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Cities and the Environment (CATE)

Volume 4 | Issue 1 Article 8

2-23-2012

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We examined the diet of a portion of Calgary's urban coyotes to provide baseline data on feeding ecology, to determine spatial and seasonal effects on diet, and to assess whether anthropogenic food sources (primarily garbage) and domestic cats or dogs were part of coyote diet. Bi-weekly surveys of seven study sites were conducted between August 2006 and September 2007. We analyzed 484 coyote scats. The top five prey types consumed by the coyotes studied were small mammals (84.71%), herbaceous plants (44.63%), crabapples (33.88%), woody plants (16.94%) and anthropogenic food sources (14.05%). Domestic animals – cats (*Felis catus*) and dogs (*Canis familiaris*) – were found in 6 scats (1.24% of all scats sampled). Large parks had the greatest amount of scats containing native berries (χ^2_6=1700, p<0.001) while smaller parks had higher levels of crabapples (χ^2_6=3700, p<0.001) and anthropogenic content (χ^2_6=413.4, p<0.001) in scats. Scats containing domestic animals were relatively few, highly localized and occurred primarily in the Calgary neighbourhood with the most frequent reports of aggression/predation behaviour in coyotes. Herbaceous plants (χ^2_2=89.273, p<0.001), crabapples (χ^2_2=5023, p<0.001) small mammals (χ^2_2=755.3, p<0.001) and anthropogenic food sources (χ^2_2=183.9, p<0.001) were all consumed most during the Dispersal season. Woody plants (χ^2_2=998.0, p<0.001) were consumed significantly more during Pup-Rearing. Coyotes in Calgary consume predominantly natural prey items. However, the presence of anthropogenic food items in 14% of scats suggests heightened risk of food conditioning, a potential for habituation to humans, which can increase human-coyote conflict. We recommend stricter enforcement of garbage laws, responsible husbandry practices with domestic pets (leash animals), and targeted educational campaigns.

Keywords
coyote, Canis latrans, diet, spatial, temporal, urban, conflict

Acknowledgements
The authors would like to thank the University of Calgary, Department of Geography, NSERC, and The City of Calgary, Animal Services. Three anonymous reviewers provided valuable feedback that strengthened the manuscript. The authors thank John Paczkowski, Warren Fitch and Dr. Axel Moehrenschlager for essential advice and equipment used in scat analysis. Finally, thanks goes out to all volunteer field assistants.

INTRODUCTION

Though considered native to the open plains and deserts of central and western North America, coyotes (*Canis latrans*) have successfully expanded their range across numerous habitats, even non-traditional cover types such as urban centers (Fox and Papouchis 2005). In Canadian cities, some members of the public have expressed concerns, especially in recent years, towards living with these wild predators (Alexander and Quinn 2011). In particular, people in Calgary, Alberta perceive that coyotes prey upon domestic cats (*Felis catus*) and dogs (*Canis familiaris*; V. Lukasik, pers. obs.). This behavior in coyotes has been linked to habituation, loss of fear towards people, and coyote attacks on humans (Carbyn 1989). We used dietary analysis of coyote scat to establish baseline information on feeding ecology of urban coyotes in the city of Calgary, and to explore the relative frequency of anthropogenic foods and domestic pets relative to other food types.

Coyotes are considered prototypical generalists (Young and Jackson 1951, Bekoff 1977, O'Donoghue *et al*. 1998a, Prugh 2005); they feed upon a variety of foods, depending upon local and seasonal availability. However, coyotes exhibit prey preferences within various environments. For instance, O'Donoghue *et al*. (1998b) found that coyotes in the Yukon preferred snowshoe hare (*Lepus americanus*) to other prey species, even during periods of low hare density. In addition, Prugh (2005) found that coyotes can act as specialists, depending upon snowshoe hare in northern parts of their range. Diet studies have found both rural and urban coyotes to consume primarily small rodents (*Microtus* spp.: Atkinson and Shackleton 1991, Cepek 2004, Morey *et al*. 2007), hare and rabbits (*L. americanus:* Dumond *et al*. 2001, Prugh 2005; *Sylvilagus floridanus:* Cepek 2004, Morey *et al*. 2007), white-tailed deer (*Odocoileus virginianus:* Cepek 2004, Morey *et al*. 2007), and vegetation (Cunningham *et al*. 2006).

