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Movement and Activity Patterns of Eastern Coyotes In a Coastal, Suburban Environment

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Abstract - We studied the activity of 11 and movement of 6 radio-tagged eastern coyotes (*Canis latrans* var.) inhabiting suburban Cape Cod, MA between June 1998 and August 2001. Coyotes were nocturnal year round except for breeding females, which were active day and night during April–June. Twenty four-hour movements of coyotes ranged up to 31.9 linear km and averaged 23.5 ± 7.3 (SD) km from 5–14 radio-fixes during each 24 hr monitoring period. There was no difference between male and female movement rates. Coyotes moved through altered open areas more than expected when compared to residential and natural areas. Coyotes inhabiting urbanized areas generally use residential areas for traveling and/or foraging.

Introduction

Comparatively little is known about the biology of coyotes (*Canis latrans* Say, 1823) in northeastern North America (Gompper 2002, Harrison and Gilbert 1985, Major and Sherburne 1987, Messier and Barrette 1982, Patterson et al. 1999). Activity and movement patterns represent a fundamental aspect of a species natural history (Patterson et al. 1999). In urban areas, it is important to know when a predator is active and where it moves, especially in relation to human activity. Knowledge of coyote activity in human-dominated areas could potentially lead to the development of management strategies to reduce conflicts with humans; e.g., residents could be encouraged to leave pets inside during times when coyotes are most likely to be active. Additionally, studying coyotes in urbanized areas provides baseline data to inform residents of how coyotes behave in human-dominated environments.

There are divergent results in the many studies of coyote movement and activity patterns. Coyotes in anthropogenic-dominated areas have been found to be mostly nocturnal (Andelt and Gipson 1979, Atkinson and Shackleton 1991, Gese et al. 1989, Grinder and Krausman 2001, Laundre and Keller 1981, McClennen et al. 2001, Person 1988, Person and Hirth 1991, Quinn 1995, Riley et al. 2003) with limited daytime

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movements, presumably to avoid human activity (Andelt 1985, Kitchen et al. 2000). Conversely, recent studies in natural, undisturbed areas of northeastern North America (Brundige 1993, Major and Sherburne 1987, Patterson et al. 1999), Yellowstone National Park (Crabtree and Sheldon 1999; Gese et al. 1996a,b,c), and southeastern Colorado (Kitchen et al. 2000), have shown coyotes to be most active during the day. Possible explanations for this diurnality includes increased availability of cover which effectively keeps coyotes better hidden from people, inactivity of prey during daylight hours (i.e., to stalk them while bedded), and reduced human persecution. Individuals within a population may also have variable activity periods. For example, Tremblay et al. (1998) reported that rural coyotes were as active during daylight as at night during the denning period, whereas coyotes living in more wild areas were mostly nocturnal during the denning period.

Studies of coyotes in northeastern North America have found daily movement distances that are considerably greater than in other areas of North America (Andelt and Gipson 1979, Andelt 1985, Atkinson and Shackleton 1991, Litviatis and Shaw 1980, Patterson et al. 1999; although, see Woodruff and Keller 1982). Lower prey abundance, larger home range sizes, and/or the larger body size and uncertain taxonomic status of coyotes in the northeast have been offered as suggestions for the greater distances traveled by eastern coyotes (Brundige 1993; Gompper 2002; Harrison 1992a,b; Messier and Barrette 1982; Patterson and Messier 2001; Thurber and Peterson 1991; Tremblay et al. 1998; Wayne and Lehman 1992).

Relatively few studies have been conducted on coyotes inhabiting urbanized areas (Atkinson and Shackleton 1991, Gibeau 1998, Grinder and Krausman 2001, McClennen et.al 2001, Quinn 1995, Riley et al. 2003, Shargo 1988, Tigas et al. 2002), and all of these studies have occurred in western North America. Atwood and Weeks (2003) and Person and Hirth (1991) studied eastern coyotes within predominately agricultural (but with some areas of suburbanization) regions of Indiana and Vermont, respectively. Understanding the response of coyotes to suburban development is an important component of wildlife management in developed areas (Grinder and Krausman 2001, McClennen et al. 2001). Results have varied as to the habitat choice of coyotes in human-dominated areas. For example, Quinn (1997), Riley et al. (2003), and Tigas et al. (2002) found coyotes selecting mainly natural areas within an urbanized landscape. Conversely, Grinder and Krausman (2001) found coyotes preferring park and residential areas and using fewer natural patches than were available within their urban study area. Given this variation, and the importance of these questions to managing human-wildlife conflict, more research is needed to examine coyote habitat use in urbanized areas. This is especially true in northeast North America, where

they colonized Massachusetts ca. 45 years ago (Parker 1995), and are of uncertain taxonomy (Gompper 2002, Thurber and Peterson 1991). Therefore, we studied their movement and activity patterns on Cape Cod, MA, between June 1998 and August 2001. The specific objectives of our study were to: (1) describe coyote activity patterns during different seasons, (2) determine the daily distances traveled by coyotes in an anthropogenic-dominated environment, and (3) determine habitat selection of coyotes while traveling in a human-dominated landscape.

