SPACE USE BY COYOTES (Canis latrans) IN AN URBANIZING LANDSCAPE
AND IMPLICATIONS FOR MANAGEMENT

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SPACE USE BY COYOTES (Canis latrans) IN AN URBANIZING LANDSCAPE
AND IMPLICATIONS FOR MANAGEMENT

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Thesis

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ABSTRACT

Over the past 100 years, the coyote (*Canis latrans*) has expanded its geographic range across North America. As a result of their adaptability and behavioral flexibility, coyotes are now a common occupant of urban areas in the United States. Because their expansion from rural to urban areas is recent, there is limited research on coyote space use within different levels of development when ranging from truly urban to truly rural environments.

We studied a total of 34 radiocollared coyotes in the Cuyahoga Valley, OH region from October 2009 through October 2012 to determine variation in coyote home range size, home range land cover composition, and habitat selection in northeast Ohio. Mean composite home ranges of transient coyotes (\(\bar{x} = 108.614 \pm 16.667 \text{ km}^2\)) were significantly larger than those of resident coyotes (\(\bar{x} = 6.63 \pm 0.729 \text{ km}^2\)) in the Cuyahoga Valley, Ohio. Home ranges did not vary by sex or season for resident and transient coyotes, but resident subadults had significantly larger composite home ranges than other age classes. Home range sizes of transient coyotes were significantly larger than resident coyotes during the breeding, pup-rearing, and dispersal seasons. Neither sex nor age significantly influenced resident or transient coyote seasonal home range. Resident coyote home range size was smaller than found in previous studies. An a priori prediction that coyote home range size in the Cuyahoga Valley would be intermediate to coyote home range size in more urban and more rural habitats was, therefore, not supported.
Within the study area and individual home ranges, coyotes commonly avoided land-cover types associated with human development and predominately selected natural habitats (i.e. deciduous forests, grasslands, etc.) more than they were available with little variation as a function of resident status, sex, age, or season. Although we did find that coyotes use areas of high human activity, we found little evidence that coyotes widely utilized areas associated with human development across the landscape.
DEDICATION

My deepest gratitude will always go out to my Aunt Evona and Uncle Mike Myers. Without them, I would never have had the ‘push’, motivation, support, resources, and criticism that kept me wanting to keep striving forward- knowing that I was always in good hands along the way.
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CHAPTER I
SPACE USE BY COYOTES IN AN URBANIZING LANDSCAPE AND
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Introduction

For the first time in history, Homo sapiens is an urban species; more people now live in urban/suburban areas than rural areas (Gehrt and Riley 2010). It is predicted that by 2030 approximately 60% of the human population will be urban dwellers (United Nations Population Fund 2007). As human development continues to spread, wildlife must adjust to this human-modified system, or be excluded from urbanized environments (Lowry et al. 2012). Given such changes, human-wildlife conflicts have the potential to become more frequent. Human-wildlife conflicts can occur whenever an action by humans or wildlife has an adverse impact on the other (Conover 2002). These conflicts can occur when wildlife cause damage to crops or livestock, injure or kill domestic animals, or threaten or kill people (Madden 2004). Once considered to be unsuitable habitat for wild fauna, urban/suburban areas now provide habitat for a multitude of wildlife species such as black bear (Ursus Americana, Lyons 2005), mountain lion (Puma concolor, Torres et al. 1996), bobcats (Lynx rufus, Riley 2006), gray fox (Urocyon cinereoargenteus, Riley 2006), raccoons (Procyon lotor, Smith and Engeman 2002;
Prange et al. 2003), and skunks (*Mephitis mephitis*, Rosatte et al. 1992)- many of them formerly believed to be restricted to rural or pristine habitats (Ditchkoff et al. 2006). Increased use of human-modified habitat by wildlife may ultimately lead to more negative interactions.

As more wildlife species take refuge in these areas of high human activity, management of those species will become an increasingly pressing issue. For example, the coyote (*Canis latrans*) is increasing in abundance in urbanized areas as a result of their adaptability and behavioral flexibility. Developing adaptive management strategies for such species will be important for the health and protection of humans, as well as the health and well-being of wildlife.

Coyotes were historically distributed throughout the western half of North America prior to the arrival of the first Europeans (Bekoff 1978, Figure 1). In the last 100 years, the geographic range of coyotes has expanded, mostly due to alteration of habitat, the elimination of wolves (*Canis lupus* and *Canis rufus*) (Bekoff1978; McClennan et al. 2001; Gompper 2002), and the population growth of white-tailed deer (*Odocoileus virginianus*) (Weckel et al. 2010). Currently, coyotes are geographically distributed from northern Alaska to Central America and from the Pacific Coast to the Atlantic Coast (Gehrt and Riley 2010, Figure 1). The first documented sighting of coyotes in Ohio occurred in Logan County in 1919 (Weeks et al. 1990). Over the past century, coyote abundance in northeast Ohio has also increased substantially (Weeks et al. 1990; ODNR 2008), and human-dominated areas continue to impact natural spaces.
Figure 1. Historical range prior to European settlement and current geographic range of *Canis latrans* across North America. (The Cook County, Illinois, Coyote Project, http://www.urbancoyoteresearch.com/Image5.jpg).
Understandably, the local park districts are concerned with minimizing potential negative interactions between coyotes and people and pets.

Many species are displaced by urbanization, while others survive and thrive in close proximity to dense human populations (Riley 2006). Wildlife populations such as deer (*Odocoileus* spp.), squirrels (*Sciurus* spp.), and geese (*Branta* spp.) have adjusted to human-dominated landscapes by adapting their basic ecology through a process defined as synurbanization (Luniak 2004), leading to changes in population size, sex and age structure, behavior, and habitat use (McCleery et al. 2006). Urban-based populations, such as that of coyotes, exhibit behavioral modifications that differ from their rural counterparts (Lowry et al. 2012). A common example of behavioral modification of urban wildlife is the spatial and temporal variation in activity patterns (Ditchkoff et al. 2006).

Limiting activity to crepuscular and/or nocturnal periods, coupled with spatial avoidance of humans, may influence survival and mortality, diet and nutrition, disease, and reproduction (McClenen et al. 2001; Ditchkoff et al. 2006). Though some wildlife populations limit their activity to times when human presence is low (Olsen et al. 1998; Tigas et al. 2002; Sweanor et al. 2007), it has also been found that individuals who utilize urban areas such as golden jackals (*Canis aureus*, Rotem et al. 2011), raccoons (Prange et al. 2004), and wild boars (*Sus scrofa*, Podgorski et al. 2013) exhibit smaller home ranges than those who do not. Most of these results are thought to be a response to high natural or anthropogenic resources, allowing individuals in urban areas to meet their energetic requirements in a smaller area (Gould and Andelt 2013).
Recently, coyotes have become occupants of many urban/suburban areas across the United States such as Seattle, WA (Quinn 1997), Los Angeles, CA (Tigas et al. 2002; Riley et al. 2003), Tucson, AZ (Grinder and Krausman 2001b; Grubbs and Krausman 2009), and Chicago, IL (Gehrt et al. 2009; Gese et al. 2012). Given the movement of coyotes into urban/suburban habitats, researchers are now learning more about how coyotes behave in such man-made environments (e.g. Quinn 1997; Grinder and Krausman 2001b; Tigas et al. 2002; Gehrt et al. 2009; Gehrt and Riley 2010). In order to meet their daily needs, it has been suggested that coyotes must increase their home range size in urban areas due to a reduction in available resources (Riley et al. 2003). However, most studies have found that coyotes have smaller home ranges in urban landscapes than rural areas (Gehrt et al. 2009; Grubbs and Krausman 2009).

Decreases in home range size may be the result of increased resource availability as a result of anthropogenic inputs to the system or it could be that home range size is limited by patch size of preferred habitats due to increased fragmentation. One might also argue that home range size in these fragmented systems would increase simply as a result of the increased isolation of fragmented patches, leading to increased travel distances between disconnected patches of natural landscapes. However, Tigas et al. (2002) found home ranges of bobcats and coyotes in developed, fragmented habitats were not significantly larger than undeveloped, unfragmented areas; possibly due to the high number of rabbits and rodents, as well as human-related food such as fruit, garbage, and household pets. Though the presence of coyotes in areas of high human activity is likely a
reflection of their adaptability, we still lack information on coyote space use in transitional, urbanizing landscapes (Atwood et al. 2004), within a matrix of growing human presence and expanding development.