Large carnivores (such as bears and wolves) are absent, by exclusion, from most urban ecosystems. Consequently, the more adaptable and human-tolerant coyote often becomes the apex predator in these ecosystems (Crooks and Soulé 1999). Moreover, because coyotes can modify populations of smaller predator species (mesopredators) and prey species, through competition and predation, they are considered keystone predators (Henke and Bryant 1999). As a keystone predator, it has been proposed that coyotes have a critical role in maintaining ecosystem function (Crooks and Soulé 1999, Bekoff and Gese 2003). For example, coyotes have been shown to maintain breeding bird diversity (Crooks and Soulé 1999), provide indirect benefits to the greater sage grouse (*Centrocercus urophasianus*; Mezquida *et al*. 2006), and control Canada geese (*Branta canadensis*) and white-tailed deer populations (Henke and Bryant 1999, Gehrt 2004). As such, coyotes are an important component of urban ecosystems as they promote biodiversity and ecosystem health.

Though coyote diet has been studied in some suburban and urban areas in North America (*e.g.*, Quinn 1997, Morey *et al*. 2007, Grigione *et al.* 2011), it has never been investigated in Calgary, despite apparent public concerns towards coyotes (CBC 2005). In 2005, a child in the city of Calgary was reportedly bitten by a coyote (CBC 2005), and food conditioning was implicated in that attack. Deliberate feeding of coyotes and access to garbage were cited in media publications, and concerns were raised by the public about coyotes consuming domestic pets (Alexander and Quinn 2008). Thus, we initiated a study of urban coyote diet, using the analysis of scats collected across the city of Calgary from August 2006 to September 2007, with a focus on understanding whether this diet included domestic pets or human garbage. We also examined whether coyote diet varied seasonally or spatially over the year collected, which can provide insight about what times of year certain dependencies may arise (*e.g.,* whether coyotes are more likely to consume garbage during the dispersal season, when juvenile coyotes seek out new territories in which to live). One year of diet data does not capture potential variability in diet that may take place across years, and as such further studies on urban coyote diet in Calgary are necessary. A key aim of our project was to provide baseline data as a starting point which could provide the city with information to improve waste management, be integrated into educational material and improve human-coyote co-existence.

Study Area

Research was conducted in the city of Calgary (51º60'N, 114º10'W), located in southwestern Alberta, in the foothills of the Canadian Rocky Mountains. Calgary has a population of over 1.2 million in an area of 5107 km^2 (Statistics Canada 2006, 2011). The city has several rivers, creeks and other water bodies running through it, a hilly topography with abrupt elevation changes, and is located within the transition zone between two ecological regions; the Aspen Parkland and Fescue Grassland Natural Region (Foley 2006). Both ecological regions were historically occupied by coyotes. This geographic area experiences brief and drastically changing temperatures in winter due to warm, dry Chinook winds, with an average temperature of -9°C in January and 16°C in July (Environment Canada 2011). Apart from coyotes, other common wildlife species that occur include, but are not limited to, southern red-backed, meadow and sagebrush vole (*Clethrionomys gapperi*; *Microtus pennsylvanicus*; *Lagurus curtatus*), deer mouse (*Peromyscus maniculatus*), muskrat (*Ondatra zibethicus*), Richardson's ground squirrel (*Spermophilus richardsonii*), gray squirrel (*Sciurus carolinensis*), snowshoe hare, white-tailed jack rabbit (*Lepus townsendii*), mule deer (*Odocoileus hemionus*), white-tailed deer, and red fox (*Vulpes vulpes*).

METHODS

Study Sites

Scat analysis is considered a common, reliable, non-invasive method to determine diet (Kennedy and Carbyn 1981, Novack *et al.* 2005, Prugh 2005, Prugh and Ritland 2005, Ruhe *et al.* 2008). Coyote scats were collected in seven sites across the city of Calgary (Figure 1). Sites were selected to represent the diversity of habitat types in the city (*e.g.,* grasslands, coniferous forest, riparian habitat; see Table 1), to have broad geographic extent, to be spatially independent due to distance between (*i.e.,* separated by the diameter of average urban coyote home range), and to have been occupied by coyotes (B. Bruce, Animal Services, City of Calgary, pers. comm.). We assumed spatial independence of sites when they were separated by the diameter of an average urban coyote home range (*i.e.,* 5 – 13 km^2; Gehrt 2007), using a circular shape to calculate diameter. In one case, two sites are closer to one another than this 4 km distance; however natural features, primarily the Bow River, act as a barrier instead. Study sites were predominantly Calgary Parks (herein called Parks), where land is managed for public use by the city of Calgary, as well as an urban provincial park (Fish Creek) and a private property (Arbour Lake; a rural setting within the city).

