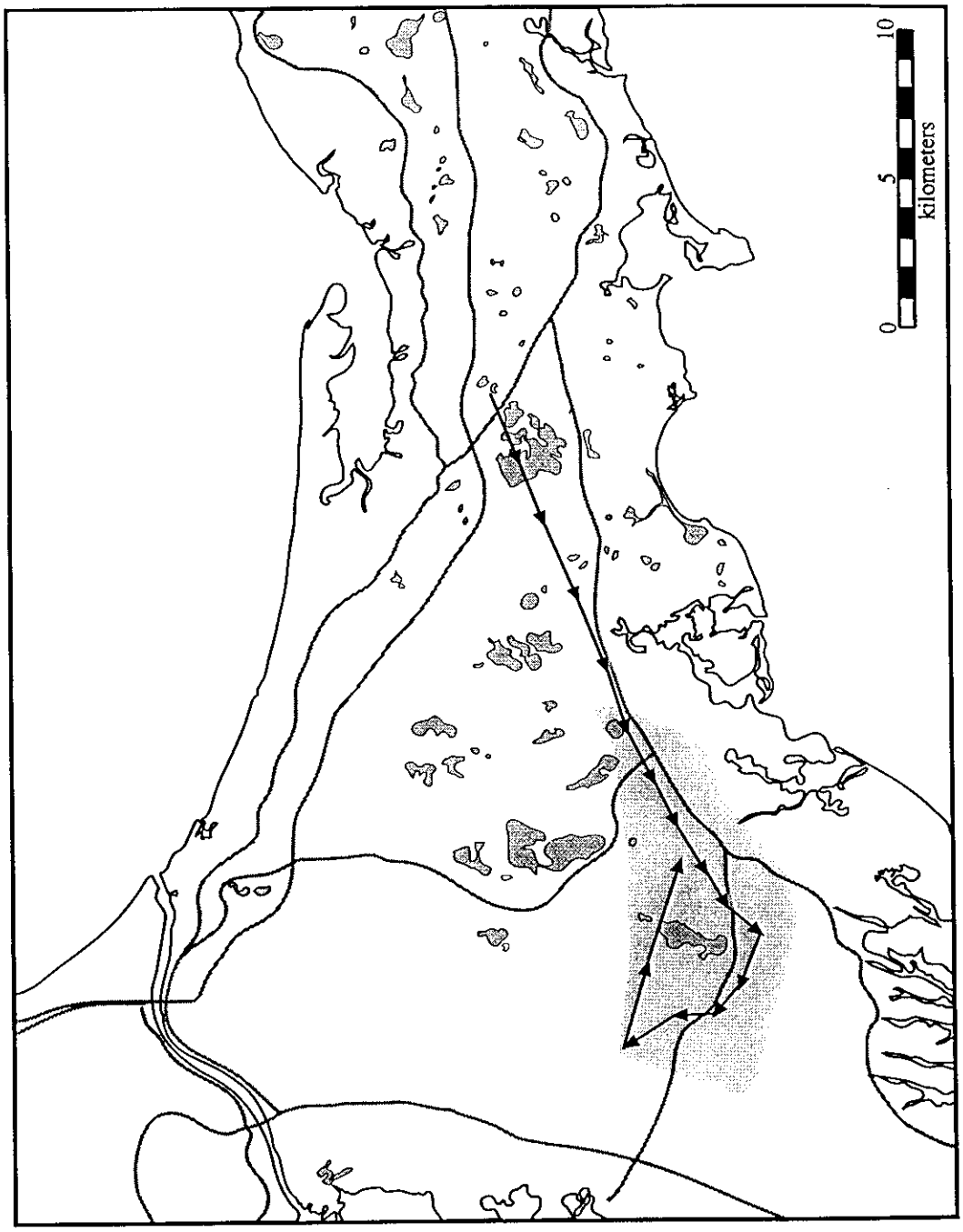

Figure 3.4 Long distance movements of *Sill* (see Table 3.7) with his 95% MCP vertex edited home range displayed (shade).