Study Area

Research was conducted within Barnstable County, Cape Cod, MA (approximate area 250 km^2), with a concentration in the town of Barnstable (land area = 155.5 km^2, Fig. 1). 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).

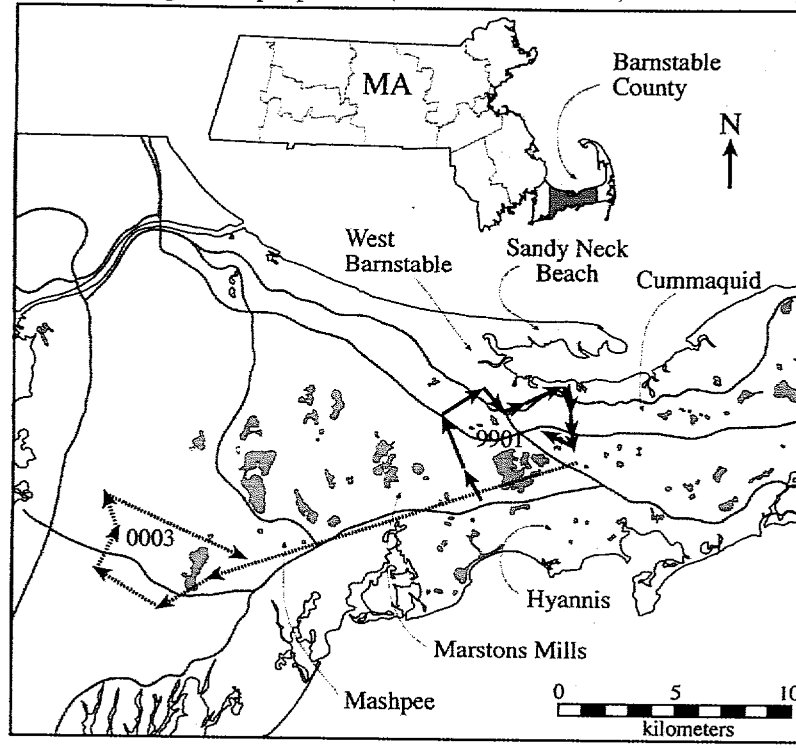

Figure 1. Study site showing principle locations, main roads (lines), and bodies of water (shaded) within Barnstable County, Cape Cod, MA. The movements (see Table 1) of coyotes 0003 (26 h) and 9901 (16 h: 1300–0500) are overlaid on the map to illustrate the daily distances typically traveled for coyotes inhabiting this suburban area. Coyote 0003's movement actually involved moving through 5 of the 12 different towns on Cape Cod

The highest and lowest densities of people were found in Hyannis, with 556/km^2, and West Barnstable, with 89 people/km^2. Housing units varied from 328.3/km^2 in Hyannis to 39.3/km^2 in West Barnstable, and averaged 157.5/km^2 (U.S. Census Bureau, 1998 estimates). Road density, defined as centerline km of roadway per km^2, was 4.7 for the town on Barnstable and 4.0 for Barnstable County (Cape Cod Commission, 1998, Barnstable, MA).

Cape Cod (Barnstable County) is a human-made island (1025 km^2) separated from the rest of Massachusetts by the Cape Cod Canal (< 1 km wide x 15 km long). Two bridges, each approximately 1 km in length, enable vehicle travel on and off Cape Cod. The town of Barnstable is located within 15 km of the bridges, on the western part of the peninsula. Coyotes were first documented in Barnstable in the early 1980s but were not considered relatively common until the 1990s (J. Way, unpublished data). The region is classified as a coastal temperate climate dominated by a subclimax forest of scrub oak (*Quercus ilicifolia* Wangenh.) and pitch pine, *Pinus rigida* Miller (Lazell 1976).