Table 1. Characteristics of the seven study sites (Foley 2006, Bullick 2007) where CF=coniferous forest, CL=coulees (dominated by trembling aspen, shrubs and vines), DF=deciduous forest, DL=delta, DG=Douglas fir forest, FP=Foothills Parkland (a transition from grassland to closed aspen forest), GL=grassland, PS=poplars and shrubs, QU=quarry (old quarry being naturally recolonized by flora and fauna) and RH=riparian habitat.

Site	Size of Park/Greenspace	Major Habitat Types	Park Established
Arbour Lake (AL)	0.14 km^2 ("Private")	GL, PS	N/A
Edworthy Park (ED)	1.27 km^2 ("Medium")	DG, FP, RH	1962
Fish Creek Provincial Park (FC)	13.48 km^2 ("Large")	CF, DF, GL, RH	1973
Nose Hill Natural Environment Park (NH)	11.28 km^2 ("Large")	GL, CL, QU	1980
Weaselhead Natural Wildlife Area and North Glenmore Park (NGW)	2.37 km^2 ("Medium")	CG, DL, DF, GL, PS, RH	1971
Stanley Park, Rideau, and Erlton-Roxboro Natural Area (SPR)	0.40 km^2 ("Small")	DF, GL, PS	1984
Tom Campbell's Hill (TCH)	0.18 km^2 ("Small")	GL, PS	1991

1) Arbour Lake (AL): This site, located in Northwest Calgary, comprised primarily of a private property that resembles a small urban ranch, as well as public pathways and greenspaces which consist solely of grass fields. This site contains no off-leash areas and the property owners have horses, but no dogs or cats. Vegetation present is primarily grasses and forbs, with some shrubs. The site is located in a residential sector and borders houses, a shopping center, a playground, and a school.

2) Edworthy Park (ED): Edworthy Park borders the Bow River in western Calgary. This park includes a variety of vegetation types: Douglas fir, grassland, upland forest, and riparian habitat. It has a varied terrain, including a steep escarpment that is thought to have been historically used as a buffalo jump (Bullick 2007), contains a playground, has cargo trains passing along its border, and encompasses a large dog off-leash area. Residential development is taking place southwest of the park. It is surrounded by a residential area, the Bow River, and a highway.

3) Fish Creek Provincial Park (FC): Fish Creek is the only provincial park in Canada contained within a city (Foley 2006) and is Canada's largest urban park. It is located in southern Calgary, and stretches across the city laterally, from the eastern to the western city boundaries. The park was created around the riparian area of Fish Creek. The park contains coniferous and deciduous forest, grassland, wetlands and shrub lands. Numerous paved and gravel trails encourage cyclists and runners as well as leisure visitors. Fish Creek is a day-use only park. There are no off-leash areas in the park, and it is surrounded by residential area, a major road, and has service by public transit (bus and light rail train).

4) Nose Hill Natural Environment Park (NH): Nose Hill is the largest city park in Canada, and only 200 ha smaller than Fish Creek Park. It is located in northern Calgary, and was created to preserve the region's natural ecosystem. Nose Hill is vegetated primarily with native prairie grassland habitat, and has varying topography of hills and coulees. It includes both on and off-leash areas, and has numerous walking and bike paths throughout. Busy roads bound all sides of the park, with residential neighbourhoods beyond in all directions.