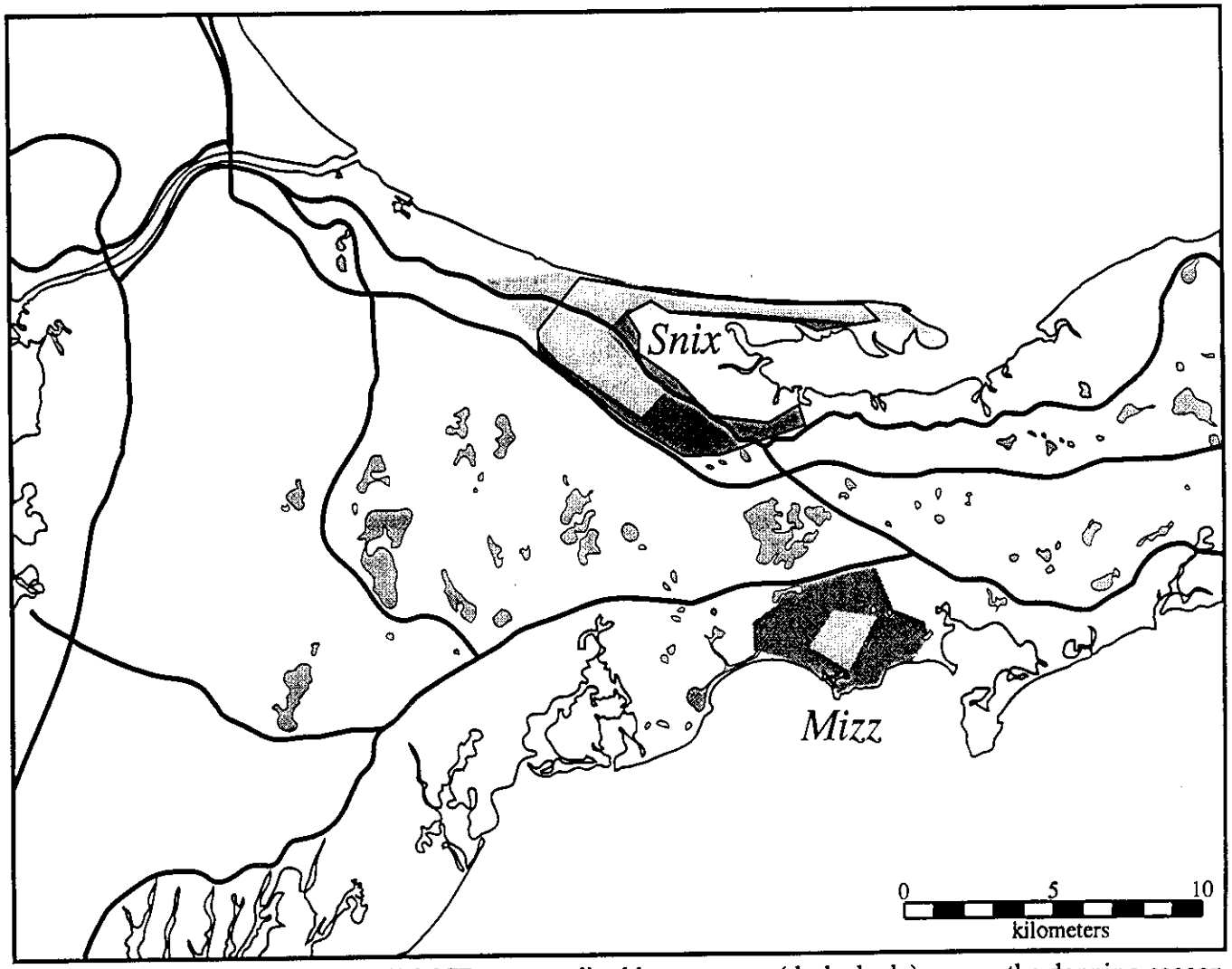

Figure 3.5. A contrast of the 95% MCP vertex edited home range (dark shade) versus the denning season home range (light shade) of a non-reproductive (*Snix*) and reproductive adult female coyote (*Mizz*) Cape Cod, MA.

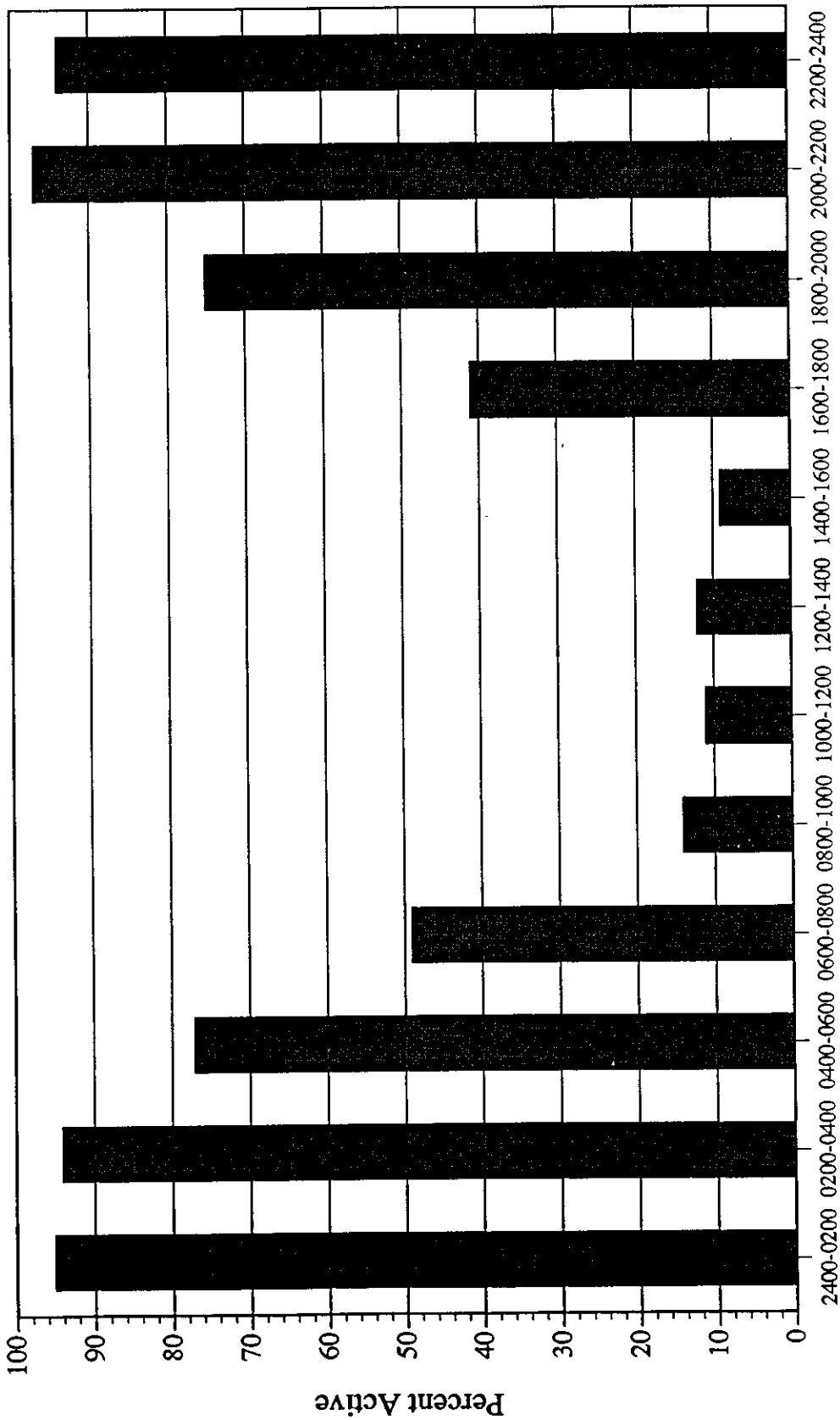

Figure 3.6. Estimated percent of time active by daily time period for 11 eastern coyotes on Cape Cod, MA, between June 1998 and March 2000.

Figure 3.7. Movements of a transient coyote, *Glope*, (shaded thick lines) overlayed over 95% MCP vertex edited ranges of other coyote home ranges on Cape Cod, MA.