Methods

Coyotes were captured in model 610B & 610C Tomahawk box traps (Tomahawk Live Trap Co., Tomahawk, WI; Way et al. 2002). Traps were baited with supermarket meat scraps and road-killed animals (mainly eastern gray squirrels [*Sciurus carolinensis* Gmelin, 1788], woodchucks [*Marmota monax* Linnaeus, 1758], and eastern cottontail rabbits [*Sylvilagus floridanus* [J.A. Allen, 1890]), and were checked 2 times a day when set for capture. Non-coyote captures were immediately released, whereas captured coyotes were given a hand-held intramuscular injection of 8 mg/kg of telazol® (A. H. Robins Co., Richmond, VA; Ballard et al. 1991, Sillero-Zubiri 1996). 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 1 year of age, based on body size and dentition, were classified as adults (Bekoff and Jamieson 1975), and all adults were radio-collared. Pups received either an implant (summer captures) or a radio-collar with foam taped inside an adult circumference (30–35 cm) sized collar to allow for growth (captures after 1 August). Care and use of animal subjects was approved by the University of Connecticut's Institutional Animal Care and Use Committee (protocol YEE 0101), by Boston College's Institutional Animal Care and Use Committee Protocol Number 01-02, and by Massachusetts Division of Fisheries and Wildlife permits # 038.98LP and #046LP01.

Coyotes were classified as breeding residents, resident associates (i.e., betas), juveniles, or transients (Andelt 1985, Gese et al. 1996a, Way 2000). 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 or betas 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 exhibiting 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. Using a vehicle, we homed in on the animal's signal until its location was pinpointed by using the loudest-signal method (Springer 1979). Due to the urbanized environment and the associated high density of roads, once a signal was obtained for a given coyote we were confident that these radio-fixes were accurate. An assessment of telemetry error for this method with 30 test transmitters determined a mean error as 10 ± 3 m (SD) (90% of errors were ≤ 50 m).

No systematic methodology (i.e., Andelt 1985) was employed to locate coyotes over a 24-hour period because only 1 person radio-tracked. Rather, coyotes were opportunistically located 5–14 times over a ca. 24-hr period. Locations were taken between 15 min and 8 hr apart and a complete tracking session took multiple locations during the course of a monitored night (i.e., when they were most likely to travel). Estimates of daily (24 hr) distances traveled were extrapolated from the total distance traveled during each monitoring session (Patterson et al. 1999) by rounding up or down to standardize 24 hr movement rates. However, most sessions included in the analysis ended up being close to 24 hr in duration, so little change occurred using this standardization procedure. Furthermore, we believe that the 2 movements recorded < 20 hr in duration (16 and 13 hr bouts; Table 1) then subsequently standardized into a 24-hr movement rate (which may have inflated movement rates because the unsampled periods were mostly during the daytime for those two examples) were offset by the low number of locations for each tracking bout in Table 1, which no doubt underestimated total movement rates for all of the coyotes in this study. Universal Transverse Mercator (UTM) coordinates from each coyote location were determined using a digitized mapping program (Terrain Navigator, Maptech, Greenland, NH). Coyote movements were mapped and distances calculated using

ArcView 3.x animal movement extension in the animal movement analysis Arc View extension program (Hooge and Eichenlaub 1997).

For each location we classified a coyote as being in a residential, altered, or natural landscape (Riley et al. 2003). Residential areas included areas around housing developments (e.g., driveways and front yards), local neighborhood roads, and commercial areas. Altered areas included human-manipulated areas such as dumps that were capped (i.e., no trash available to animals), cranberry bogs, cemeteries, athletic fields, sandpits, golf courses, powerlines, railroad tracks, and main roads and highways. Natural areas consisted of wooded areas, marshlands, and ponds/lakes: i.e., areas that were not permanently human altered. Natural areas (6–500 ha), cranberry bogs (2–50 ha), and golf courses exist in scattered, patchy areas throughout the study site. They were not typically directly connected to other undeveloped areas (Meffe and Carroll 1994); rather, they were isolated fragments separated from other open areas by development, and sometimes connected by narrow semi-natural corridors such as powerlines and railroad tracks. We used data from the Cape Cod Commission's GIS Department (1997) to obtain percent land availability as residential, altered, and natural areas within the study area by combining data from the townships of Barnstable and Mashpee.

When locating a study animal, we attempted to get as close to the animals as possible (Grinder and Krausman 2001, Riley et al. 2003) to determine exactly what habitat it was using. Therefore, radio collared coyotes and companions were often sighted during tracking efforts. Occasionally we positioned vehicles in predicted areas of coyote travel (e.g., along railroad tracks or powerlines) and directly observed coyotes traveling in front of our turned-off vehicles. When moonlight was not sufficient, we sparingly used a spotlight to directly observe radio-collared coyotes (Way 2000). Areas were scanned for 4–8 seconds each time a coyote was believed to be close to our vehicles. Because the coyotes ran away from the spotlights on > 90% of the sightings, we used spotlights for < 8 sec per social group per tracking session to reduce our intrusion. If an individual or group was successfully sighted via spotlighting we typically left the area for > 1 hr and went to find a new coyote group to reduce our intrusion. Based on subsequent coyote locations we believe that these precautions typically only temporarily altered their behavior. On the rare occasion where our presence was apparently more intrusive, we immediately left the area. Thus, while we made all attempts to minimize our influence, it is possible that our efforts to observe individuals may have artificially increased the distance they traveled or altered their normal travel routes.