We investigated space use of coyotes in northeast Ohio by examining home range size and land cover composition within home ranges, as well as the relative use and selection of available land cover types within an “urbanizing landscape”- an area that is not completely urban or rural, but transitional between the two types. In previous habitat selection studies, urbanized coyotes have been found to vary in the habitat types they prefer. Those habitat types include grassland elements (Atwood et al. 2004), corridors (Tigas et al. 2002; Atwood et al. 2004), open spruce forests, wet meadows, wet spruce forests, and open aspen forests (Gibeau 1998), early successional habitat and hardwood stands (Schrecengost et al. 2009), and multiple levels of human development (Gibeau 1998; Riley et al. 2003; Way et al. 2004; Gese et al. 2012). To better understand how coyotes utilized land cover types within the urbanizing landscape and within individual home ranges, we quantified preference and avoidance of specific land cover types in the Cuyahoga Valley, OH region. Given variation in the landscape such as topography, human development, and the availability of natural areas, we predicted that coyote home range size in the Cuyahoga Valley would be intermediate to coyote home range size in more urban and more rural habitats. With the potential to have shifts in human activity, and/or available resources, we also expected to observe seasonal variability among resident coyote home range size, with little to no change in transient home range size.
Understanding coyote selection or avoidance of particular urban land types can provide managers with insight as to how coyotes utilize the landscape, as well as inform management decisions that can help minimize human-wildlife conflicts. Previous studies have found that coyotes prefer undeveloped and natural habitat (Gehrt et al. 2009), while others have shown coyotes increase in proximity to urbanization (Ordeñana et al. 2010). For our system, we hypothesized that coyotes would show preference for natural landscapes (forest, grassland, etc.), while avoiding man-made landscapes (urban/suburban, developed, etc.). Further, we hypothesized that these preferences might not be universal among coyotes but that there would be differences in habitat preference based on resident status, age, sex, and season.

Proper management of wildlife in developed areas demands information on behavioral modification and prospective adaptations of animals that use the urban-rural interface (McClennan et al. 2001). The increasing abundance of coyotes in urbanized areas of the U.S. is a testament to their ability to adapt to nearly any environment. It is important to gain a more complete understanding of how coyotes respond to urbanization by expanding research to urbanized areas with different patterns and levels of development when compared to truly urban or truly rural environments (Gehrt 2007). We believe the information from this study will aid managers and biologists in understanding the behavioral ecology of coyotes in similar ‘urbanizing’ areas.
CHAPTER II

METHODS

Study Area

This study was conducted in the Cuyahoga River Valley region, found in Cuyahoga and Summit counties of Northeast Ohio (Figure 2). The study area is approximately 14,052 ha (34,723 acres) of public land maintained by the Cuyahoga Valley National Park and adjoining properties of Cleveland Metroparks, and Metro Parks, Serving Summit County. The Cuyahoga Valley region, consisting predominantly of forested and developed areas, is fragmented by areas of high human activity such as roads, highways and recreational trails. The estimated human population is 1,280,122 and 541,781 for Cuyahoga (Cleveland) and Summit (Akron) counties, respectively (U.S. Census Bureau 2010).

The Cuyahoga Valley landscape includes upland forests, rolling floodplains, ravines and steep valley walls (National Park Service 2009). Along with riparian habitat, land tracts also include mixed-mesophytic forests, wetlands, various-staged successional fields, and cultivated agricultural lands (National Park Service 2009). This region is predominantly made up of deciduous hardwoods, with dominant communities of Acer spp. (maple), Quercus (oak), Plantanus occidentalis L. (Sycamore), and Carya spp. (hickory) (Burls and McClaugherty 2008).
Figure 2. Map of the study area in the Cuyahoga Valley, OH composed of the Cuyahoga Valley National Park, Metro Parks, Serving Summit County, and Cleveland Metroparks.
Trapping, Collaring, and Telemetry

Coyotes were trapped by a professional trapper within properties controlled by Metro Parks, Serving Summit County, Cleveland Metroparks, and the National Park Service. Trails were either closed for trapping, or traps were placed far enough away from recreation sites to minimize risk to park guests and pets. Traps were checked each morning. Animals were trapped with padded-leg-hold traps or neck snares with stops to prevent injury and strangulation. Coyotes were immobilized with Medetomidine and Butorphanol. During processing, coyotes were weighed, sexed, aged by tooth wear (Gier 1968), given a fecal exam, and a blood sample was taken to assess health conditions. Individuals received a numbered ear tag, pit tag, and were fitted with either a Lotek WildCell GPS collar (Lotek Wirelessss, Inc., Newmarket, Canada), or a VHF (Very-High-Frequency) collar (Advanced Telemetry Systems, Isanti, Minnesota) for real-time satellite tracking or radiotelemetry monitoring. Upon completion of processing, coyotes were given a reversal injection of antipamezole, and were released at the site of capture. All methods were approved by the University of Akron Institutional Animal Care and Use Committee (Approval #11-2B) and followed guidelines approved by the American Society of Mammalogists (Sikes et al. 2011).

VHF collared individuals were monitored from December 2009 thru May 2012. During VHF/ radiotelemetry monitoring, single locations were collected 1-2 times per week for each animal during daylight hours (6am to 6pm). This process was done in order to maintain contact with each animal, as well as to locate an animal and/or its collar quickly in case of mortality. From December 2009 thru May 2011, each VHF collared
animal was tracked for at least one 12h session per month to monitor movement during nighttime hours (6pm to 6am). For overnight tracking, three research stations were positioned around an individual animal, and point locations were collected approximately every 30 minutes. From May 2011 thru May 2012, each VHF collared animal was also tracked for at least one 12h session per month during daylight hours. In this case, locations were collected approximately every 60 minutes. Usually, daytime locations were collected by one researcher. For VHF tracking, locations were triangulated using the Universal Transverse Mercator (UTM) geographic coordinate system and the program LOCATE III (Pacer, Truro, Nova Scotia, Canada). Data collected in the field via Palm Pilot were uploaded into a computer for analysis.

For GPS collars, location coordinates of coyotes were sent via ‘short messaging service’ (SMS) every 90 minutes during overnight hours, 6pm-6am, and every five hours during daylight hours, 6am-6pm. The data were then uploaded into ArcGIS (Environmental Systems Research Institute, Redlands, California), with locations specified for each individual. Collars remained on an individual coyote for approximately one year, after which time the collar was designed to drop off. Collars were retrieved and refurbished for use on other individuals.

Analysis

Spatial data were analyzed primarily using ArcGIS 9.3 geographical information system (GIS) software (Environmental Systems Research Institute, Redlands, California). The data were analyzed in the UTM 17N Projected Coordinate System. ArcGIS 10.0 was
used to run models for bulk analysis using the ‘Iterator’ feature. This GIS model allowed for efficient calculation of land cover composition within each animal’s composite and seasonal home ranges.

VHF locations had a varying amount of estimated location error, largely due to conditions during collection such as electronic static, road access, etc. that occurred within the animals’ home range. To minimize error with VHF locations, a conservative Tukey estimator was applied to the location points using Locate III. This was done for each coyote, because each individual’s habitat resulted in different amounts of error (Appendix B). The 5% of locations with the largest error were removed from the analysis. Incomplete locations, those having ‘0’ in the Latitude and Longitude, were also deleted along with location points that were obviously not part of the animal’s usual whereabouts (e.g. the veterinarian’s office or impossible locations calculated due to human error). Gese et al. (1990) found that the minimum sample size, as defined by the asymptote of the area-observation curve, ranged from 23 to 33 day locations and 28 to 36 night locations were required to delineate home range size. Given this, only home ranges with ≥30 VHF point locations were used for analysis.

GPS locations were usually downloaded daily to monitor mortality and to observe individual movements from the previous day. GPS locations were collected and analyzed from October 04, 2010 thru October 31, 2012. For each animal, 2D and non-validated point locations (those locations taken by less than five satellites) were removed from the analysis due to higher amounts of associated error (Rempel and Rodgers 1997).
Eliminating locations with high amounts of error results in the use of the most accurate locations which help to minimize bias in habitat selection (Rempel and Rodgers 1997).

Individuals were broken down by social group (resident or transient), age class (adult, subadult, juvenile), and sex. Resident and transient coyotes were categorized by their home-range characteristics. We defined resident coyotes as individuals tending to utilize one defined area for ≥ 1 biological season, and transient coyotes are being nomadic, showing no permanent preference for a single area (Gese et al. 1988). In our study, we reassured our classification of individuals as resident or transient by observing movements of individuals with respect to their home range size. Residents often maintain small home ranges (<10 km²) while transients used larger areas (>10 km²) (Andelt 1985). Individuals were aged by looking at tooth wear (Gier 1968). Coyotes were considered a “juvenile” if they were <1 year old, “subadult” if 1-2 years old, and “adult” if >2 years of age (Kamler and Gipson 2000; Hennessey et al. 2012). In cases of small sample size, individuals were pooled by age class for analysis, where “adults” were considered >2 years of age and “young” were juveniles and subadults combined.

Seasonal analysis was broken into three time periods: breeding (1 Jan-30 April), pup-rearing (1 May- 31 August), and dispersal (1 September- 31 December) (Morey et al. 2007; Gehrt et al. 2009; Gese et al. 2012). For the best representation of an individual’s space use, only data that comprised at least half of a season (≥2 months) or at least half of a month (≥14 days) were used for analysis.
Home Range Size

To estimate home range size, we used the minimum convex polygon (MCP) method (Mohr 1947), calculated using the Home Range Tool extension (Rodgers et al. 2007) in ArcGIS 9.3. This method is commonly used and thus allows comparison of results across studies (Gese et al. 1988; Kamler and Gipson 2000; Grinder and Krausman 2001b; Riley et al. 2003; Gehrt et al. 2009). Composite (comprised of all data for each individual), seasonal, and monthly home ranges were calculated in km². Due to a lack of location points, only composite and seasonal home ranges were estimated for VHF radiocollared coyotes. Since some coyotes are transient and can travel large distances, home ranges were calculated separately for individuals that remained in the study area and for all animals regardless of whether or not they left the study area.