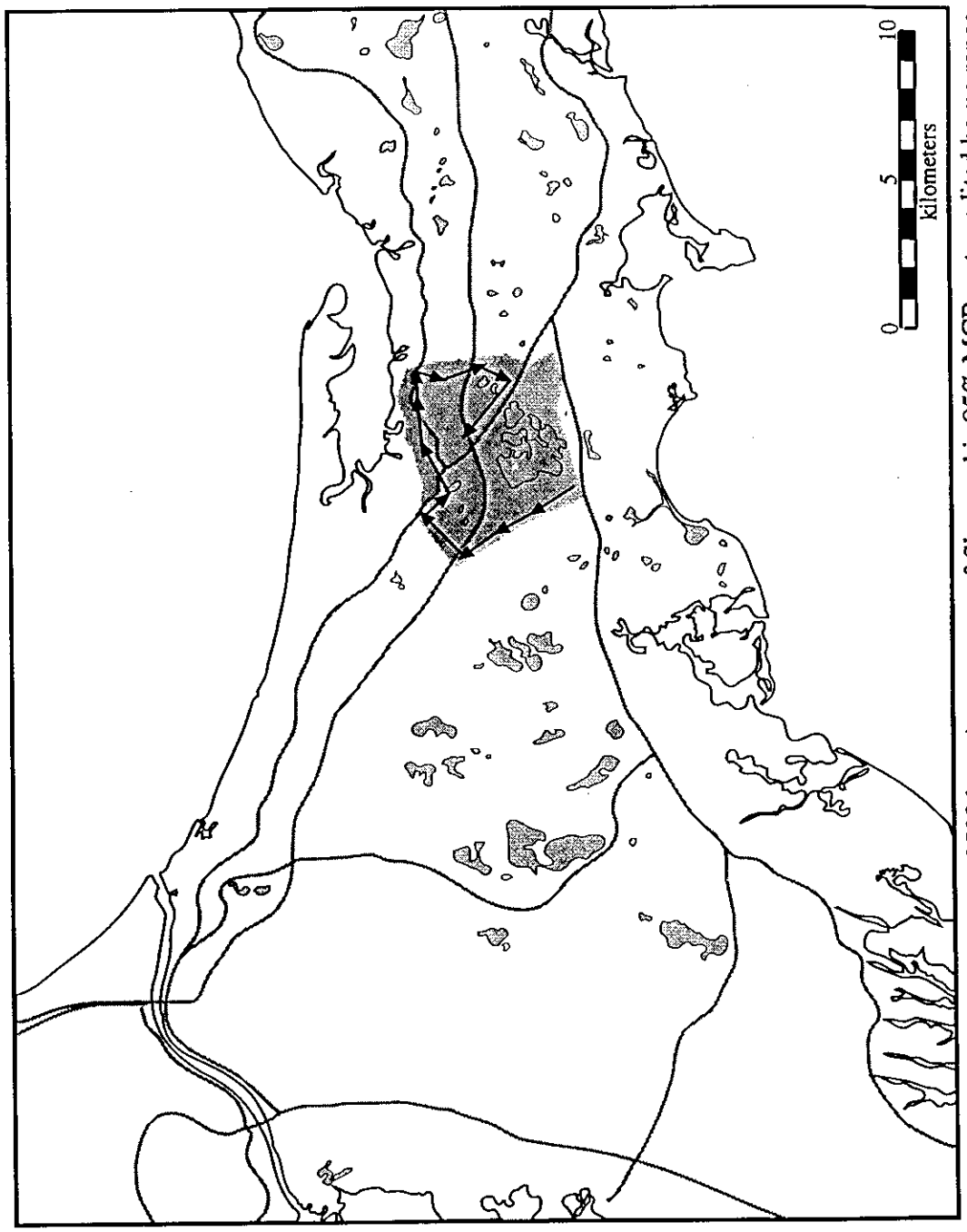

Figure 3.8. A16-hour (1300 to 0500 hours) movement of *Sly* over his 95% MCP vertex edited home range on Cape Cod, MA.