Animal activity was recorded as either resting or active based on signal modulation. Following Patterson et al. (1999), we assessed signal modulation by placing the antennae in a stationary position

and listening for fluctuations in signal pitch or strength. Harrison and Gilbert (1985) suggested that locations separated by a time interval of > 4.5 hr ensured independence between coyote relocations. Therefore, to avoid pseudoreplication (Hurlbert 1984) we only used values obtained from relocations separated by > 4.5 hr (Harrison and Gilbert 1985, Patterson et al. 1999) and typically only sampled for activity ≤ once/day during a given time period (e.g., dawn, day, dusk or night). Due to sample size constraints (we typically only had 4–6 animals collared at one time), we pooled all activity data across individuals (except females during the pup rearing season; Tremblay et al. 1998) to analyze for differences in activity patterns during the seasons. Although we recognize that pooling data has important consequences for inference and it does not use the animal as the sampling unit (Erickson et al. 2001), we believed it to be an appropriate test for determining seasonal activity of our study subjects, especially since we had low numbers of tagged coyotes for each sex and social class. Daily time periods were classified as dawn, day, dusk, or night depending on seasonal sunrise/sunset times. Dusk and dawn time periods for all seasons were classified as 2 hr each, while the length of day and night varied with seasons.

We used the chi-square test of homogeneity to detect for differences in daily activity periods and in habitat use (i.e., available versus used) (Ott 1993). We used an independent samples two-tailed t-test (SPSS Inc., Chicago, IL) to compare movement rates.

Results

We monitored activity and movements of 11 (between June 1998 and May 2000) and 6 (between August 1999 and August 2001) coyotes during the study. All of the coyotes monitored for movements were also used in the activity analysis. We recorded 2973 radio-locations during 208 coyote months (1 coyote month equaled 1 month that an individual radio-tagged coyote was alive during the study) of tracking. No data was collected between June and December 2000. Of 11 coyotes monitored for activity, 4 were juveniles, 3 were breeding females, 2 were breeding males, 1 was a transient, and 1 was a resident associate. Of the 6 coyotes monitored for movements, 3 were breeding males, 2 were breeding females, 1 was a transient, and 1 was a resident associate or beta. One coyote (#0001) changed from a transient to a breeder during the study (sometime between July and December 2000).

Coyotes showed a preference to be active mostly during dawn, dusk, and especially at night ($\chi^2 = 721.2$, 11 df, $P < 0.0001$; Fig. 2a). Overall, coyotes were active 48% (total average, biased towards a higher proportion of daytime fixes) or 56% (averaged per 2-hr time periods, n = 2973) of the time and displayed uni-modal activity with generally little day-time activity, moderate amounts of dawn and dusk activity, and high amounts of night-time activity (Fig. 2a). This trend was apparent for all seasons: during winter ($\chi^2 = 232.1$, df = 3, P < 0.0001; Fig. 2b), spring ($\chi^2 = 87.7$, df = 3, P < 0.0001; Fig. 2c), and summer ($\chi^2 = 104.3$, df = 3, P < 0.0001; Fig. 2d) coyotes were active more than expected during dawn, dusk, and nighttime; during fall coyotes were active more than