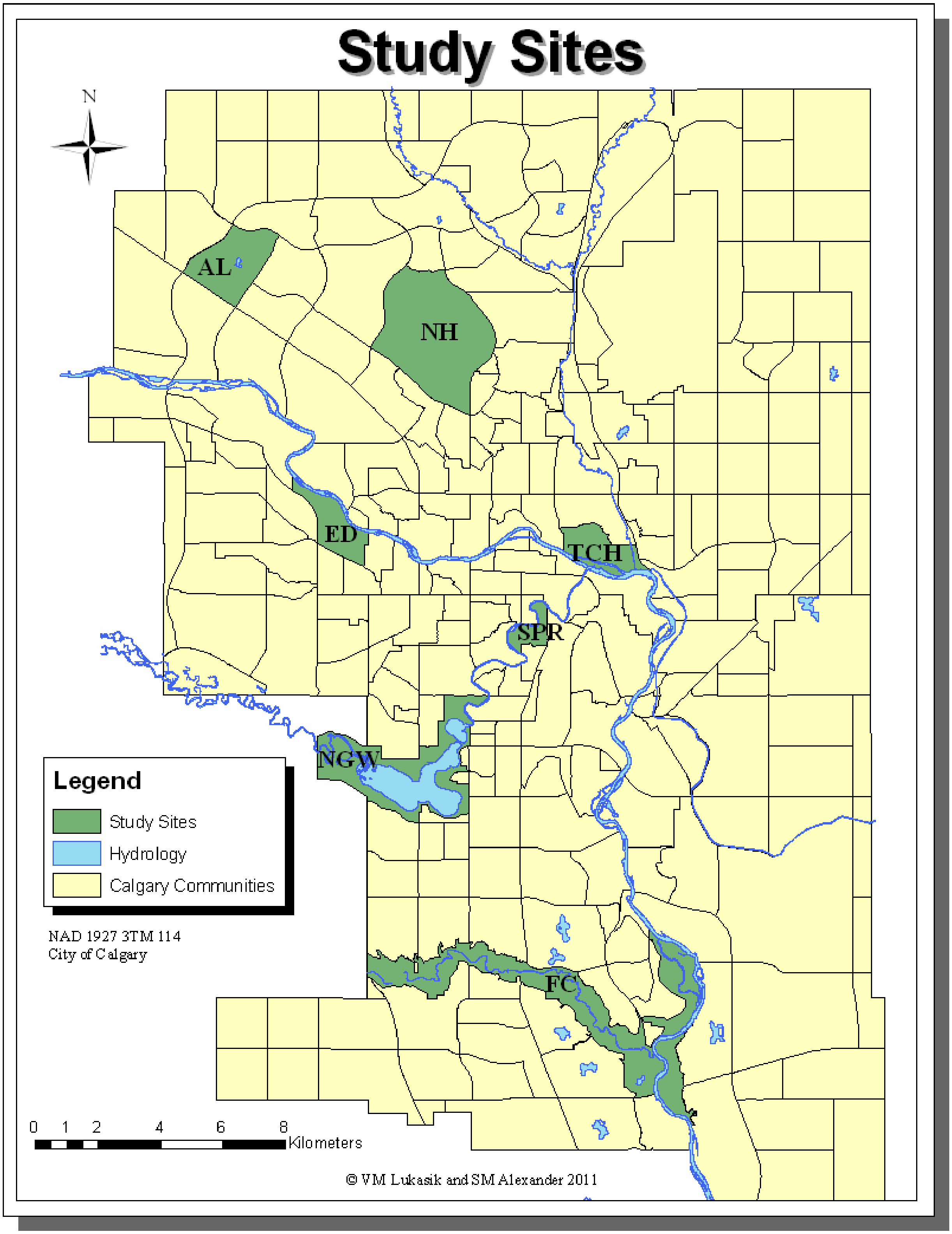


Figure 1. Study sites and surrounding communities in Calgary, Alberta. AL=Arbour Lake, ED=Edworthy Park, FC=Fish Creek Provincial Park, NH=Nose Hill Natural Environment Park, NGW=North Glenmore Park and Weaselhead Natural Wildlife Area, SPR=Stanley Park, Rideau and Erlton-Roxboro Natural Area, TCH=Tom Campbell's Hill.

5) North Glenmore Park and Weaselhead Natural Wildlife Area (NGW): The Glenmore Park and Weaselhead Natural Area lay on the western boundary of Calgary. Together, their area equals approximately one tenth that of either Fish Creek Provincial Park or Nose Hill Park. This site includes a variety of paved and gravel pathways for pedestrians, cyclists and even horseback riders. Within this site is part of the Elbow River and the Glenmore Reservoir. Habitats range from riparian to grassland to closed coniferous and deciduous forest. The park is surrounded primarily by a residential area, South Glenmore Park, a major roadway and the Tsuu T'ina Reserve.
6) Stanley Park, Rideau and Erlton-Roxboro Natural Area (SPR): This site is located in Calgary's southeast, and is central to the city. The study site included a portion of Stanley Park, sidewalks in the community of Rideau, and a portion of the Erlton-Roxboro Natural Area. This site has designated off-leash areas. Main habitats included grassland, riparian habitat, poplars (*Populus spp*.) and shrubs and deciduous forest. The terrain also varied from flat to steep sloped. The site is bordered by a residential area, a school, the Elbow River and roadways.
7) Tom Campbell's Hill (TCH): Tom Campbell's Hill is a small park in northeastern Calgary. Most of the park is treated as an off-leash area. Soccer fields are present in the northwestern part of the park. The habitat is primarily grassland, but also includes some poplar groves. It is surrounded by a residential area, the city zoo, soccer fields and is close to a major highway.