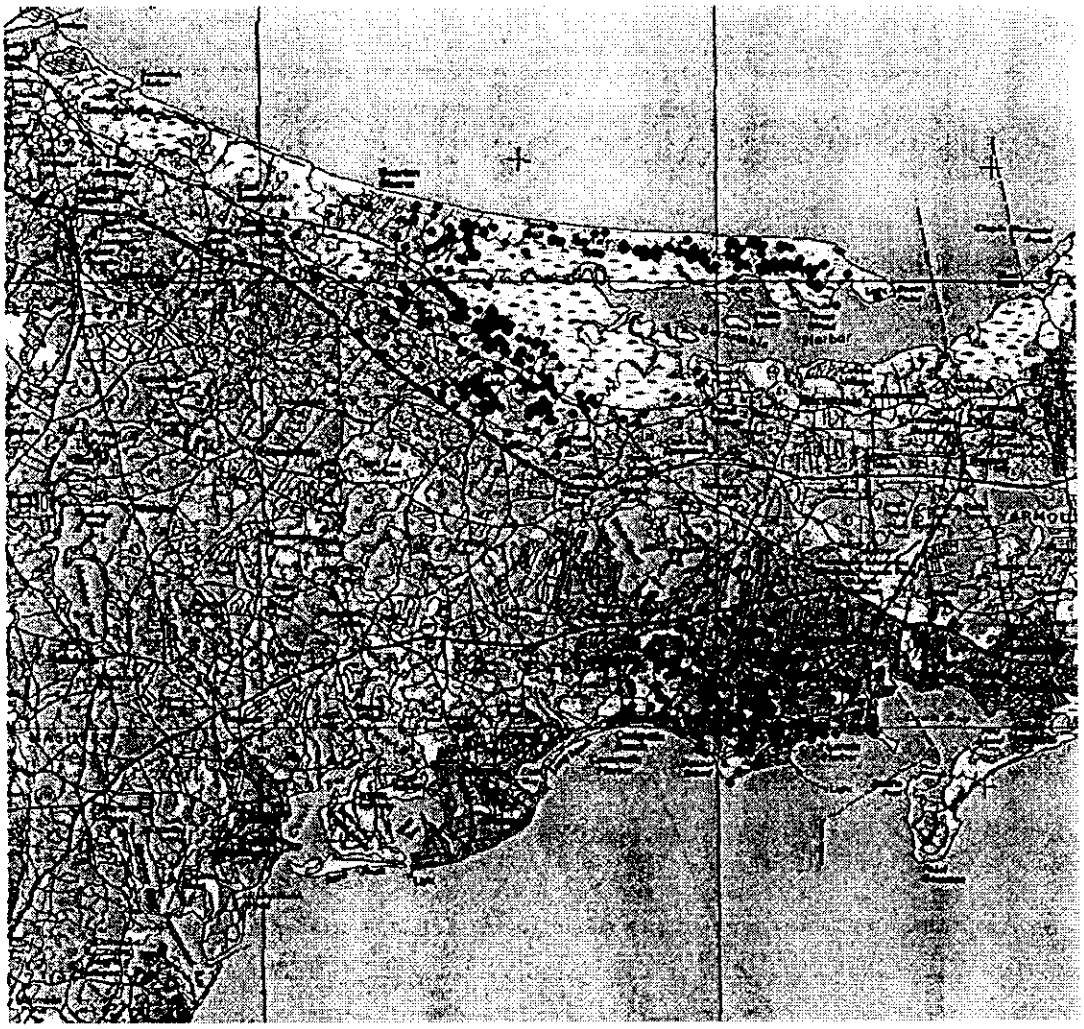

Figure 3.9. An illustration of the large number of radio location fixes obtained for two coyotes (*Snix* and *Mizz* – see Table 3.1) on Cape Cod, MA.

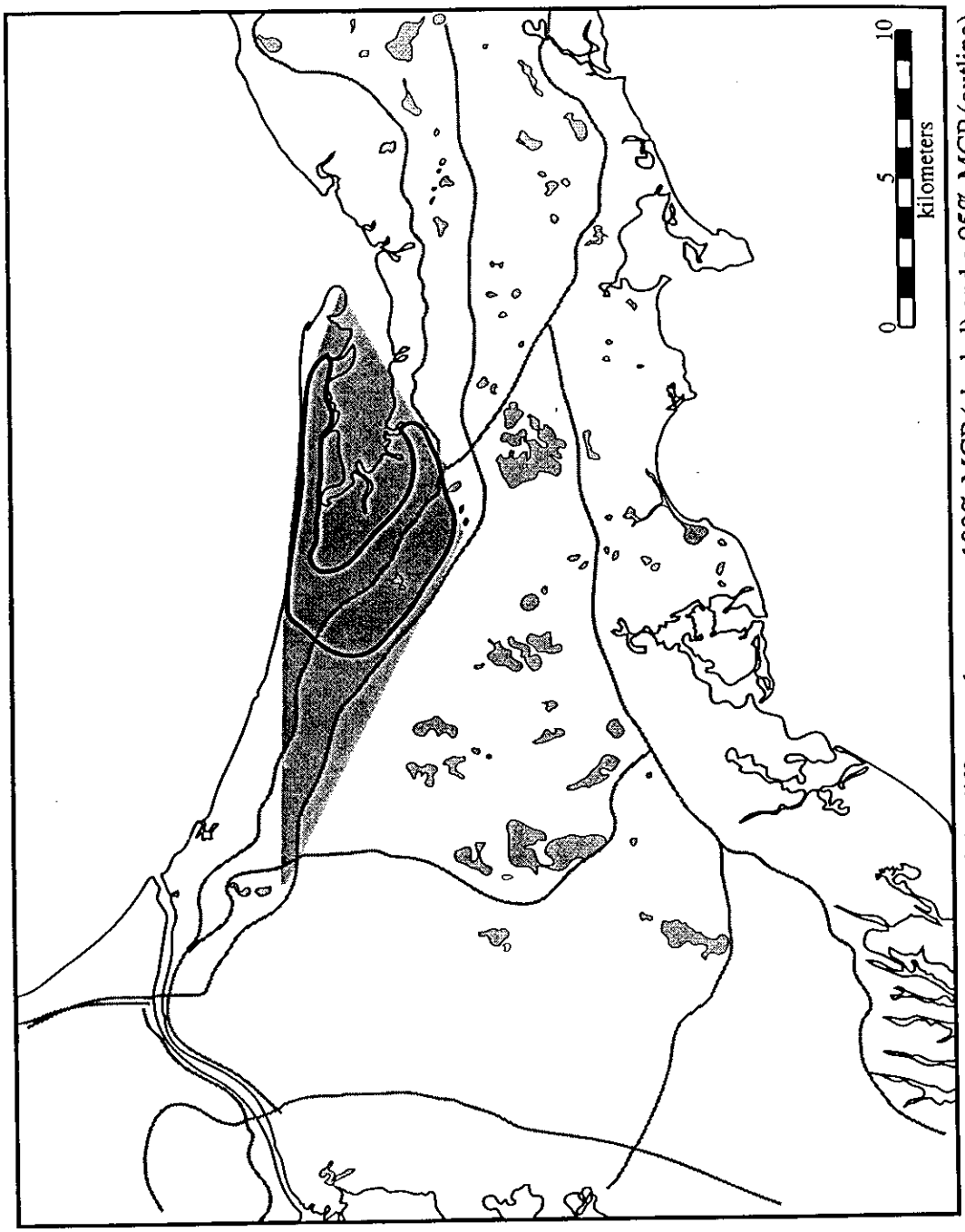

Figure 3.10. An illustration of the difference between a 100% MCP (shaded) and a 95% MCP (outline) vertex edited Polygon of *Snix's* home range. Note the areas that the 100% MCP includes.