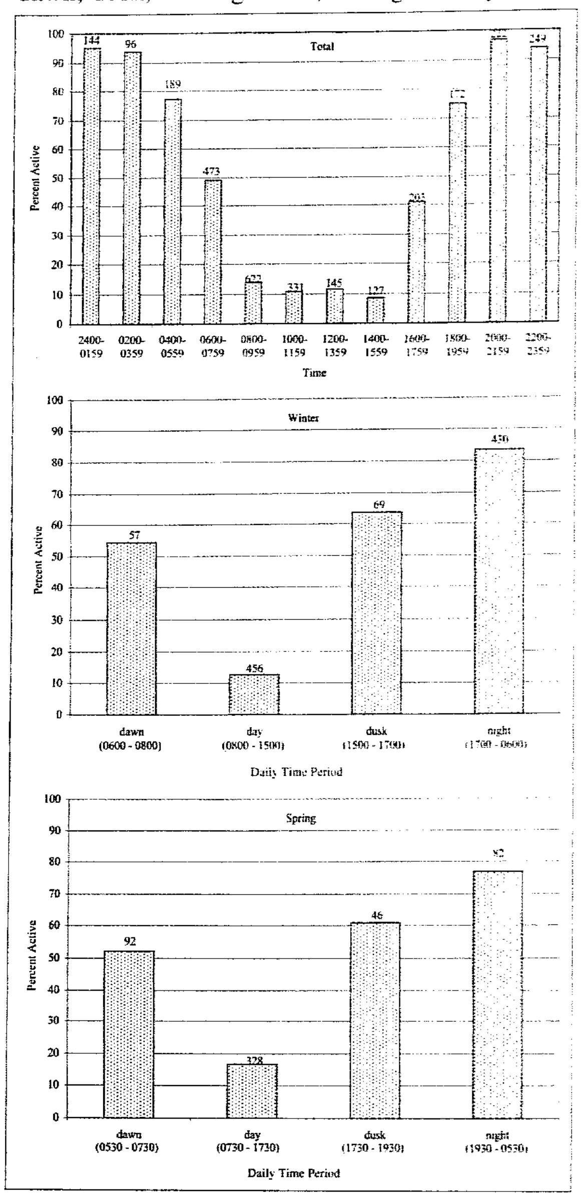

Figure 2. Graphs of activity patterns for coyotes on Cape Cod, MA, between June 1998–May 2000. Numbers above the bars are the sample sizes for each time period. (a) Total activity patterns. Coyotes were noticeably nocturnal throughout the study period ($\chi^2 = 721.2$, 11 df, P < 0.0001). (b) Activity patterns of coyotes during winter (Dec–Feb). Coyotes were active more than expected during dawn, dusk, and nighttime ($\chi^2 = 232.1$, df = 3, P < 0.0001). (c) Activity patterns of coyotes during spring (Mar–May). Coyotes were active more than expected during dawn, dusk, and nighttime ($\chi^2 = 87.7$, df = 3, P < 0.0001).

expected during dusk and nighttime ($\chi^2 = 109.0$, df = 3, P < 0.0001; Fig. 2e). The only exception for nocturnality throughout the year was for 2 breeding adult female coyotes (9902 and 9804) that were tending and nursing pups between April and June 1999 and April and May 2000 (Fig. 2f). They showed no clear preference in activity per daily time period but were marginally more active at night than expected ($\chi^2 = 6.74$, df = 3, P = 0.08).

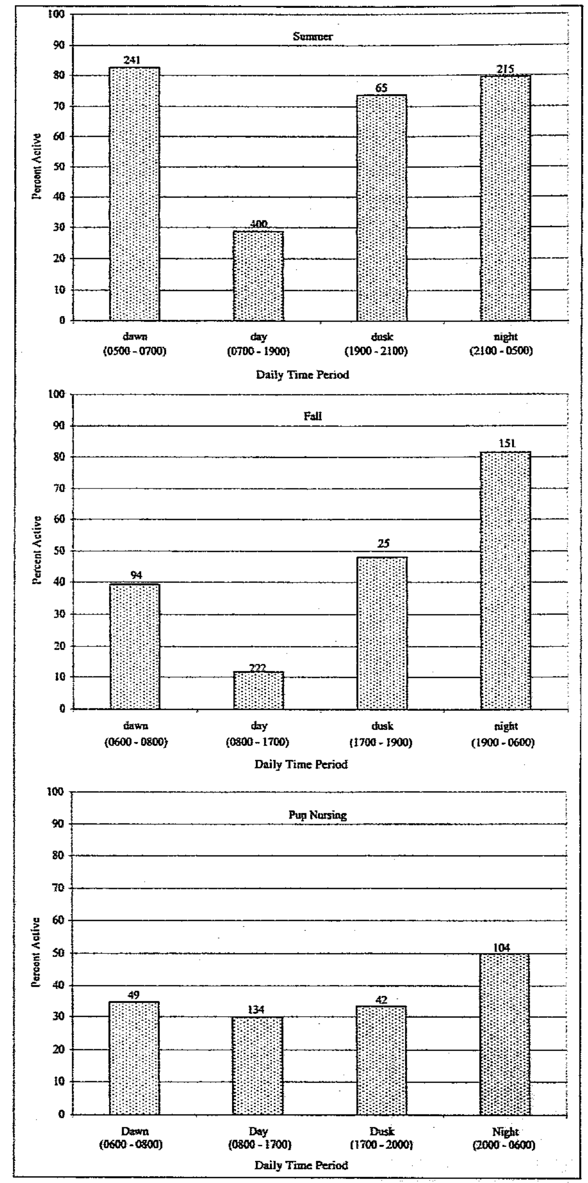

Figure 2, continued. (d) Activity patterns of coyotes during summer (Jun–Aug). Coyotes were active more than expected during dawn, dusk, and nighttime ($\chi^2 = 104.3$, df = 3, P < 0.0001). (e) Activity patterns of coyotes during fall (Sep–Nov). Coyotes were active more than expected during dusk and nighttime ($\chi^2 = 109.0$, df = 3, P < 0.0001). (f) Activity patterns of breeding female coyotes during the pup-nursing period (Apr–Jun). Breeding females displayed no clear preference in activity per daily time period but were marginally more active at night than expected ($\chi^2 = 6.74$, df = 3, P = 0.08).