Once home range sizes were estimated, t-tests were used to compare composite home ranges of resident and transient coyotes, and male and female coyotes of each social group. A one-way ANOVA, with a Bonferroni t-test as a Multiple Comparison Procedure, was used to compare differences among age groups. Seasonal home ranges were log-transformed to maintain normality for one way ANOVA and t-test analysis.

Home Range Land Cover Composition

Land cover composition” refers to the proportion of each habitat type available to or used by an animal; each habitat composition necessarily sums to 100%. We estimated the percentage of land cover types within each coyote’s composite and seasonal home range to evaluate differences in space use as a function of age and sex of individuals. The
2006 National Land Cover Dataset (NLCD 2006) layer was retrieved from the U.S.G.S. Seamless Viewer (Fry et al. 2011), and was used for habitat analysis. Fifteen different land cover types are found within the Cuyahoga Valley (Appendix A), and we measured the percentage of each land cover type found within the home range of each individual. This was done using the ‘Tabulate Area Tool’ in ArcGIS9.3. The numbers of cells of each land cover type were counted within the estimated home range of each animal, and a percentage of each land cover type was calculated using the total number of all cells.

To evaluate the accuracy of the NLCD 2006, we tested the GIS land cover layer using 2010 and 2011 aerial county photos. We selected 100 random coyote locations, from all animals, and assessed whether or not the location assigned in the NLCD matched the location in the aerial photo. Of the location points checked, 94% were assigned a correct land cover type. The errors could be explained as points assigned to a similar land cover to their actual classification, (e.g. pasture assigned as grassland, wetland assigned as water).

Land cover composition of home ranges was calculated for all resident and transient coyotes. A Multivariate Analysis of Variance (MANOVA) was used to test for differences in the proportion of land cover types within a home range by social group, sex, and age of coyotes. We analyzed the proportion of land cover in each composite home range for all coyotes’ range within and outside of the Cuyahoga Valley, OH.

To better understand if levels of urbanization influence home range size, we used simple linear regression. We calculated the combined proportion of open, low, medium,
and high levels of development, and regressed this measure with the size of the log-transformed home range. This included data of individuals who left the Cuyahoga Valley. All other analyses were composed of data limited to the Cuyahoga Valley, OH.

*Land Cover: Use-By-Availability*

Although multiple land cover types may be available in an animal’s home range, it is not an indicator of use. To assess the use of available land cover types, we quantified locations within each land cover type for every individual in a measure of second and third-order selections as described in Johnson (1980). Analysis was carried out in ArcGIS 9.3 using the Intersect Tool by combining each individual locations shapefile with the ‘Raster to Vector’ shapefile of the NLCD 2006. This provided a field that gave the land cover type within which each location point was found. We then created new layers for each animal by season and month for analysis. By using the ‘Select by Location’ tool, we were able to select points within a specific home range (whether by season or month) and summarize the percentage of all location points found within specific habitat types. Our attempt was to quantify land use in similar ways to previous studies (e.g. Gehrt et al. 2009; Randa and Yunger 2006) so that results may be comparable across studies.

We also determined if individuals used land cover types more or less frequently than expected based on the relative availability of that habitat type. To do so we used the following metric:

\[
\bar{x}U_i - \bar{x}A_i = d
\]

where the mean available land cover proportion (A) of a specific habitat type (i) within
the home range (composite and seasonally) was subtracted from the mean proportion of locations within the same land cover type \( (U_i) \). In this study, we’ve termed the value \( (d) \) a “Selection Score”. As a result, if an individual were using a specific land cover type more than expected given its availability, the selection score would be positive. A negative selection score occurs when there is a smaller percentage of locations within a particular land cover type than would be expected given its availability. For habitat selection studies, VHF locations were removed that had an error ellipse greater than the mean land cover patch size of 0.026617 km\(^2\), as calculated by ArcGIS. Mean patch size was calculated by transforming the NLCD 2006 raster to a vector layer and then quantifying polygon size in ArcGIS. Consequently, only 2 VHF collared coyotes were used for composite home range habitat selection due to the limited number of locations.

**Preference**

A standard approach for testing the hypothesis of preference for a specific habitat type was created by Neu et al. (1974). A chi-square goodness of fit test is used to statistically determine whether specific habitat types are used in proportion to their availability. All coyote locations within the study area were identified to a habitat type. These counts of locations within each habitat type constituted our observed values. Expected values were calculated by multiplying the proportion of each habitat type in the study area by the total number of locations from all coyotes combined in order to give an expected distribution of points if coyotes were randomly distributed throughout the landscape. Location points outside of the study area were eliminated for this analysis, and a goodness of fit test was run separately for each social group and for each sex.
The chi-square goodness of fit test was used congruently with the selection score metric to visually and statistically represent habitat preference.
CHAPTER III

RESULTS

We captured a total of 40 coyotes from October 2009 through February 2012 throughout the Cuyahoga Valley, OH. Due to sickness or small size, four individuals remained un-collared, and two additional animals were thrown out of the analysis due to vehicular collisions shortly after release that provided little data. Therefore, 34 coyotes (15 female, 19 male; 16 adults, 8 subadults, 10 juveniles; 18 residents, 16 transients; Figure 3) were analyzed from October 2009 thru October 2012, resulting in 74,889 individual location points (Table 1). The majority of the coyotes stayed within the Cuyahoga Valley region, with the exception of 4 transients who left the study area, and 2 residents that were trapped, and remained, outside of the study area. One dispersing resident VHF animal was analyzed as a juvenile and as a subadult for home range analysis since it was monitored for over one year and spent considerable time in two different regions.

Because the movements of some coyotes are much greater than others, several individuals, whether dispersing residents or transients, left the focal study area. However, these animals were included in several analyses in order to quantify space use of coyotes across a larger geographic area than just the Cuyahoga Valley.
Figure 3. Distribution of VHF and GPS location data for 34 individual coyotes tracked in northeast Ohio from October 2009 – October 2012.
Home Range Size

We estimated home range size for 19 resident and 16 transient coyotes (95% MCP composite home range; Figure 4; Table 1). Mean size for composite home ranges of resident animals was 6.97± 0.82 km² (Table 2), and mean size for composite home ranges of transient coyotes was 240.86 ± 73.5 for all individuals regardless of whether or not they left the study area (Table 2). Composite home range estimates for resident coyotes were similar by sex ($t = 0.257$, $d.f. = 17$, $P = 0.80$), but there were significant differences in mean composite home range size as a function of age ($F = 6.50$, $d.f. = 2, 16$, $P = 0.009$), with subadult coyotes having significantly larger home ranges than adults ($P=0.015$) and juveniles ($P = 0.020$). Transient coyotes showed no difference in composite home range by sex ($t = 0.027$, $d.f. = 14$, $P = 0.979$), and no difference as a function of age ($F = 0.502$, $d.f. = 2, 13$, $P = 0.616$). Mean (±SE) composite home ranges of transient coyotes were larger ($t = 3.48$, $d.f. = 33$, $P = 0.001$) than composite home ranges of resident coyotes. Four collared transient individuals covered large tracts of land, crossing multiple counties, and even crossing state lines entering Pennsylvania, causing mean transient home ranges to become inflated.

Home range size of transient coyotes were significantly larger ($P<0.001$) than resident coyotes during the breeding, pup-rearing, and dispersal seasons. Neither resident nor transient coyotes showed any significant difference in seasonal home range size as a function of sex or age (Figure 5).
Figure 4. Calculated home ranges of coyotes in the Cuyahoga Valley, OH, October 2009-October 2012. White polygons represent resident coyotes, colored polygons are transient coyotes.
Table 1. Home range areas (km$^2$) for 34 coyotes (15 female, 19 male; 16 adults, 8 subadults, 10 juveniles; 18 residents, 16 transients) collared in the Cuyahoga Valley.

<table>
<thead>
<tr>
<th>Animal ID</th>
<th>Collar Type</th>
<th>Sex</th>
<th>Age</th>
<th>Social Group</th>
<th>Total Points</th>
<th>95% MCP Home Range</th>
<th>50% MCP Home Range</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>No. locations</td>
<td>Home range size</td>
</tr>
<tr>
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<td>VHF</td>
<td>Male</td>
<td>Subadult</td>
<td>Resident</td>
<td>226</td>
<td>219</td>
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</tr>
<tr>
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<td>VHF</td>
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<td>Juvenile</td>
<td>Resident</td>
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<td>213</td>
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<tr>
<td>2</td>
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<td>Resident</td>
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<td>460</td>
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</tr>
<tr>
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<td>Subadult</td>
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<td>243</td>
<td>231</td>
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<tr>
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<td>Juvenile</td>
<td>Transient</td>
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<td>2498</td>
<td>63.40</td>
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</table>
Table 2. Home range summary for 34 collared coyotes trapped in the Cuyahoga Valley, OH. Analysis was done on individual the study area and those who went abroad. Composite home range summary consists of all recorded location points for each individual.