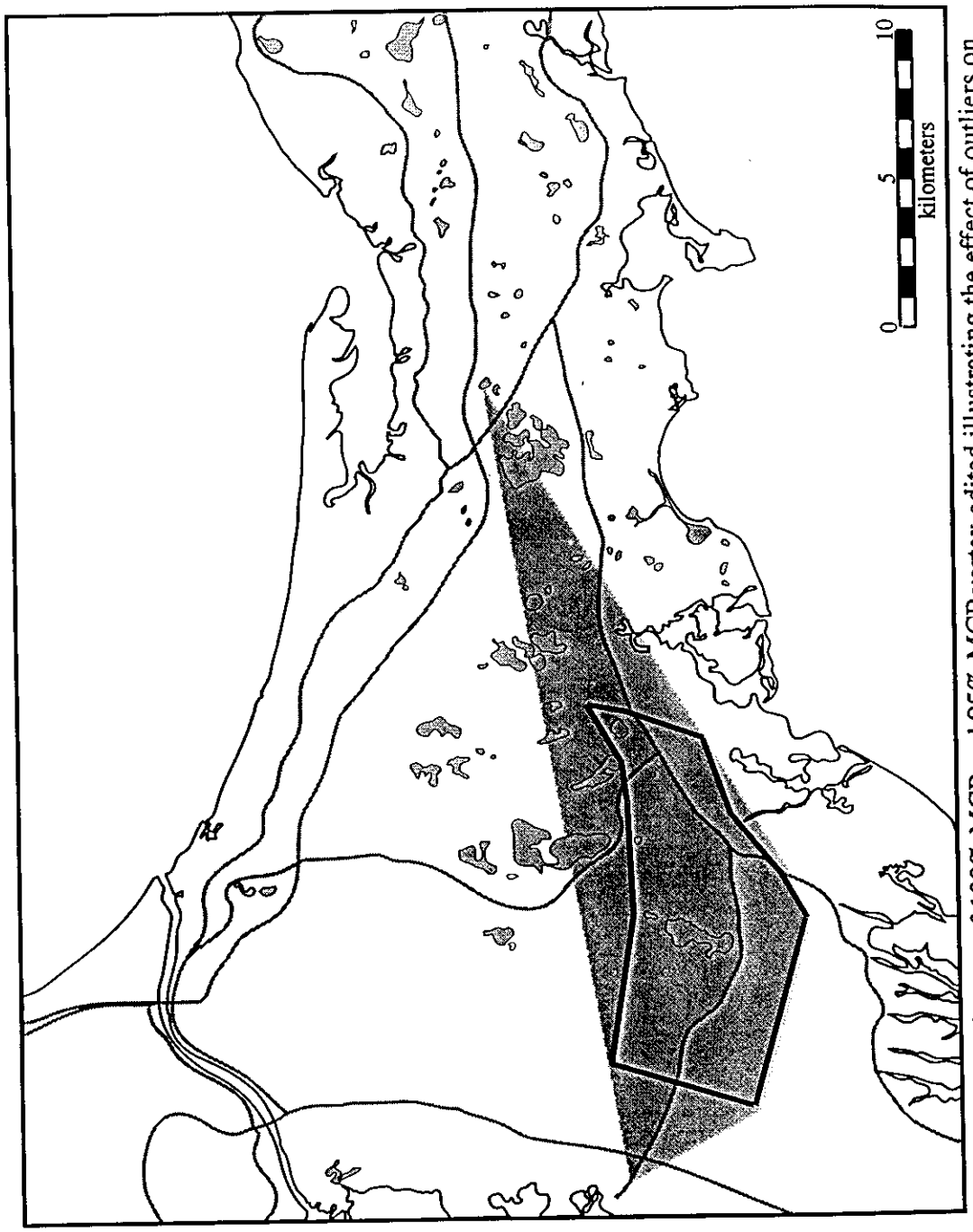

Figure 3.11. Polygons of 100% MCP and 95% MCP vertex edited illustrating the effect of outliers on data.