Scat Collection and Identification

We conducted field surveys for coyote scats over one complete year (August 2006–September 2007, inclusive). Coyote scats were identified and collected during bi-weekly surveys of representative transects at each of the seven study sites. Transects were located along gravel, asphalt and dirt trails that bisected survey sites. Each transect had a fixed length and placement, though variations took place when little or no scat was found, in response to possible changes in coyote home ranges. Transect length varied with park size; transects of approximately 3 km in length were conducted in small parks, 5 km in medium parks, and 8 km in the large parks. Transects were selected if preliminary surveys (2 conducted per site) yielded scats. Surveys were conducted on foot. We used existing linear features (*i.e.,* roads, pathways, trails) because prior research suggested this was a viable approach (Prugh and Ritland 2005). For instance, Macdonald (1980) observed that coyotes travel along such linear features and deposit scat at strategic and often conspicuous locations, including trail junctions and borders. O'Donoghue *et al*. (1998b) also found that coyotes use both wildlife and human trails while hunting. All scat found and identified as coyote scat during surveys were collected, including those seen on adjacent trails when visible.

In Calgary, red foxes and domestic dogs are the only canids that yield scats similar in morphology to those of coyotes. Coyote scats were distinguished from dog scats using several morphological criteria (Halfpenny and Biesiot 1986):

- **Size:** 12-30 mm in diameter (variable in dogs)
- **Colour:** dark, gray or reddish colour (not yellowish as often in dogs)
- **Shape:** thick or folded cords, often tapered (smooth, tubular for dogs)
- **Texture:** firm to hard, except when primarily consisting of berries (soft and grainy for dogs)
- **Location:** usually on paths and trails, or edge of paths and trails (dogs tend to defecate in grassy areas off trails and paths)

Coyote scat was typically easy to distinguish from dog scat, however when identification was uncertain, scat was discarded. In addition, though coyote scats may be as small as 12mm in diameter, we discarded all scats less than 18mm in diameter (the maximum diameter of fox scats) to reduce the risk of including fox scats, which are similar in morphology to coyote scats. Seven field assistants helped to collect approximately 40% of all scat over the study period. Field assistants were all trained in the same manner by the two principal researchers; Prugh and Ritland (2005) demonstrated that trained observers can identify coyote scats in the field with enough accuracy for dietary studies, even in the presence of other similar-sized carnivores. To further reduce inter-observer bias, the lead author verified all scats prior to commencing dietary analysis, which was recommended by Cunningham *et al*. (2006). Scats were collected, bagged, dated, marked and stored in a freezer for later dissection and dietary analysis (reviewed below).

Diet Analysis

Scat samples were deep frozen at -80ºC for a minimum of 72 hours to eliminate the danger of any parasite transmission to the analyst; particularly that of the granular tapeworm (*Echinococcus* spp.; Kennedy and Carbyn 1981). Verified and sanitized scats were sub-sampled by site and season in order to obtain approximately 30 scats per site and season, when more than 30 scats per site and season were collected. Sub-sampling was conducted in a stratified random manner; samples were separated by date and approximately equal samples were chosen for analysis from each collection date, where possible, in order to prevent a situation where most samples analysed for a season were those collected on the same date.