<table>
<thead>
<tr>
<th>MCP</th>
<th>Group</th>
<th>Age</th>
<th>n</th>
<th>Study Area Only</th>
<th>All Animals</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Home Range size (km²)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>( \bar{x} )</td>
<td>SE</td>
</tr>
<tr>
<td>95%</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Resident</td>
<td>ALL</td>
<td>16</td>
<td></td>
<td>6.630</td>
<td>0.729</td>
</tr>
<tr>
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<td>Adult Male</td>
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<td>5.566</td>
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<tr>
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<td>Adult Female</td>
<td>5</td>
<td></td>
<td>5.905</td>
<td>0.545</td>
</tr>
<tr>
<td></td>
<td>Subadult Male</td>
<td>1</td>
<td></td>
<td>10.364</td>
<td>--</td>
</tr>
<tr>
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<td></td>
<td>12.010</td>
<td>2.307</td>
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<td></td>
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<td>Subadult Female</td>
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<tr>
<td></td>
<td>Juveniles</td>
<td>5</td>
<td></td>
<td>136.507</td>
<td>28.524</td>
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</table>

\( n = \) number of coyotes
Figure 5. Mean seasonal home range sizes for resident and transient coyotes (*Canis latrans*) in Northeast Ohio- predominately the Cuyahoga Valley. Age classes with an ‘*’ indicate only one individual in that class. Composite home range sizes of transient coyotes were significantly larger (*P*=0.001) than resident coyotes as well as during the breeding, pup-rearing, and dispersal seasons (*P*<0.001). Neither resident nor transient coyotes showed any significance in seasonal home range size as a function of sex or age.
There was variation in monthly home range size between social group, sexes, and pooled age classes (Appendix C1). We found little variation in home range size over a calendar year for resident individuals. Transient home range size fluctuated heavily across the calendar year. Transient male home ranges were predominately larger than transient females’ throughout the calendar year, and young transient coyote home range size fluctuated mostly throughout the breeding season. The monthly home range size of transient males and transient adults was inflated during the month of July as a result of one transient coyote traveling extensively throughout northeast Ohio during much of the pup-rearing season.

Land Cover Composition Within Home Ranges

Forested and developed habitat types are the predominant land covers in the Cuyahoga Valley region (Figure 6). Home range composition of both resident and transient coyotes was dominated by natural habitats (Figure 7). For all coyotes combined, there was a significant difference in home range land cover composition across social groups (Wilks’ λ= 0.255, F = 3.70, P = 0.004), but no difference as a function of sex (Wilks’ λ= .621, F = 0.774, P = 0.689) or pooled age class (Wilks’ λ= 0.385, F = 2.024, P = 0.074). Resident coyotes showed no differences in land cover composition between sex (Wilks’ λ= 0.124, F = 2.014, P = 0.261), or pooled age class (Wilks’ λ= .236, F = 0.923, P =0.598). Transient coyotes showed no difference in home range land cover composition by sex (Wilks’ λ= 0.122, F = 0.513, P = 0.816), or pooled age class (Wilks’ λ= .053, F = 1.288, P = 0.607).
Figure 6. Land cover composition of the Cuyahoga Valley, OH based on the 2006 National Land Cover Database (Fry et al. 2011).
Figure 7. Box plots of mean land cover composition within composite home ranges for resident and transient coyotes (*Canis latrans*) in Northeast Ohio- predominately the Cuyahoga Valley. Horizontal lines represent the mean, the box represents the standard deviation T-bars represent 95% confidence intervals, and points outside confidence intervals.
The presence of developed areas (i.e. anthropogenic influence) was not a significant predictor of coyote home range size. For all coyotes combined, there was no significant relationship between home range size and proportion of development ($r^2 = 0.041, n = 35, P = 0.245$) within the home range. Further, home range size of coyotes showed no relationship to the amount of developed area within them for residents ($r^2 = 0.142, n = 19, P = 0.112$) or transients ($r^2 = 0.021, n = 16, P = 0.591$). Likewise, we found no relation between home range size and percent development for female ($r^2 = 0.012, n = 14, P = 0.707$), male ($r^2 = 0.067, n = 21, P = 0.258$), adult ($r^2 = 0.054, n = 16, P = 0.388$) or pooled young ($r^2 = 0.024, n = 19, P = 0.528$) coyotes.

**Land Cover Use - Composite**

For all coyotes combined, we found no significant difference in percent use of land cover types within composite home ranges (Figure 8) between social groups (Wilks’$\lambda = 0.396, F = 1.637, P = 0.177$), sex (Wilks’$\lambda = 0.480, F = 1.160, P = 0.388$), or pooled age class (Wilks’$\lambda = 0.348, F = 2.007, P = 0.087$). Resident coyotes showed no significant difference in land cover use between sex (Wilks’$\lambda = 0.010, F = 7.643, P = 0.277$) or pooled age class (Wilks’$\lambda = 0.034, F = 2.217, P = 0.486$; Figure 9). Transient coyotes showed no significant difference between sex (Wilks’$\lambda = 0.198, F = 0.311, P = 0.904$) or pooled age class (Wilks’$\lambda = 0.114, F = 0.600, P = 0.781$; Figure 9).
Figure 8. Mean use of land cover types in composite home ranges of coyotes (*Canis latrans*) by social group and sex in Northeast Ohio—predominately the Cuyahoga Valley, October 2009–October 2012. No significant differences were detected.
Figure 9. Mean use of land cover types in composite home ranges of coyotes (*Canis latrans*) by pooled age class in Northeast Ohio - predominately the Cuyahoga Valley, October 2009-October 2012. No significant differences were detected.
Land Cover Use- Seasonal

Across all coyotes, we found no significant difference in land cover use between seasons (Wilks’λ= 0.674, $F = 0.950$, $P = 0.544$). Comparing seasons, we found a significant difference between social groups (Wilks’λ= 0.662, $F = 2.261$, $P = 0.015$), but no difference as a function of sex (Wilks’λ= 0.781, $F = 1.241$, $P = 0.271$) or pooled age class (Wilks’λ= 0.726, $F = 1.668$, $P = 0.086$). Resident coyotes showed no difference between sex (Wilks’λ= 0.691, $F = 0.799$, $P = 0.662$), but there were significant differences as a function of pooled age class (Wilks’λ= 0.345, $F = 3.390$, $P = 0.004$). Transient coyotes showed significant difference in land cover use by sex (Wilks’λ= 0.300, $F = 3.664$, $P = 0.003$), but no significance between pooled age class (Wilks’λ= 0.494, $F = 1.610$, $P = 0.154$). We found no significant differences in land cover use when data were analyzed for each individual season (Appendix C2-C7).

Land Cover Preference

To determine if coyotes are distributed randomly throughout the landscape or if a preference for specific habitat types might exist, we performed a $\chi^2$ Goodness of Fit (Neu et al.1974) test comparing the distribution of observed coyote locations within land cover types to a distribution of expected coyote locations as a function of the relative availability of each land cover type for all coyotes combined. We found that the distribution of all coyote locations in the Cuyahoga Valley were distributed non-randomly as a function of land cover ($\chi^2 = 23453.87$, $d.f. = 14$, $P < 0.001$; Figure 10). Resident coyotes showed distributions that differed significantly from random for males
(χ² = 1851.85, d.f. = 14, P < 0.001) and females (χ² = 2187.06, d.f. = 14, P < 0.001). There was also a significant non-random distribution for pooled age classes (Figure 11), adults (χ² = 3155.21, d.f. = 14, P < 0.001), and young (χ² = 986.35, d.f. = 14, P < 0.001).

Transient coyotes showed significance for males (χ² = 2406.04, d.f. = 14, P < 0.001) and females (χ² = 1932.06, d.f. = 14, P < 0.001). There was also a significant non-random distribution among pooled age classes (Figure 11), adults (χ² = 2251.49, d.f. = 14, P < 0.001) and young (χ² = 2089.83, d.f. = 14, P < 0.001).

Significant differences between observed and expected coyote locations indicate that the individuals are not simply using the habitat as a function of availability. We found that coyote locations in the Cuyahoga Valley were non-randomly distributed, indicating preference and avoidance of specific land cover types. Among all coyotes there was a strong preference for deciduous forest land cover types, and avoidance of human-developed land cover types. Adult resident coyotes showed little difference in land cover preference by sex, and there was similarity between subadults and juveniles when using composite selection scores (Figure 12). Adult transient coyotes also showed little variation in land cover preference by sex and between subadults and juveniles (Figure 13).