Coyotes in our study area regularly traveled long distances (Table 1). For movements collected over a period > 12 hours, average standardized 24-hour distances traveled were 23.5 ± 7.3 (SD) km with 5–14 radio-fixes during each monitoring period. These distances were not different than the average of the actual (i.e., not standardized) distances traveled in Table 1 (18.8 ± 6.3 km; P = 0.16, t = 1.468, df = 16); thus, we feel further justified in reporting the standardized 24-hr distances (see methods). Males averaged 26.0 ± 4.6 (SD) km and females 20.4 ± 9.6 (SD) km per 24 hr; this difference was not significant (P = 0.29, df = 7, t = 1.156). Based on radio-location data, coyotes were documented traveling in all available habitats within their respective home ranges including the center of large neighborhoods (> 1 km^2). However, most travel was noted on powerlines, dirt roads, railroad tracks, and golf courses, and coyotes used these altered areas more than expected based on availability (Table 2; $\chi^2 = 162.5$, df = 2, $P < 0.0001$), while using natural and residential areas less than expected. Coyotes always slept in wooded/natural areas (n = 1140) or more remote altered areas (i.e., the back part of cranberry bogs bordering natural areas, n = 54) during the day, often within 50 m of a house, but occasionally were observed resting in altered (n = 46) and residential areas (n = 23) during the night.

Table 1. Daily distances traveled by eastern coyotes within Barnstable County, Cape Cod, MA.

ID(s)	Status	Total fixes taken	Date and time: Beginning	Date and time: End	Total time (hr)	Distance traveled (km)
9901	Breeding male	11	8/3/99, 1300	8/4/99, 0500	16	14.5
9804	Breeding female	5	8/17/99, 1000	8/18/99, 0900	23	10.5
9804	Breeding female	7	5/17/01, 0835	5/17/01, 0649	10	7.3[a]
9902	Breeding female	5	7/11/01, 2312	7/12/01, 2015	21	13.0[b]
9804	Breeding female	9	8/3/01, 0520	8/3/01, 0850	3.5	8.9[a]
9902 & 0001	Breeding pair	8	1/9/01, 1330	1/10/01, 1030	21	20.7
9902 & 0001	Breeding pair	14	4/10/01, 1945	4/11/01, 0845	13	17.5
0001	Transient male	13	1/15/00, 1000	1/16/00, 1010	24	22.9
0003	Beta male	9	2/15/00, 0800	2/16/00, 1000	26	31.9

[a]All movements recorded during the day in suburban areas. These locations were not included in the reporting and analysis of movement rates.
[b]Includes moving 5.48 km through Hyannis, the most densely populated part of Cape Cod.

Table 2. Habitat use of eastern coyotes during movements on Cape Cod, MA. Refer to text for habitat type descriptions. Coyotes preferred altered areas ($\chi^2 = 162.5$, df = 2, $P < 0.0001$), while using natural and residential areas less than expected.

Habitat type	Locations	Available (%)
Residential	27 (26%)	36.3
Altered	50 (48%)	10.3
Natural	27 (26%)	53.4
Total	104	100.0

Beta coyote 0003 regularly left his natal home range (Fig. 1) and then returned under the cover of darkness along natural corridors, mostly via powerlines. Transient coyote 0001 traveled nomadically around the study area with no apparent predetermined pattern, but was often sighted crossing roads on powerlines and railroad tracks. Breeding male and female coyotes regularly traveled throughout their established home ranges on a nightly basis (Fig. 1). Breeding female coyotes 9804 and 9902 even traveled considerable distances (≤ 9 km) through suburban neighborhoods during the day in the pup-rearing season (Table 1; Fig. 2f). Coyotes were seen in all parts of neighborhoods (e.g, streets, front and back yards) and seemed very capable of moving through residential areas, except they did appear to avoid fenced yards and/or dogs where present. Coyotes traveling through neighborhoods were surprisingly difficult to follow because they were normally traveling at a high rate of speed (typically ca. 10 km/hr).

Discussion

The high nocturnal activity of coyotes on Cape Cod was very similar to that found by other studies where anthropogenic effects dominate the environment (Andelt 1985, Atkinson and Shackleton 1991, Gese et al. 1989, Laundre and Keller 1981, McClennen et al. 2001, Person 1988). This was not surprising given the suburban, human-dominated environment in which this study was conducted. Coyotes appeared to be much more comfortable traveling at night, and even stood in yards and driveways without appearing nervous. This sharply contrasted their behavior in the daytime when they usually traveled through these areas relatively quickly. Coyotes were only occasionally active in residential areas during day, although they commonly bedded down within 50 m of houses. Neighborhoods that bordered natural or altered areas were especially used on a frequent basis. Apparently, coyotes were comfortable in residential areas when it was dark and they likely spent a good deal of time foraging in these areas, as also found in urban Tucson, AZ (Grinder and Krausman 2001). Thus, eastern coyotes in our study area fit the general pattern found in coyotes in their western range, with mainly nighttime activity in anthropogenic areas.