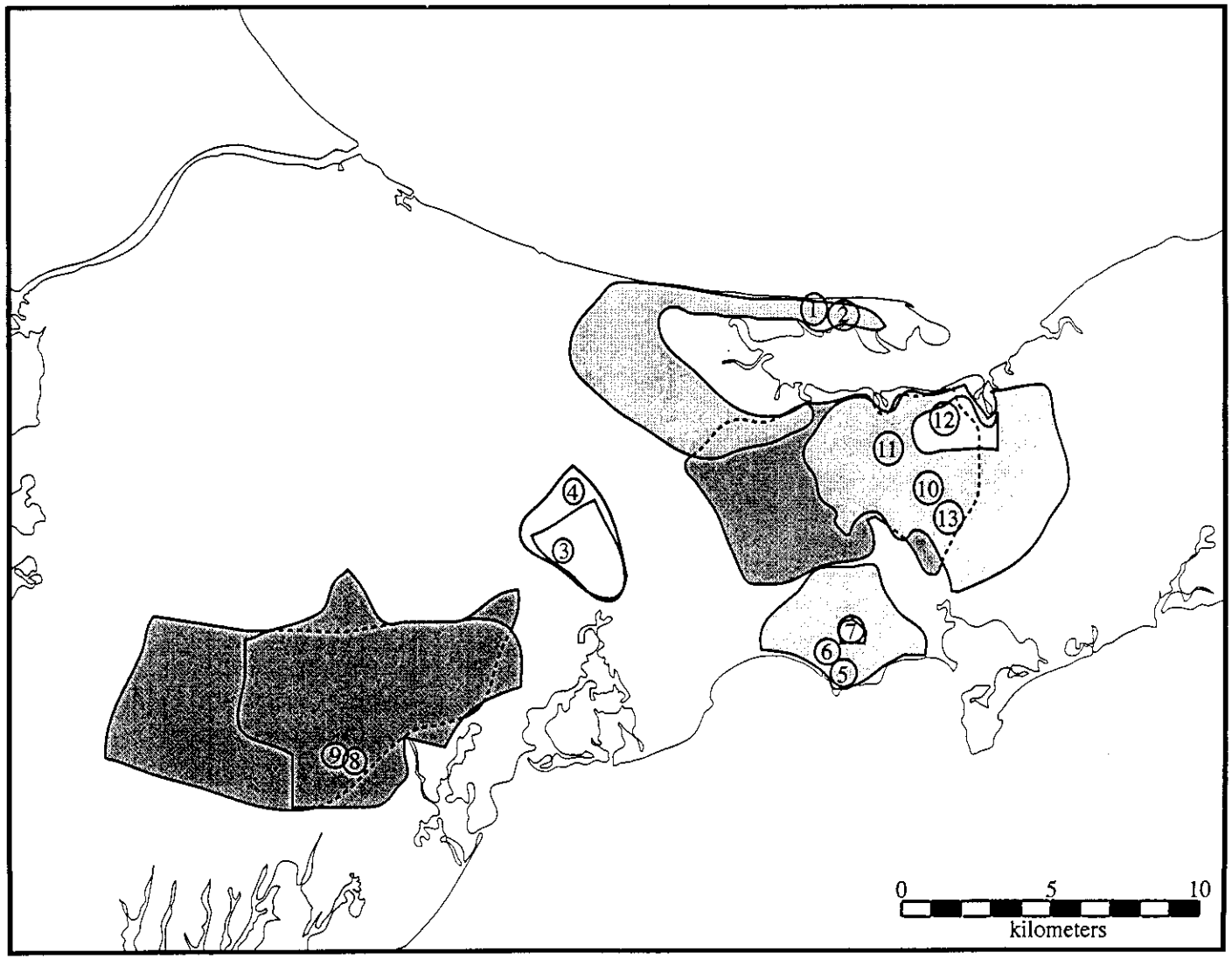

Figure 3.12. Den and rendezvous sites (numbers inside of circle) within coyote home ranges on Barnstable County, MA. Dark shades are male, light shades are female, and white outline are pup home ranges.

APPENDIX I

Protocol for handling coyotes

Preparatory work for handling coyotes was accomplished by working in a veterinarian clinic to learn how veterinarians handle and care for domestic dogs.

- Capture coyote in model 610 Tomahawk box trap.
- Inspect general health of animal. If problems arise during handling, immediately contact veterinarians at the Hyannis Animal Hospital (Dr. L. Venezia, Dr. P. McCartin).
- Chemically restrain coyote with an intra-muscular injection of 3.6 mg/kg of Telazol (tiletamine hydrochloride and zolazepam hydrochloride). Restraining drugs obtained and use monitored through veterinary doctors.
- Place coyote in shade or warm area depending on weather conditions.
- Record induction time.
- Monitor for overheating or hypothermia and stress.
- Safely pull sedated coyote out of cage.
- Cover eyes to protect coyote vision.
- Install a radio-collar around the neck of an adult animal or put an implant radio-transmitter into the abdomen of a juvenile. Necessary sterilization of implants and abdomen area are necessary for surgery. Penicillin will be administered after surgery to safeguard against adverse reactions.
- Apply any necessary ear tags.
- Weigh coyote.
- Record body measurements.
- Monitor Temperature, Pulse and Respiration (TPR) if a veterinarian is present.
- Take fur and blood samples.
- Take video and photographs concurrent with the capture procedure.
- Check completeness of data form.
- Place coyote back in box trap and either bring the coyote to a shed to recover or have someone stay by the cage at all times until the animal is released.
- Keep coyote in cage until fully alert and ready to release. This usually is 6-8 hours after the capture or generally the night after a morning capture workup procedure.

APPENDIX II

Eastern Coyote Social Groups

Introduction

The following is a description of eastern coyote social groups monitored on suburban Cape Cod, Massachusetts. It should be noted that most sightings during daylight hours involved walking in on bedded radio collared coyotes and attempting to directly observe them. The rarity of observing coyotes naturally active during the day (i.e., they were moving not because of my presence) was documented in Chapter 3. Most coyote movements were documented during the nighttime. It quickly became apparent that coyotes traveled on human built corridors such as powerlines, dirt roads, railroad tracks, golf courses, open areas, neighborhoods and side streets. Thus, it was rather easy to see coyotes during nighttime radio tracking. On a typical nocturnal tracking bout (when I located at least three or four of the radio-transmitted coyotes) I had approx. 75% success in sighting coyotes. Almost 100% of the sightings came as a direct result of following radio tagged animals.

It was apparent that most groups consisted of three members. *Snix*'s group (West Barnstable) was the only exception to this trend; however, she was never determined to successfully raise a litter of pups. Whether the majority of pups died or dispersed from their natal areas is unknown, but *Cup*'s (Cummaquid) dispersal seems to suggest that of the pups that survive to the fall, only one of these juveniles remained with their natal group. Although this statement is difficult to defend without having a greater proportion of resident (and dispersing) coyotes radio-tagged, a few individuals, based on their appearance, were repeatedly observed with collared adults.

I walked in on bedded animals approximately 150-200 times. Although there were sometimes as many as three or more coyotes (including pups) in association with a radio-transmitted coyote when I approached by foot, not once did a coyote come close to threatening me. In fact, it was rare enough just to simply see the animals when I deliberately walked in on them. Of the few times that I was able to approach close enough to visually sight coyotes, when the coyote(s) first became aware of my presence they ran full speed in the opposite direction. There were only a couple of instances where coyotes lingered around in my presence. I was confident that they simply were trying to figure out what I was.

Marstons Mills

A litter of five pups and at least two unknown adults (one was small and tannish brown in color; the other one was fairly robust and gray in color) were observed during June 1997 in the Marstons Mills area. Two male pups, *Pon* (6.7 kg) and *Poo* (6.9 kg), were captured in separate incidents in box traps during June 1998. They were both given implant radio-transmitters. The two pups belonged to a litter of five during 1998. Two different uncollared adults were observed interacting with *Pon* and *Poo*. One was silvery-gray in color with very distinct white shoulder blades. I thought that he was the adult male of the group because of his large, massive appearance. This animal was observed 12 separate times. Another coyote, which I presumed to be the breeding female, appeared to be considerably smaller than the first adult observed. This animal was reddish-tawny in color and was observed only a couple of times.

On 13 Sept. 1998 *Poo* was hit and killed by a car on route 149. This was well within his normal home range. He weighed 12.3 kg at the time of his death. On 6 Oct. 1998 *Pon* was hit and killed by car on River Road. This was also well within his normal home range. He was a robust 15.9 kg.