Seasonally, both residents and transients strongly selected for deciduous forest land cover types, and avoided developed land cover types, predominantly open developed and low intensity land cover types (Figure 14, 15, 16). We found that transient coyotes tended to utilize more cultivated crop and woody wetland land cover types than their
resident counterparts, while resident coyotes utilized more grassland land cover types throughout the seasons. The different utilization of various land cover types by transient coyotes between seasons could be a result of their constant movement throughout the landscape. Seasonal comparisons of land cover preference between sex and age class for each coyote social group can be found on Appendix E (Page 140).
Figure 10. Selection of habitat types for all coyotes (Canis latrans) in the Cuyahoga Valley, OH from October 2009- October 2012. Positive values indicate habitat selection, whereas negative values indicate avoidance. Significant differences between observed and expected coyote locations indicate that the individuals are not simply using the habitat as a function of availability.
Figure 11. Selection of habitat types by age group for resident and transient coyotes (*Canis latrans*) in the Cuyahoga Valley, OH from October 2009 – October 2012. Positive values indicate habitat selection, whereas negative values indicate avoidance. Significant differences between observed and expected coyote locations indicate that the individuals are not simply using the habitat as a function of availability.
Figure 12. Selection of habitat types by age group for resident coyotes (*Canis latrans*) in the Cuyahoga Valley, OH- 2009-2012. Positive values indicate habitat selection, whereas negative values indicate avoidance. Significant differences between observed and expected coyote locations indicate that the individuals are not simply using the habitat as a function of availability.
Figure 13. Selection of habitat types by age group for transient coyotes (*Canis latrans*) in the Cuyahoga Valley, OH- 2009-2012. Positive values indicate habitat selection, whereas negative values indicate avoidance. Significant differences between observed and expected coyote locations indicate that the individuals are not simply using the habitat as a function of availability.
Figure 14. Mean selection scores of land cover types by resident and transient coyotes (*Canis latrans*) during the breeding season (1 Jan – 30 April) in Northeast Ohio—predominately the Cuyahoga Valley. Positive values indicate habitat selection, whereas negative values indicate avoidance. Significant differences between observed and expected coyote locations indicate that the individuals are not simply using the habitat as a function of availability.
Figure 15. Mean selection scores of land cover types by resident and transient coyotes (*Canis latrans*) during the pup-rearing season (1 May – 30 Aug.) in Northeast Ohio—predominately the Cuyahoga Valley. Positive values indicate habitat selection, whereas negative values indicate avoidance. Significant differences between observed and expected coyote locations indicate that the individuals are not simply using the habitat as a function of availability.
Figure 16. Mean selection scores of land cover types by resident and transient coyotes (*Canis latrans*) during the dispersal season (1 Sept. – 30 Dec.) in Northeast Ohio—predominantly the Cuyahoga Valley. Positive values indicate habitat selection, whereas negative values indicate avoidance. Significant differences between observed and expected coyote locations indicate that the individuals are not simply using the habitat as a function of availability.
CHAPTER IV
DISCUSSION

Variation in coyote home range size is apparent across North America (Andelt and Gipson 1979; Person and Hirth 1991; Holzman et al. 1992; Kamler and Gipson 2000; Tigas et al. 2002) and may be influenced by habitat composition (Gese et al. 1988; Riley et al. 2003; Gehrt et al. 2009; Grubbs and Krausman 2009). Radiotelemetry studies have reported coyote space use in relatively rural and natural areas (Andelt 1985; Gese et al. 1988; Kamler and Gipson 2000; Schrecengost 2009), ranching and agricultural areas (Danner and Smith 1980; Althoff and Gipson 1981; Person and Hirth 1991; Kamler et al. 2005), and urbanized areas (Quinn 1997; Riley et al. 2003; Gehrt et al. 2009; Grubbs and Krausman 2009; Gese et al. 2012). The now increasing occupancy of coyotes in exurban, suburban, and urban areas is an illustration of their adaptability to nearly any environment. In our system, we found that resident coyotes, on average, had slightly smaller home ranges than previous urban studies. Our coyotes also utilized habitat types disproportional to their availability, showing a strong preference for deciduous forest and natural land cover types, while avoiding human developed land cover types.
Population density, social factors, resource availability, and human impact have all been shown to influence intraspecific variation in home range size (Moyer et al. 2007). During this study resident coyotes had relatively small home ranges, and the majority of the home ranges had some overlap. Mean composite home range estimates for resident coyotes in the Cuyahoga Valley, Ohio were 6.63 km$^2$ with a range from 2.7 to 10.4 km$^2$. This estimate is comparable to the mean of urban coyote home ranges across similar studies ranging from 3 to 30 km$^2$, averaging 7.3 km$^2$ (Gehrt 2007). In contrast, resident coyote home range estimates in rural areas ranged from 3 to 42 km$^2$ with a mean of 17.5 km$^2$ (Bekoff and Gese 2003; Gehrt 2007). Other species who utilize urban areas such as northern goshawks (*Accipiter gentilis*, Rutz 2006), Virginia opossums (*Didelphis virginiana*, Wright et al. 2012), and bobcats (Riley 2006) exhibit smaller home ranges when in those urban areas. Contrary to the prediction that coyote home ranges in the Cuyahoga Valley would be intermediate to that of truly urban and rural areas, we found that the mean composite home ranges of coyotes were slightly smaller than home ranges found in both urban and rural studies.

Our smallest home range size by a resident coyote in our “urbanizing” Cuyahoga Valley was 2.7 km$^2$. These smaller coyote home ranges in the Cuyahoga Valley region may be an indicator of high population densities of coyotes (Gehrt and Riley 2010), or high resource abundance, or both. Our study area is comprised of local park systems infiltrated and surrounded by human development, resulting in little to no hunting.
pressure on coyotes or their prey. As a result, higher deer densities and prey abundance could allow coyote populations to grow while reducing the need for larger home ranges, as is seen with wolves (Mattisson et al. 2013). Smaller home range sizes could also be attributed to the fragmented landscape, limiting habitat patch size. The mean patch size for deciduous forest in the study area was 0.7 km\(^2\). It might be predicted that home range size in a fragmented system would increase simply as a result of the increased isolation of fragmented patches, resulting in increased travel distances between disconnected patches of natural landscapes. But that is not what we found. In our study, even in this fragmented system, mean composite home ranges were smaller than expected. Resource utilization theories suggest that individuals must operate at larger spatial scales if resources are clumped across the landscape (O’Neill et al. 1988). An urban matrix typifies a landscape with isolated, clumped resources (Grinder and Krausman 2001a). However, past research has found home ranges of bobcats and coyotes in developed, fragmented habitats were not significantly larger than undeveloped, unfragmented areas; possibly due to prey abundance and availability of anthropogenic resources (Tigas et al. 2002).

The home range size of transient coyotes in our study area were similar to that of other studies (Grinder and Krausman 2001; Schrecengost et al. 2009), but considerably larger than the urban transient coyotes of Chicago (Gehrt et al. 2009). Four collared transient individuals covered large tracts of land, and in most cases left the Cuyahoga Valley study area. Long-term monitoring of individuals allowed us to witness variation in
transient coyote activity. For example, we found that a juvenile transient individual
would confine itself to a specific region for a period of time, then become transient and
confine itself in a new region before becoming transient again. Covering large tracts of
land, an older male coyote left the study area, following highways and rivers to Lake Erie
and back before his collar detached, and a young dispersing female pup crossed the state
line into Pennsylvania. Camenzind (1978) postulates that transients serve as a reserve
from which individuals are recruited into the resident reproductive faction of the
population; therefore, a stationary transient may be waiting for a recruiting opportunity.

We found no relationship between home range size and proportion of
development within the home range, and found extensive variation in home range size
irrespective to home range land cover composition. Our findings are similar to that of
Quinn (1997) where habitat composition of coyote home ranges were similar in scale to
habitat types available in the study area (Figure 6, 7). Deciduous forest was the most
prominent land cover type found within coyote home ranges, comprising 60% of home
range space on average. Deciduous forests make –up approximately 40% of available
land cover within the study area as a whole.

Variation In Home Range Size With Sex, Age, or Season

We found no differences in home range as a function of sex for resident or
transient coyotes. Our results are similar to other studies (Laudre and Keller 1884; Gese
et al. 1988; Person and Hirth 1991; Gehrt et al. 2009; Schrecengost et al. 2009) that
compared home range differences between male and female coyotes. Contrary to our
study, Riley et al. (2003) found that males have significantly larger home ranges than females, whereas Holzman et al. (1992) and Chamberlain (2000) detected larger home ranges in females than males. Other species, such as black bear, have shown variation in home range size as a function of season and reproductive status (Moyer et al. 2007). We did, however, detect a significant difference in home range size as a function of age, with resident subadult coyotes having a significantly larger home range than adults and juveniles. This could be a result of subadults looking to disperse due to aggressive behavior from pack members, to find their own territory, or to enhance reproductive potential (Harrison 1992).

We found that coyote home ranges in the Cuyahoga Valley, Ohio did not vary by season for residents or transients. Other urban studies have also found no seasonal variation (Grinder and Krausman 2001b; Gehrt et al. 2009), while Gese et al. (2012) found seasonal variation in home ranges based on levels of human development in the Chicago metropolitan area. Since home range size can be an indicator of the availability of food, water, and cover, coyotes in the Cuyahoga Valley may have their basic requirements available to them during all times of the year. For some individuals, home ranges shifted in geographical extent from season to season; in some cases, with little overlap. This may be a result of shifts in human activity (e.g. construction, shifts in use of recreational areas, hunting pressure, etc.) that may attract or deter coyotes, or it could reflect changes in the behavior of individual coyotes.
Land Cover Use

Coyotes optimize the use of habitat types by balancing factors such as availability and abundance of resources, intraspecific competition, and access to geographic features of the surrounding landscape (Stoker et al. 2012). Relatively undisturbed, forested habitats were the most intensely used land cover types by coyotes among sexes, age, and social group. In similar studies, natural areas make up the dominant land-cover type within coyote home ranges, and show that coyotes utilize more natural/undeveloped areas of their home range even if it is the least available land cover type (Riley et al. 2003; Gehrt et al. 2009; Gehrt and Riley 2010).