Scat samples were then examined; all components in each scat were identified, including bones, hairs, seeds, feathers and other materials (Hernandez *et al*. 2002, Prugh 2005). Hairs were identified to the species level, by comparing the scale and medulla patterns as seen through a compound microscope to guide books and keys for identification (Adorjan and Kolenosky 1969, Moore *et al*. 1974, Kennedy and Carbyn 1981, Halfpenny and Biesiot 1986). Bone identification to species level was confirmed by comparison with samples from the zoological collection of the Department of Biosciences, University of Calgary. Mammalian species were identified to the lowest taxonomic level possible without sacrificing certainty, typically to species level. Vegetation remains were identified by appearance of berries, seeds and leaves based upon knowledge of local vegetation and comparison with guide books (Royer and Dickinson 2007). Insects and birds were both identified to Order, based upon exoskeletal remains and barbules on feathers, respectively (Bland and Jaques 1978, Kennedy and Carbyn 1981). Anthropogenic food items were identified with the help of a dissecting microscope and comparison with everyday items (*e.g.*, plastic bags, food wrappers, toys).

Following the identification of dietary components, we estimated the percent by volume composition for each component, using the point-frame method (Chamrad and Box 1964). The percentage was obtained by placing a clear plastic, 2.5 cm grid over the dissected and separated sample and counting the number of squares occupied by each food item. This number was then divided by the total squares occupied by the sample and converted to a percentage. We believed this method to be less subjective than the common visual estimation of percent by volume (*e.g.,* as in Schrecengost *et al*. 2008). Any item that made up less than two percent of the scat volume was considered 'trace' and removed from further analysis in order to minimize biased emphasis (Weaver and Hoffman 1979, Morey et al. 2007). For instance, it is unlikely that a scat would contain only a single hair of a prey it consumed. In this case, it was assumed that this hair may have been ingested while consuming other items from the environment or while grooming (in the case of a coyote hair found in scat samples).

In order to obtain large enough samples for analysis, food items were amalgamated into the following main categories: herbaceous plants including all grasses (Family Poaceae), sedges (Family Cyperaceae) and rushes (Family Juncaceae); woody plants including choke cherry (*Prunus virginiana*), common buckthorn (*Rhamnus cathartica*), saskatoon (*Amelanchier alnifolia*), prairie rose (*Rosa arkansana*) and mountain ash (*Sorbus scopulina*); crabapples (*Malus* spp.); small mammals (all mammals other than deer and domestic animals); large mammals including mule and white-tailed deer; birds; insects; anthropogenic food sources (predominantly garbage); and domestic animals (cat and dog remains, including both hair and bone). This method of agglomerating food items has been used successfully in other studies (Morey *et al*. 2007, Schrecengost *et al*. 2008). We next calculated the "Relative Frequency of Occurrence" of each food type, based on Álvarez-Castañeda and González-Quintero (2005) and Sokal and Rohlf (1995). This value is calculated as the number of scats containing the food item (Frequency) divided by the total number of scats, multiplied by 100, and is represented by the equation below (Equation 1):

$$RF = (f_i / \Sigma n)(100) \qquad (1)$$

where f_i is the number of scats containing the food item (Frequency) and Σn is the total number of scats (in this case, 484). This value represents how common a food type is, relative to the number of scats. This value was calculated for each item identified in the scats. Further analyses were based upon the aggregated groups described above, and are discussed below.

We compared diet composition among all survey sites in the city of Calgary. Diet composition was also tested among park sizes (see Table 1). We tested for difference among sites and then sizes using a chi-square contingency analysis, as in Morey *et al*. (2007) using SPSS (PAWS Statistics 17 2008).

We conducted a seasonal analysis of diet, based on biologically significant time periods, as defined in Morey *et al*. (2007); Breeding (January 1 – April 30), Pup-Rearing (May 1 – August 31) and Dispersal (September 1 – December 31). These seasons incorporate the life history patterns of coyotes on an annual basis. It is thought that certain behaviours, such as pup-rearing, can put coyotes under food stress, and can amplify conflict between humans and coyotes (Carbyn 1989). Other studies showed that during dispersal, juveniles of many carnivore species move into sub-standard habitats, and as a result may rely upon easy food sources, such as human garbage (Timm *et al*. 2004). As seasonal changes in behaviour may relate to food choices by coyotes, which in turn may be implicated in conflict with people, we believed this was a useful aggregation for our analysis. Due to small sample sizes (less than 30 scat samples per season at four sites; Table 2), we pooled the dietary results from all study sites and tested for differences across time. We used a chi-square test (Zar 1999), and compared our observed frequencies of each food type against uniform expected frequencies for each of the three seasons.