The majority of daytime activity in our study area was by two adult female coyotes near their den and summer rendezvous sites (Harrison and Gilbert 1985, Mech 1970). The nutritional demands (Harrison and Gilbert 1985) or the need for more nighttime protection of pups (Vila et al. 1995) presumably required the adults to spend more time foraging. Most of these movements were relatively localized, with residential areas being generally avoided until nighttime. However, all coyotes did occasionally move through neighborhoods during broad daylight. Daytime activity was documented during all seasons (Figs. 2a–2f), although consistently less than other times of the day, and typically over short distances.

We consider our movement estimates to be minimal actual distances traveled by coyotes, as they were estimated from only 5–14 location points per 24-hr period (Table 1). Huegel and Rongstad (1985) found that not sampling throughout a 24-hour period could underestimate coyote movements by up to 85–90%. Based on the flat, coastal nature of Cape Cod and our knowledge of each coyote's home range, we do not believe that movements were underestimated as much as Huegel and Rongstad found. Nonetheless, some areas traveled by coyotes during the sampling periods were no doubt missed. For instance, because of the low number of locations taken (n = 9) on 0003's movement (Table 1, Fig. 1), two lakes (not frozen) and other areas likely not used by 0003 were included in the straight-line point-to-point calculations.

Average movements by coyotes in our study (males = 26.0 km and females = 20.4 km per 24 hr) were greater than found in most studies of western coyotes. Adult males and females averaged 8.1 km and 7.8 km during 24-hr travel budgets in Texas (Andelt 1985), 1.3 to 6.2 km per night in Tucson, AZ (Grinder and Krausman 2001), 10.9 km per day in Nebraska (Andelt and Gipson 1979), 3.3–9.9 km in British Columbia (Atkinson and Shackleton 1991), and 6.3 km in Oklahoma (Litvaitis and Shaw 1980). Two eastern coyote studies reported coyotes also traveling short distances: 6 km in New Brunswick (Parker and Maxwell 1989) and 1.59–1.84 km at night in Vermont (Person 1988, using straight-line distance values at 8-hr intervals). However, a comparison of these results should be taken conservatively because these studies used different methods when reporting movement rates. For instance, both of the studies of eastern coyotes collected data over shorter intervals (8 hr, Person 1988; to daily, Parker and Maxwell 1989); thus, the movements of these coyotes would also be underestimated (Huegel and Rongstad 1985, Jedrzejewski et al. 2001). Conversely, Andelt (1985) and Andelt and Gipson (1979) took bearings at regular intervals throughout a 24-hr period. Our data are more consistent with the larger distances traveled by coyotes from New York (Brundige 1993), Nova Scotia (Patterson et al. 1999), and Idaho (Woodruff and Keller 1982), averaging distances per 24-hr periods of 24.4, 20.2, and 27.7 km respectively. Woodruff and Keller (1982) did not offer suggestions why coyotes in their western study area traveled such large distances, but it is of interest to note that coyotes in their study area had large home range sizes (30–50 km^2), similar to reported values from the east. There were no apparent trends of coyote movement rates in urbanized versus more natural areas in the literature. Possibly the increased disturbance that humans cause to coyotes in an urbanized landscape (i.e., forcing them to be nocturnal) is offset by the ease of extensive travel along golf courses, powerlines, and roads (Grinder and Krausman 2001). Therefore, we agree with Patterson et al. (1999) that, regardless of prey density, the maintenance of the large territories typically found for coyotes in the northeast would require greater 24-hr movement distances to be fully patrolled (Messier and Barrett 1982, Patterson and Messier 2001, Way 2000). In addition, compared with western coyotes, the larger body size of the eastern coyote (Thurber and Peterson 1991, Wayne and Lehman 1992; J. Way, unpublished data) might make it better suited to travel longer distances, regardless of habitat type. In fact, the distances that coyotes 0003 (31.9 km), 0001 (22.9 km), and 9902 and 0001 (20.7 km) covered were in the range of those reported for wolves (*Canis lupus* Linnaeus, 1758) (14.4–49 km, Mech 1970; 13 km, Vila et al. 1995; 22.8 km, Jedrzejewski et al. 2001).