Open developed, and grass land types were also utilized by coyotes, but in smaller proportions. These land cover types include open park areas, golf courses, and cemeteries where coyotes may scavenge on the anthropogenic food sources, or the rodents and birds that are attracted to these areas. Agricultural (e.g. pasture/hay and cultivated crops), grassland, and wetland land cover types were the next most used types. In our system, livestock and agriculture patches are found throughout the region, and aside from small rodents, coyotes could be attracted to the livestock and poultry associated with these patches (Danner and Smith 1980; Althoff and Gipson 1981; Kamler et al. 2004).

In our study, the smallest percentage of location points were found in areas of more intensely developed land cover types. Ordeñana et al. (2010) found the presence of coyotes increased with urbanization. However, other studies similar to ours have shown that coyotes tend to avoid such developed land-use types (Riley et al. 2003; Gehrt et al. 2009). These high intensity developments include areas where people reside or work in
high numbers, such as apartment complexes, and commercial and industrial areas. Such land covers may not have any attraction to coyotes for fear of humans or lack of prey. It is possible that if the local coyote population continues to persist and grow, individuals may become more conditioned to areas of high human activity, and therefore serve as a sink for transients and dispersing coyotes. Given that coyotes are extremely flexible in their habits and landscape use, it is not surprising that we have such varied results relative to the level of synanthropy in coyotes (Tigas et al. 2002; Gehrt et al. 2009; Gehrt and Riley 2010)

We measured the use of specific land cover types in proportion to their availability to identify specific habitat selection. Coyotes in our investigation had a non-random (i.e., use of habitats were disproportional to availability) distribution of points in the study area (second order selection) as well as in home ranges (third order selection). Our results support the prediction that coyotes show preference for natural landscapes (forest, grassland, etc.) while avoiding man-made landscapes (urban/suburban, developed, etc.). We also hypothesized that there would be differences in habitat preference based on resident status, sex, and age, and season, but our results showed little variation.

Deciduous forest habitats were consistently the most preferred land cover type and were used more widely than they were available. The deciduous forest in the Cuyahoga Valley consists of dominant communities of Acer spp. (maple), Quercus (oak), Plantanus occidentalis L. (Sycamore), and Carya spp. (hickory), with varying degrees of understory providing ample amounts of cover for coyotes. Within these forested patches,
the rugged terrain provided denning spots for coyotes along hillsides and uplifted roots. Other natural areas such as woody wetlands were also utilized more than they were available. These wetlands and floodplains that are situated on the banks of the Cuyahoga River, and its feeder streams, provide woody wetland vegetation that can provide cover for coyotes in avoidance of human activity or for hunting purposes.

These natural areas are fragmented by highways, roads, and recreational trails which are used for walking and biking. Coyotes here are exposed to people and pets on a regular basis, but nonetheless have more opportunity to escape and find cover than in developed areas. Coyotes in the Cuyahoga Valley park systems have been found to become more active in the morning and night, and less active during the day and evening (Wallace 2013), which is consistent with other studies of urban coyote activity (Grinder and Krausman 2001b; McClennen et al. 2001). Coyotes in our system have also been found to shift their locations further away from trails during the day, which coincides with increased human activity, and shifted closer to trails during nocturnal periods when human activity was reduced (Wallace 2013).

Land cover types associated with human development were avoided in our study area. Coyotes in our system, though exposed to human activity in the parks, may not yet be conditioned to areas of human use. For example, open developed areas which include open parks and recreational areas, cemeteries, and golf courses were the least preferred land cover type, though there was variation among individuals. The location points found in these land cover types could be a result of coyotes marking territorial boundaries, or as a means of traveling through habitat patches; therefore, they may not be using these areas.
for hunting or pursuit of human resources. In previous diet studies of coyotes in the Cuyahoga Valley, most food items were mammalian, with some of the most frequent species being meadow voles (*Microtus pennsylvanicus*), eastern cottontail (*Sylvagus floridanus*), and white-tailed deer (Cepak 2004; Bollin-Booth 2007). Other contents of coyote scat consisted of raccoons, beetles, unknown mammals, vegetation and nuts, grass hoppers and birds; however very little evidence of trash, domestic pets, or livestock in the diets of coyotes were found (Cepak 2004; Bollin-Booth 2007, unpublished data). Therefore, we find very little evidence that coyotes in the Cuyahoga Valley are attracted to, or rely on, areas of high-human activity or development.

**Conclusion**

Our results demonstrated that coyotes in the Cuyahoga Valley, on average, maintain smaller home range size than the average home range sizes of previous urban and rural studies, possibly as a result of increased population density, social factors, resource availability, or human impact (i.e. human development and fragmentation). However, we found no relationship between home range size and proportion of development within the home range, and found extensive variation in home range size irrespective to home range land cover composition. These home ranges did not vary by season or social group, but the age of resident coyotes did play a factor in home range size.

Coyotes in our system were found to use deciduous forests heavily. This habitat type composed roughly 60% of home range land cover composition, and a majority of
coyote location points were found in this habitat type. Other natural land cover types were also used readily, such as grassland and woody wetlands. Previous studies on coyotes in the Cuyahoga Valley have demonstrated changes in diel activity as a result of human activity, and little evidence of anthropogenic foods in their diet. This supports our interpretation that coyotes typically exhibited avoidance of areas associated with humans, irrespective of sex, age, social group or home range composition. Our unique system in the Cuyahoga Valley provides us with a nearly 50% forest and 50% human-developed landscape. Though the level of synurbanization in our coyotes would be difficult to measure, we can speculate that the available natural habitats of the Cuyahoga Valley provide enough sufficient space and resources to allow multiple family groups and transients to inhabit them, mimicking the habitats preferred by coyotes in non-urban areas with minimal need to utilize any non-native or man-made features in the local environment.
CHAPTER V
IMPLICATIONS FOR MANAGEMENT

Natural areas such as deciduous forests, grasslands, wetland, and sometimes agricultural patches were some of the most commonly preferred land cover types in the Cuyahoga Valley region. Though coyotes limited themselves to these natural patches, this area is predominately composed of local park systems, and an abundance of recreation trails fragment the landscape. Therefore, it is important as biologists and managers to implement ways to maintain healthy populations, and also minimize the opportunity for human-coyote interactions.

*Healthy Coyote Populations*

Conserving healthier wildlife populations and habitats in urban, suburban, exurban and rural areas can occur when land-use planners integrate community planning and design with ecological principles (McCleery et al. 2012). Since coyotes in the Cuyahoga Valley region preferred deciduous forests, managers could ideally set aside large, protected tracts of land for populations to utilize with minimal opportunity for human-coyote interactions. Protecting large, natural habitat fragments may be superior to protecting several fragments, especially for conserving vertebrate species (Soulé 1991). To maintain such large tracts there are specific measures that can
be taken in the Cuyahoga Valley region that can limit what kinds, and how much, of development can exist. Zoning ordinances have the opportunity to designate acceptable land-use types (e.g. open space, resident, and commercial; Pejchar et al. 2007) within communities that surround the parks systems and natural areas. Governments can also protect natural areas by zoning controls known as ‘Urban Growth Boundaries’ (UGB) that separate designated development areas from rural and natural lands (McCleery et al. 2012). Here, development is encouraged within the UGB, whereas development is strongly discouraged outside of the boundary.

Smaller, isolated fragments found throughout the Cuyahoga Valley may be unable to support coyote populations as development expands, so corridors are often suggested to maintain patch connectivity. Road underpasses, animal bridges, and riparian systems can be used to form the introductory framework of a corridor network. We found that our animals used riparian areas along the Cuyahoga River and Chagrin River, along with natural habitats along interstates as corridors to move throughout northeast Ohio. For short distances between habitat patches, the ‘stepping stone’ approach can be used and maintained to encourage movement (McCleery et al. 2012). Here, stepping stones are suitable habitat matches positioned within the urban matrix so that individuals are able to move throughout the landscape from one suitable patch to another (McCleery et al. 2012).

_Human-Coyote Conflicts_

Locally, individuals may appreciate listening to coyote howls near their homes or even seeing them on or near trails or in urban areas, but there is general concern over the
welfare and safety of people, children, and pets. As coyote populations continue to persist in the Cuyahoga Valley region, it is imperative that managers and biologists devise a way to inform the public on the potential risks when coming into contact with coyotes.

In the Cuyahoga Valley, Wallace (2013) found that coyotes were less active during times when human-use of the local parks systems were at their highest, leading coyotes to become more nocturnal, and also tending to keep a greater distance away from recreational trails. Managers and biologists can better prepare the public by placing signs on trailheads that lead into areas where there are known coyote populations. The public should be advised to stay on the established trails and to also keep pets on a leash, especially during the breeding and pup-rearing seasons when human-coyote or coyote-pet conflicts can occur. Trail heads leading to, or near, known denning sites should also be closed to prevent those conflicts from occurring.

It is recommended that the local law enforcement, Cleveland Metroparks, Metro Parks Serving Summit County, and Cuyahoga Valley National Park standardize coyote incident report forms and database that all agencies can access. This will allow for better monitoring of reports about coyotes including number of reports, locations, measure of coyote aggressiveness, and actions taken (Berchielli 2007). In the case of incidents with aggressive coyotes, the local park systems should develop a standard operating procedure for lethal control (Berchielli 2007).

In addition, public education is also key in the proper management of coyotes. People should be discouraged from purposefully or negligently feeding coyotes, this includes leaving pet food or trash outside at night, maintaining feeders that attract other
wildlife, and monitoring pets. It could be advised that small pets should be kept indoors and closely monitored when outdoors if yards are not fenced into exclude other larger mammals from entering.