Table 2. Number of scat analysed per site and season. All samples confirmed as belonging to coyote were sampled except where more than 30 were collected per season for a site. AL=Arbour Lake, ED=Edworthy Park, FC=Fish Creek Provincial Park, NH=Nose Hill Natural Environment Park, NGW=North Glenmore Park and Weaselhead Natural Wildlife Area, SPR=Stanley Park, Rideau and Erlton-Roxboro Natural Area, TCH=Tom Campbell's Hill.

Site \ Season	Breeding	Pup-Rearing	Dispersal	Total
AL	32	30	30	92
ED	9	16	27	52
FC	30	30	34	94
NH	2	20	27	49
NGW	30	29	29	88
SPR	7	10	29	46
TCH	9	13	41	63
Total	119	149	217	484

The diversity of coyote diet, or dietary breadth, was calculated by the Shannon diversity index (Shannon and Weaver 1949), which is a relative measure of diversity, often used as a measure of biodiversity in an ecosystem (Spellerberg and Fedor 2003). Values can range from zero to over 3.5, where zero represents one species in an ecosystem and 3.5 represents many species, with no one dominant species, in that ecosystem. When using this index to measure dietary breadth, the greater the value the greater the variety and evenness of food types in the animal's diet. Dietary breadth was calculated for all samples using the non-aggregated data, and this value was compared to each site and season using Hutcheson's t-test (Zar 1999). An alpha level of 0.05 was used to determine significance.

RESULTS

Dietary analysis of 484 scats indicated that small mammals and vegetation had the largest percentage occurrence in coyote scat samples (Figure 2). Small rodents were the most common food items found in coyote scats (84.71%), followed by herbaceous plants (44.63%). Crabapples were the next most common type of plant matter found in scats (33.88%), and were separately identified because of the large abundance of this fruit and association with residential areas. Woody plants (berries) were less commonly (16.94%) found than other vegetation. Lastly, anthropogenic food sources – mainly garbage – were found in 14.05% of the scats and typically made up very small proportions of the scats. Domestic animals – cats and dogs – were found in six scats (1.24%).