After the death of both pups, I lost contact with this group despite constant trapping efforts in this area right up to the end of the study period. I did however receive reports of pups and adults during summer 1999 at *Pon* and *Poo*'s previously used rendezvous sites. Two male coyotes were captured during January 2000 (*Glope* and *Sill)* in the Marstons Mills area. However, it quickly became apparent from the movement patterns that they displayed that they were not part of a group belonging to the Marstons Mills area.

West Barnstable

In June of 1994 and 1996, five pups were observed along with random observations of adults on Sandy Neck Beach in the Town of Barnstable. No more than two adults were sighted at a time. *Snix*, a 14.5 kg yearling/adult female coyote was captured on Sandy Neck on 19 Jun. 1998. She was consistently observed with a more massive white-faced male coyote during 1998 and early 1999. Successful reproduction was not documented in 1998 or 1999 from this group. It appeared that in late spring 1999 *Snix* might have switched companions as a new, dark faced coyote was consistently observed traveling with her (n=9 sightings). *Snix* was recaptured on 19 Jan. 2000 and was given a new radio collar. On 27 Jan. 2000 *Snix* was found barely alive at the eastern part of Sandy Neck Beach. She was brought to a veterinary clinic (Hyannis Animal Hospital) and was put to sleep on 28 Jan. 2000 when it was

determined that she had acute renal failure (Glomerulonephritis). She was never determined to be reproductive. This was the only group where there was never a sighting involving more than two coyotes traveling together.

Cummaquid (East Barnstable)

This group was first monitored on 30 Nov. 1998 when *Casper*, a 23.2 kg adult female, was captured off Mary Dunn Road. She was very robust and had a thick layer of fat, presumably because I baited that trap for three months before arming it.

Casper was consistently seen with two other adults. One adult was tall and light brown (blondish) in color; the other coyote was small and reddish blonde in color. An intensive, yet unsuccessful, search for *Casper*'s group's pups began during late April 1999. This group was truly elusive, and no pups were seen, until 11 Jul. 1999 when a 7.3 kg female pup, dubbed *Cup*, was captured. *Cup* was given an implant-radio transmitter because of her small size. A litter of four pups (including *Cup*), along with at least three adults (*Casper* and two others) were documented during July 1999.

Casper was consistently located near *Cup* during the rest of the summer, but by September, they were rarely found together. This was surprising since *Cup* remained in the same general area as her summer rendezvous (above ground den) sites. However, *Cup* was observed using only a portion of *Casper*'s total home range before dispersing (see Chapter 3).

Casper was captured a total of three times during the study (30 Nov. 1998, 6 Mar. 1999, 26 Jul. 1999). She was released without handling during her second capture. However, on the third capture, she was re-collared in order to replace her transmitter

with a new one. She weighed 19.5 kg on 26 Jul. 1999. Judging from her body condition, it appeared that she whelped pups that summer.

Throughout fall 1999, *Casper* was observed traveling with a light tan colored and taller than *Casper* coyote, which I assumed was her mate. The third coyote was blondish in coloration and appeared to be the same size or smaller than *Casper*. I estimated this coyote to be a non-reproductive, helper female coyote. On 1 Dec. 1999 a reddish-brown coyote was struck and killed by an automobile on Phinney's Lane. This road is situated at the edge of the estimated home ranges for the Cummaquid and Centerville/Barnstable social groups. Less than one week after this mortality took place, *Sly* (originally from the Centerville/Barnstable area) was observed traveling with *Casper* and at least one other coyote (mid-December). In addition to sightings with *Sly*, *Casper* was also observed traveling during this period with a very tall, light colored coyote that was limping. I guessed this animal to be *Casper*'s probable mate during summer 1999. I do not know what happened to the limping coyote (see *Glope* for further information), but *Sly* was found exclusively with *Casper* (and a third, silver in color, coyote) from mid-December to the end of the study period. It was assumed that *Casper* and *Sly* pair bonded for the breeding season, but the identify of the third (silverish) coyote remained a mystery. From the literature (see Chapter 3), I am guessing that 1999's (blondish colored) helper dispersed and a pup from *Casper*'s 1999 litter (i.e., one of *Cup*'s same aged siblings) remained on its natal home range to act as an associate.

From mid-December – March *Casper* and *Sly* were found to range widely and traveled through most of both of their respective original ranges. However, *Casper*

was found to localize in mid-April 2000 when a litter of 5-6 pups were found in a 2.25 m long den in the Hyannis Ponds management area behind the Hyannis Airport (this is where she also denned last year). *Sly* was monitored tending this den site.

Centerville/Barnstable

This group was first monitored on 15 May 1999 with the capture of *Sly*, a 17.6 kg yearling male eastern coyote off Shootflying Hill Road. Trapping efforts were conducted for five months leading up to *Sly*'s capture. On the evening of 14 May 1999 I placed artificial scent/lure on the actual trap pan along with rotten bait in the back of the trap. The next day, *Sly* was captured.

During summer 1999, *Sly* was consistently sighted with another coyote. It was strongly suspected that it was not always the same coyote traveling with *Sly*. However, this hypothesis was difficult to accurately demonstrate, because almost all sightings were made in the dark making it very difficult to positively identify a non-collared coyote. However, one coyote appeared to be a dark and tall animal, while another coyote appeared to be considerably shorter and redder in color. During summer 1999, *Sly* was not observed localizing in any area indicating that he probably did not help in the raising of a litter (however, he may possibly have been an associate coyote that intermittently tended pups).

On 1 Dec. 1999 a coyote was hit on Phinney's Lane (see Cummaquid group). This was at the border of the Centerville/Barnstable and Cummaquid groups. Immediately after this incident (early-mid December), *Sly* was consistently found with *Casper* in the Cummaquid area. After one week of exclusively occupying the Cummaquid area, *Casper* and *Sly*'s movements appeared to then encompass both

groups' home range areas (beginning mid-December). After 1999, refer to the Cummiquid group for *Sly*'s activities.

Mashpee

Monitoring of this group began on 16 Dec. 1998 with the capture of *Kett*, a lanky, dark brown, German Shepard looking 19.3 kg male coyote, in the village of Cotuit located in the Town of Barnstable. It was quickly found that *Kett* used most of the Town of Mashpee as his home range. His capture took place at the eastern edge of his home range.