Ecological Impacts

As the apex predator in Ohio, coyotes can have significant impacts on flora and fauna throughout the Cuyahoga Valley Region, and in some cases may incite other forms of human-wildlife conflict and interactions. Playing a keystone role, coyotes can affect the persistence, abundance, distribution, and diversity of other species. Similar examples of predators serving as keystone species have been observed, such as the role of sea otters (*Enhydra lutris*) in kelp forests (Estes and Palmisano 1974), and wolves on Isle Royal (McLaren and Peterson 1994).

Removal of coyotes has been found to increase the populations of several other mesopredators such as raccoons, opossums, fox, domestic cats, badgers, striped skunks, and bobcats (Henke and Bryant 1999; Gehrt and Clark 2003). Crooks and Soulé (1999) found that mean total mesopredator abundance was more than twice as high in areas where coyotes were absent. With the potentially growing abundance of these other mesopredators, a cascading effect through the food web could apply additional pressures to preferred prey items, such as increased predation on ground nesting birds and eggs (Henke and Bryant 1999), and can cause songbird populations to decline (Crooks and Soulé 1999). This should be taken into consideration in the management of wild turkey
*Meleagris gallopavo*, ruffed grouse (*Bonasa umbellus*), and northern bobwhite quail (*Colinus virginianus*) populations.

Aside from other mesopredators, the presence or removal of coyotes have been found to affect the population, diversity, and richness of other species. It has been found that coyote removal can result in the decline of small rodent richness and diversity (Henke and Bryant 1999), and increase fawn survival by 30% (Ballard et al. 2003). With the absence of predators, deer populations will continue to grow. It has been shown that over-browsing by white-tailed deer can form an extremely low diversity herbaceous understory- causing local extirpation of shrubs, driving forbs to extremely low abundance, and has cause a 60-80% decline in herb and shrub richness (Goetsch et al. 2011).

**Summary**

Maintaining the balance between coyote persistence and control can be a challenge for managers and biologists alike, and can also receive mixed reviews from the general public. The presence of coyotes in the Cuyahoga Valley region can be seen as a ‘double-edged sword’, having both favorable and unfavorable consequences. On one hand, large tracts of land would provide plenty of room for coyotes and would provide more areas away from trails that might limit human-coyote interaction. The presence of coyotes could be more aesthetic to visitors of the local park systems, provide more species richness and diversity in the area, and lessen fawn recruitment. Coyote persistence will also keep white-tailed deer and other mesopredator populations limited,
resulting in less human-wildlife conflicts (i.e. raccoons getting into trash, nest predation on game bird species, higher white-tailed deer populations grazing on landscaping or causing vehicle collisions). Secondly, coyote persistence can lead to negative coyote-human interactions, jeopardizing the safety of humans, livestock, or and pets, and may also result in less use of the park systems. But we suggest that maintaining healthy coyote populations and reducing negative human-coyote interactions are not mutually exclusive goals. We recommend the continued coexistence of coyotes and people in the Cuyahoga Valley region, and that every action should be considered in minimizing human-wildlife conflicts. The closure of trails, educating the public, maintaining detailed records of human-coyote interactions, and the removal of ‘culprit’ individuals can result in a diverse, healthy, and enjoyable region for humans and coyotes alike.
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APPENDIX A

NATIONAL LAND COVER DATABASE CLASSIFICATION DESCRIPTIONS OF LAND COVER TYPES. (MODIFIED FROM THE U.S. EPA MULTI-RESOLUTION LAND CHARACTERISTICS CONSORTIUM, HTTP://WWW.EPA.GOV/MRLC/DEFINITIONS.HTML.

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<th>Class Value</th>
<th>Classification Description</th>
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<tbody>
<tr>
<td>Water</td>
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</tr>
<tr>
<td>11</td>
<td>Open Water - areas of open water, generally with less than 25% cover of vegetation or soil.</td>
</tr>
<tr>
<td>12</td>
<td>Perennial Ice/Snow - areas characterized by a perennial cover of ice and/or snow, generally greater than 25% of total cover.</td>
</tr>
<tr>
<td>Developed</td>
<td></td>
</tr>
<tr>
<td>21</td>
<td>Developed, Open Space - areas with a mixture of some constructed materials, but mostly vegetation in the form of lawn grasses. Impervious surfaces account for less than 20% of total cover. These areas most commonly include large-lot single-family housing units, parks, golf courses, and vegetation planted in developed settings for recreation, erosion control, or aesthetic purposes.</td>
</tr>
<tr>
<td>22</td>
<td>Developed, Low Intensity - areas with a mixture of constructed materials and vegetation. Impervious surfaces account for 20% to 49% percent of total cover. These areas most commonly include single-family housing units.</td>
</tr>
<tr>
<td>23</td>
<td>Developed, Medium Intensity – areas with a mixture of constructed materials and vegetation. Impervious surfaces account for 50% to 79% of the total cover. These areas most commonly include single-family housing units.</td>
</tr>
</tbody>
</table>
Developed High Intensity - highly developed areas where people reside or work in high numbers. Examples include apartment complexes, row houses and commercial/industrial. Impervious surfaces account for 80% to 100% of the total cover.

Barren

Barren Land (Rock/Sand/Clay) - areas of bedrock, desert pavement, scarps, talus, slides, volcanic material, glacial debris, sand dunes, strip mines, gravel pits and other accumulations of earthen material. Generally, vegetation accounts for less than 15% of total cover.

Forest

Deciduous Forest - areas dominated by trees generally greater than 5 meters tall, and greater than 20% of total vegetation cover. More than 75% of the tree species shed foliage simultaneously in response to seasonal change.

Evergreen Forest - areas dominated by trees generally greater than 5 meters tall, and greater than 20% of total vegetation cover. More than 75% of the tree species maintain their leaves all year. Canopy is never without green foliage.

Mixed Forest - areas dominated by trees generally greater than 5 meters tall, and greater than 20% of total vegetation cover. Neither deciduous nor evergreen species are greater than 75% of total tree cover.

Shrubland

Dwarf Scrub - Alaska only areas dominated by shrubs less than 20 centimeters tall with shrub canopy typically greater than 20% of total vegetation. This type is often co-associated with grasses, sedges, herbs, and non-vascular vegetation.

Shrub/Scrub - areas dominated by shrubs; less than 5 meters tall with shrub canopy typically greater than 20% of total vegetation. This class includes true shrubs, young trees in an early successional stage or trees stunted from environmental conditions.

Herbaceous

Grassland/Herbaceous - areas dominated by graminoid or herbaceous vegetation, generally greater than 80% of total vegetation. These areas are not subject to intensive management such as tilling, but can be utilized for grazing.

Sedge/Herbaceous - Alaska only areas dominated by sedges and forbs, generally greater than 80% of total vegetation. This type can occur with significant other grasses or other grass like plants, and includes sedge tundra, and sedge tussock tundra.

Lichens - Alaska only areas dominated by fruticose or foliose lichens generally greater than 80% of total vegetation.
Moss - Alaska only areas dominated by mosses, generally greater than 80% of total vegetation.

Planted/Cultivated

81 Pasture/Hay – areas of grasses, legumes, or grass-legume mixtures planted for livestock grazing or the production of seed or hay crops, typically on a perennial cycle. Pasture/hay vegetation accounts for greater than 20% of total vegetation.

82 Cultivated Crops – areas used for the production of annual crops, such as corn, soybeans, vegetables, tobacco, and cotton, and also perennial woody crops such as orchards and vineyards. Crop vegetation accounts for greater than 20% of total vegetation. This class also includes all land being actively tilled.

Wetlands

90 Woody Wetlands - areas where forest or shrubland vegetation accounts for greater than 20% of vegetative cover and the soil or substrate is periodically saturated with or covered with water.

95 Emergent Herbaceous Wetlands - Areas where perennial herbaceous vegetation accounts for greater than 80% of vegetative cover and the soil or substrate is periodically saturated with or covered with water.
## APPENDIX B

**ASSOCIATION OF ERROR FOR EACH VHF COLLARED COYOTE USED FOR ANALYSIS**

<table>
<thead>
<tr>
<th>No. locations attempted</th>
<th>Mean error of locations (Km²)</th>
<th>No. successful locations</th>
<th>Mean error of remaining 95% points (Km²)</th>
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APPENDIX C

RESULTS (CONT’D): SEASONAL COMPARISONS OF LAND COVER PREFERENCE BETWEEN SEX AND AGE CLASS FOR EACH COYOTE SOCIAL GROUP

When social groups were broken down for seasonal analysis by sex and pooled age class, we found that all resident coyotes still typically preferred deciduous forests, and mostly avoided developed land cover types. During the breeding season, resident coyotes used available land cover types similarly by sex; however, when broken down by pooled aged class, we found that young coyotes selected deciduous forest less than adults, and avoided developed land cover types less than adults as well (Appendix C8). During the pup-rearing season, resident males and females typically used land cover types in similar proportions, with the exception of females heavily utilizing deciduous forest types (the most prominent type in the Cuyahoga Valley) more than males (Appendix C9). Pooled age classes during the pup-rearing season, showed that young coyotes once again selected for deciduous forests less than adults, and actively selected for low intensity developed areas (Appendix C9). Resident coyotes during the dispersal
season utilized the landscape in similar proportions as the breeding season, with the exception that young coyotes selected for deciduous forests and avoided developed areas more so than any other season (Appendix C10). However, young coyotes tended to utilize areas of human impact more than adults.