Surprisingly, coyotes in this study were documented traveling in altered areas more than expected when compared to residential or natural areas (Table 2). This differs from recent studies in the western United States that found urban coyotes prefer to use the few remaining natural areas (Grinder and Krausman 2001, Riley et al. 2003, Tigas et al. 2002). Some of the altered areas in our study were narrow corridors such as railroad tracks and powerlines that coyotes used for travel. Traveling on these linear pathways is widespread in both coyotes and wolves (Harrington et al. 2000, Linhart and Dasch 1992, Mech 1970, Mech et al. 1998, Phillips and Mullis 1996, Van Ballenberghe 1984). Non-corridor altered areas such as golf courses, cranberry bogs, and dumps appeared to provide coyotes with places to hunt as well as travel. Coyotes also rested in these open altered areas on occasion, mostly when adults and pups were at summertime rendezvous sites (Harrison and Gilbert 1985). Although used rarely in proportion to their availability, coyotes routinely traveled in residential areas on Cape Cod. Although our direct sightings of animals were limited in neighborhoods, this habitat type was potentially important for hunting. We regularly observed coyotes foraging at a trotting pace, zig-zagging in and out of backyards (mostly at night) apparently searching for prey (e.g., lagomorphs and domestic cats). Coyotes were also occasionally observed tearing open trash bags and feeding on garbage in residential areas. Most natural areas in our study site did not appear to have the same abundance of prey as residential and altered areas (J. Way, unpublished data). Nevertheless, these were important habitats where coyotes mostly rested (mainly during the daytime) and important seasonal locations where coyotes gave birth and hid their young. The combination of altered and natural areas, interspersed with residential areas, seems to be a suitable environment for coyotes on Cape Cod. Although absolute measures of food abundance are difficult to measure for adaptable species such as coyotes, these are needed if future research is to compare these types of data across regions (e.g., Riley et al. 2003) and to test for the relative importance of food abundance, habitat type, and human disturbance on coyote space use.

It appears that urban coyotes typically use human-dominated (i.e., altered and residential) areas for traveling and foraging, which usually occurs at night (Grinder and Krausman 2001, Riley et al. 2003). However, natural areas are also important in the daily life cycle of an urbanized coyote. Managers should consider integrating these data when designing reserves because there may be a threshold to which coyotes can withstand human development. For example, collisions with cars were the highest source of mortality in our study population (J. Way, unpublished data). Additional research should investigate if improved reserve design (e.g., under or overpasses along strategic areas of major roads, increased connectivity to natural and/or altered areas) increases coyote presence and survivorship in urban areas. Alternatively, because urban areas have such a high density of roads, it just may be that certain individuals learn to avoid the hazards of urbanization in order to survive and reproduce regardless of any human-induced changes.

The 24-hr long distance movements accomplished by urban coyotes in this study and wilderness coyotes studied by Brundige (1993) and Patterson et al. (1999) suggest that dispersing coyotes should be able to colonize new, even distant, areas relatively quickly. Indeed, their colonization of eastern North America after the extirpation of the wolf took place in only about 50 years (Parker 1995). This high dispersal potential, combined with their tendencies towards territoriality and monogamy (Messier and Barrette 1982, Patterson and Messier 2001, Person and Hirth 1991, Way 2000), suggest that the removal of resident local adult coyotes will have little effect on overall population dynamics because other coyotes will quickly move in to fill a vacated breeding position (Patterson and Messier 2001).

With large daily movement patterns, resident coyotes can potentially be located anywhere within their home range (Way 2000) and at any given time. Our data revealed that one pack of coyotes (3– 4 individuals) can cover a total of 75–100 km per night in a territory averaging 30 km^2 (Way 2000). This, combined with increasing boldness to humans, may lead to more sightings by the general public, and the inaccurate belief that coyotes are becoming more numerous in a relatively localized area. Knowledge of activity and movement patterns of coyotes in local contexts may allow for the implementation of preventative measures to protect pets and livestock from coyote depredations. For example, households in areas where coyotes exist could be informed to keep domestic pets inside or otherwise protected, especially at night and during the pup-rearing season.

The emerging picture of coyotes that inhabit urbanized areas is that they move quickly over long distances through a human-dominated matrix

and still survive by finding enough food and avoiding death (e.g., cars). This suggests that relatively little connectivity is needed to maintain a large predator in an urban area, but even the conservation of corridors as small as powerlines could potentially connect to other larger patches of coyote habitat where fragmentation is occurring (Meffe and Carroll 1994). Natural areas could be strategically situated near altered areas to provide places for coyotes to rest, travel, and forage, which might also minimize potential conflicts with people in residential areas. However, it is important to note that the opposite scenario may also hold true; natural and altered areas situated near residential areas may create more coyote-caused problems for humans because coyotes may forage closer to bordering residential areas. Nevertheless, the ecological (Crooks and Soule 1999, Gompper 2002) and aesthetic (Kellert 1985) values of coyotes are now recognized as important components of our natural heritage and the coyote's life history needs should be addressed when creating reserve designs, especially in urbanized areas.

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