Kett was consistently seen with two other tawny-brown colored individuals. This group successfully raised pups during the summer of 1999 in the western part of Mashpee. There were few sightings of the pups; thus an actual count was not made, but *Kett* was seen with at least three other similarly sized coyotes (four total) in late fall 1999, indicating that at least one or two pups survived. In addition, group howls were heard during fall 1999 where it sounded like at least two or three pups were joining in. On 5 Nov. 1999 *Kett* was recaptured. He was recollared and weighed 20 kg. He appeared noticeably heavier than when we first captured and examined him.

On 18 Jan. 2000, *Sill*, a 16.8 kg male, was captured in the western part of Marstons Mills. It was briefly thought that he might have been the adult male of the Marstons Mills group. Radio telemetry data, however, quickly showed that he was part of the Mashpee group. He made a few journeys (>10 km) out of the Mashpee group's home range (and was not located on five radio tracking attempts) but repeatedly came back to this area, and seemed to have little trouble locating *Kett* and the rest of the group as 12 of the 20 observations of *Sill* during winter and spring

1999 also involved sighting *Kett*. *Kett*, *Sill* and a third coyote were often sighted together. The uncollared coyote was tawny brown in color and was smaller than *Kett* and *Sill* and was assumed to be *Kett*'s mate. *Sill* appeared to be the resident associate for the 2000 breeding season.

Hyannis

Monitoring of this group began on 25 Feb. 1999 with the capture of *Mizz*, a 13.6 kg adult female coyote. She was the most distinct, being very white in color (except for brown on her flanks), and was the smallest adult coyote captured during the study. She gave birth to a litter of five pups on the Hyannisport Golf Course circa 1 Apr. 1999. They were found and picked up when less than three weeks of age. I put them back in the den after a few hours and *Mizz* was observed back with them that night. When the pups were 5-6 weeks of age, *Mizz* moved them across a major road into the Simmon's Pond watershed area. This was the only significant patch of woods in the Hyannis area. A brown adult coyote with white shoulders was observed traveling with *Mizz* on a couple of occasions. Although rarely sighted, it was assumed that the brown coyote was her mate and that they hunted separately most of the time. As far as I could tell, *Mizz*'s pups stayed in that Simmon's Pond rendezvous site for most of the summer. Although all capture attempts failed, groups of 2-3 pups were sighted throughout the summer in this small patch of woods (~ 0.5 km^2).

Finally, on 1 Oct. 1999, a male juvenile, named *Hap*, was captured at the Simmon's Pond rendezvous area. It was brought to Wild Care, a rehab facility in Brewster, Massachusetts, because it had mange. It was estimated to weigh an emaciated 6.7 – 8.1 kg at the time of capture (it was not handled however until it was

ready for release). During *Hap*'s recovery, he constantly tried to dig out of his small, 10 meter by 7-meter enclosure. The director of Wild Care, Karen Von den Deale, noted that it was the first time a coyote had tried to escape from the cage (n=5 coyotes). K. V.d.Deale previously observed that most coyotes constantly paced back and forth in the pen with little or no digging. When I was in the pen covering the holes (n=7), *Hap* would hide in the dog carrier that was provided. He would not move the entire time that I was there; his eyeballs would follow my movements.

When finally deemed healthy on 23 Nov. 1999, *Hap* was transported, inside a dog carrier, to the Hyannis Animal Hospital. He was first chemically restrained at this point and was given a radio-collar and a full health check; he weighed 12.7 kg. *Hap* was released (where captured) on 24 Nov. 1999 and was supplementally fed bait in the trap where he was initially captured for three reasons: 1) to give him time to adjust to the wild, 2) to try to recondition him into the trap in case he needed to be recaptured, and 3) to potentially have other coyotes in this group watch *Hap* enter the trap with the hope that additional coyotes would eventually be captured.

After his release, *Hap* continued to use the small Simmon's Pond watershed / old rendezvous site area (~0.5 km^2). It was suspected that *Hap* was eating bait from inside the trap judging from canid tracks found inside the trap when there was snow on the ground. However, all capture attempts failed (>2 weeks) during late January and February 2000. It was unclear as to what he was eating in order to survive in such a small area. He was not documented to leave that small watershed until 20 Mar. 2000. However, he was only located three times following his departure from the small watershed. It was assumed that he dispersed and quickly left the study area.

Throughout the fall, winter and spring of 1999-2000 *Mizz* was consistently observed with two other coyotes. One was a large brownish gray coyote, thought to be *Mizz*'s mate and the other coyote was a smaller gray animal thought to be an associate coyote. On 3 Apr. 2000 *Mizz* was observed with three other coyotes. This was only the second sighting of a group of four adult coyotes (*Kett*'s group was the other sighting) during the study. It was obvious that one of the animals was the same big gray coyote; the other two coyotes were small, skinny and gray in color and were thought to be yearlings (probably *Hap*'s same-aged siblings). A den was found in mid-April 2000 where *Mizz* localized. It was not dug out but one 1-week old pup was directly observed at the mouth of the den and more were assumed to be inside the den.

Glope

On 14 Jan. 2000, *Glope*, a 20.4 kg male, was captured off Newtown Road in Marstons Mills. He was found to use a large area and never settled in a particular area. In appearance he looked very similar to *Casper*'s old (limping) probable mate (Cummaquid group) before she paired with *Sly*. He was light tan in color with a black grizzled back. The night after his release, *Glope* traveled across the entire town of Barnstable (approx. 15 km) and was located in Cummaquid.

Glope spent a considerable amount of time in the Hyannis area after leaving Cummaquid and was found near *Mizz* a number of times (see Chapter 3). *Glope*'s wide-ranging travels often lead him on documented nightly trips of over 25 km. He was documented within the ranges of all 10 of the other radio-tagged coyotes (including *Hap*'s small home range). Towards the end of the study, *Glope* was found

exclusively at the edge of *Mizz*'s home range. I estimated (based on his behavior) that he was attempting to pair bond with a female from *Mizz*'s group. I saw him with a brownish white coyote on 5 occasions. All sightings were made at the periphery of *Mizz*'s established home range.