Seasonally, when broken down by sex and pooled age class transient males and females showed similar land cover preferences as resident coyotes by selecting for deciduous forest and avoiding developed land cover types. Transient coyotes during the breeding season utilized the landscape similarly by sex and pooled age class (Appendix C11).

Transient coyotes during the breeding season utilized the landscape similar by sex and pooled age class (Appendix C11). During the pup-rearing season, land covers were selected similarly by sex, while young coyotes tended to select for deciduous forests more than adults, and strongly avoided open developed land cover types more than any other season (Appendix C12). Transient coyotes during the dispersal seasons showed similar landscape utilization to both the breeding and pup-rearing seasons with a strong preference for deciduous forest and avoidance of developed land cover types (Appendix C13). During the dispersal season, we found that female transient coyotes exhibited a strong avoidance of open developed land cover types
Appendix D1. Mean monthly home range size of resident and transient coyotes (*Canis latrans*) by sex and pooled age groups in northeast Ohio- predominately the Cuyahoga Valley, October 2009-October 2012.
Appendix D2. Mean use of land cover types by resident coyotes (*Canis latrans*) during the breeding season (1 Jan – 30 April) in Northeast Ohio—predominately the Cuyahoga Valley, October 2009-October 2012. No significant differences were detected.
Appendix D3. Mean use of land cover types by resident coyotes (*Canis latrans*) during the pup-rearing season (1 May – 30 Aug.) in Northeast Ohio- predominately the Cuyahoga Valley, October 2009-October 2012. No significant differences were detected.
Appendix D4. Mean use of land cover types by resident coyotes (Canis latrans) during the dispersal season (1 Sept. – 30 Dec.) in Northeast Ohio- predominately the Cuyahoga Valley, October 2009-October 2012. No significant differences were detected.
Appendix D5. Mean use of land cover types by transient coyotes (*Canis latrans*) during the breeding season (1 Jan – 30 April) in Northeast Ohio- predominately the Cuyahoga Valley, October 2009-October 2012. No significant differences were detected.
Appendix D6. Mean use of land cover types by transient coyotes (*Canis latrans*) during the pup-rearing season (1 May – 30 Aug.) in Northeast Ohio- predominately the Cuyahoga Valley, October 2009-October 2012. No significant differences were detected.
Appendix D7. Mean use of land cover types by transient coyotes (*Canis latrans*) during the dispersal season (1 Sept. – 30 Dec) in Northeast Ohio- predominately the Cuyahoga Valley, October 2009-October 2012. No significant differences were detected.
Appendix D8. Mean selection score of land cover types by resident coyotes (*Canis latrans*) during the breeding season (1 Jan – 30 April) in Northeast Ohio- predominately the Cuyahoga Valley, October 2009-October 2012. Positive values indicate habitat selection, whereas negative values indicate avoidance. Significant differences between observed and expected coyote locations indicate that the individuals are not simply using the habitat as a function of availability.
Appendix D9. Mean selection scores of land cover types by resident coyotes (*Canis latrans*) during the pup-rearing season (1 May – 30 Aug.) in Northeast Ohio-predominately the Cuyahoga Valley, October 2009-October 2012. Positive values indicate habitat selection, whereas negative values indicate avoidance. Significant differences between observed and expected coyote locations indicate that the individuals are not simply using the habitat as a function of availability.
Appendix D10. Mean selection scores of land cover types by resident coyotes (*Canis latrans*) during the dispersal season (1 Sept. – 30 Dec.) in Northeast Ohio- predominately the Cuyahoga Valley, October 2009-October 2012. Positive values indicate habitat selection, whereas negative values indicate avoidance. Significant differences between observed and expected coyote locations indicate that the individuals are not simply using the habitat as a function of availability.
Appendix D11. Mean selection scores of land cover types by transient coyotes (*Canis latrans*) during the breeding season (1 Jan – 30 April) in Northeast Ohio- predominately the Cuyahoga Valley, October 2009-October 2012. Positive values indicate habitat selection, whereas negative values indicate avoidance. Significant differences between observed and expected coyote locations indicate that the individuals are not simply using the habitat as a function of availability.
Appendix D12. Mean selection scores of land cover types by transient coyotes (*Canis latrans*) during the pup-rearing season (1 May – 30 Aug.) in Northeast Ohio—predominately the Cuyahoga Valley, October 2009-October 2012. Positive values indicate habitat selection, whereas negative values indicate avoidance. Significant differences between observed and expected coyote locations indicate that the individuals are not simply using the habitat as a function of availability.
Appendix D13. Mean selection scores of land cover types by transient coyotes (*Canis latrans*) during the dispersal season (1 Sept. – 30 Dec.) in Northeast Ohio—predominately the Cuyahoga Valley, October 2009-October 2012. Positive values indicate habitat selection, whereas negative values indicate avoidance. Significant differences between observed and expected coyote locations indicate that the individuals are not simply using the habitat as a function of availability.
APPENDIX E

GIS MAPS OF COYOTE LOCATIONS AND HOME RANGE
Appendix E1. Point Location and 95% MCP home range of animal #1 (Juvenile; see Table 01).
Appendix E2. Point Location and 95% MCP home range of animal #1 (Subadult; see Table 01).
Appendix E3. Point Location and 95% MCP home range of animal #2 (see Table 01).
Appendix E4. Point Location and 95% MCP home range of animal #3 (see Table 01).
Appendix E5. Point Location and 95% MCP home range of animal #4 (see Table 01).
Appendix E6. Point Location and 95% MCP home range of animal #5 (see Table 01).
Appendix E7. Point Location and 95% MCP home range of animal #6 (see Table 01).
Appendix E8. Point Location and 95% MCP home range of animal #7 (see Table 01).
Appendix E9. Point Location and 95% MCP home range of animal #8 (see Table 01).
Appendix E10. Point Location and 95% MCP home range of animal #10 (see Table 01).
Appendix E11. Point Location and 95% MCP home range of animal #11 (see Table 01).
Appendix E12. Point Location and 95% MCP home range of animal #12 (see Table 01).
Appendix E13. Point Location and 95% MCP home range of animal #13 (see Table 01).
Appendix E14. Point Location and 95% MCP home range of animal #14 (see Table 01).
Appendix E15. Point Location and 95% MCP home range of animal #16 (see Table 01).
Appendix E16. Point Location and 95% MCP home range of animal #17 (see Table 01).
Appendix E17. Point Location and 95% MCP home range of animal #18 (see Table 01).
Appendix E18. Point Location and 95% MCP home range of animal #19 (see Table 01).
Appendix E19. Point Location and 95% MCP home range of animal #20 (see Table 01).
Appendix E20. Point Location and 95% MCP home range of animal #21 (see Table 01).
Appendix E21. Point Location and 95% MCP home range of animal #22 (see Table 01).
Appendix E22. Point Location and 95% MCP home range of animal #23 (see Table 01).
Appendix E23. Point Location and 95% MCP home range of animal #24 (see Table 01).
Appendix E24. Point Location and 95% MCP home range of animal #25 (see Table 01).
Appendix E25. Point Location and 95% MCP home range of animal #26 (see Table 01).
Appendix E26. Point Location and 95% MCP home range of animal #27 (see Table 01).
Appendix E27. Point Location and 95% MCP home range of animal #28 (see Table 01).
Appendix E28. Point Location and 95% MCP home range of animal #30 (see Table 01).
Appendix E29. Point Location and 95% MCP home range of animal #31 (see Table 01).
Appendix E30. Point Location and 95% MCP home range of animal #33 (see Table 01).
Appendix E31. Point Location and 95% MCP home range of animal #34 (see Table 01).
Appendix E32. Point Location and 95% MCP home range of animal #36 (see Table 01).
Appendix E33. Point Location and 95% MCP home range of animal #37 (see Table 01).
Appendix E34. Point Location and 95% MCP home range of animal #38 (see Table 01).
Appendix E35. Point Location and 95% MCP home range of animal #39 (see Table 01).
APPENDIX F

IACUC
March 10, 2011

Dr. Smith
Department of Biology
The University of Akron
Akron, OH 44325

Dear Dr. Smith,

The University of Akron’s Institutional Animal Care and Use Committee have reviewed your protocol titled: “Coyote Ecology and Behavior In Urban and Rural Landscapes”

IACUC number 11-2B

Your project has received unanimous approval.

You must notify the committee concerning modifications to the approved protocol. In addition, yearly updates regarding the status of this project are required. IACUC must also be notified of serious or adverse reactions that occur during the course of this project. Please use the IACUC number when submitting this information to the committee.

Sincerely,

James Holda
IACUC Chair
FOR COMMITTEE USE:

Date Proposal Received: 1/31/11
Primary Reviewer: 
Data Reviewed: 2-2-11

Project Number: 11-2B
Project Director: 
Date Approved: 
Date Denial: 

Institutional Animal Care and Use Committee (IACUC) members:

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Supervisor Animal Care Facility

Mr. Robert Zickafoose
Walsh University