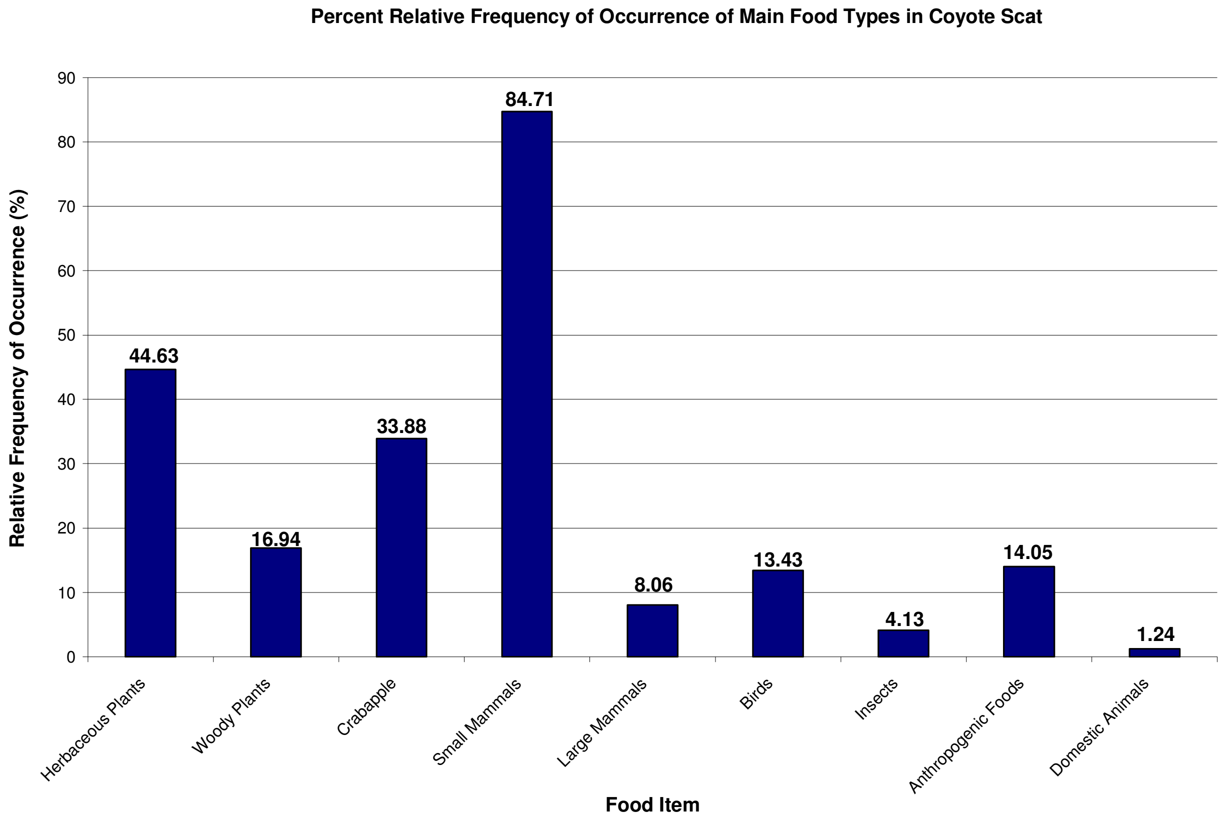


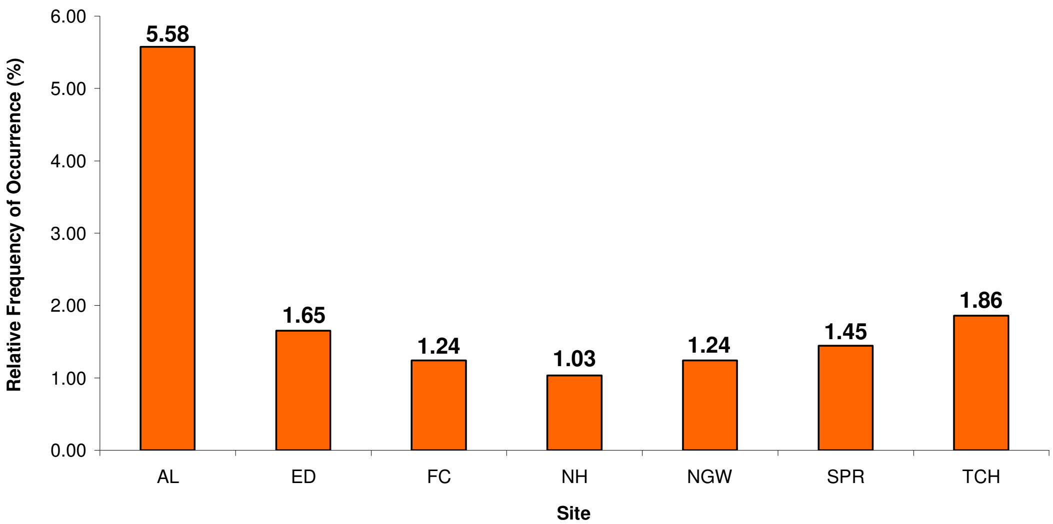
Figure 2. Relative frequency of occurrence by food type for coyotes in Calgary.

Although significant differences were found across sites for each food item, small mammals were the primary prey item of coyotes at all sites. Herbaceous plants (primarily grasses) and crabapples were common food sources at several sites. Herbaceous (χ^2_6=4473, p<0.001) and woody (χ^2_6=2211, p<0.001) plant content varied significantly across sites and both were more common in Arbour Lake (AL) than any other site, while crabapples were found significantly more in samples from Fish Creek (FC; χ^2_6=3700, p<0.001) than other sites. Small mammals varied significantly and were most common in North Glenmore Park and Weaselhead Natural Wildlife Area (NGW; χ^2_6=3707, p<0.001). Deer was also found in more scats from NGW (χ^2_4=2066, p<0.001) than other sites, and entirely absent from both Stanley Park, Rideau and Erlton-Roxboro Natural Area (SPR) and Tom Campbell's Hill (TCH) sites. Birds and insects were uncommon in scat, with birds significantly more common in SPR (χ^2_6=429.8, p<0.001) than any other site and insects significantly more common in AL (χ^2_6=127.6, p<0.001) than any other site.

Significant differences were also seen across park sizes for many food items. Herbaceous plants were more common in the private property, AL, than any of the parks (χ^2_3=1513, p<0.001). The number of scats containing woody plant content varied significantly across park sizes (χ^2_3=1700, p<0.001), and were most common in scats from large parks. Other significant differences included deer (χ^2_2=960.8, p<0.001), which was most common in large parks, and birds (χ^2_3=108.5, p<0.001), which were most common in small parks.

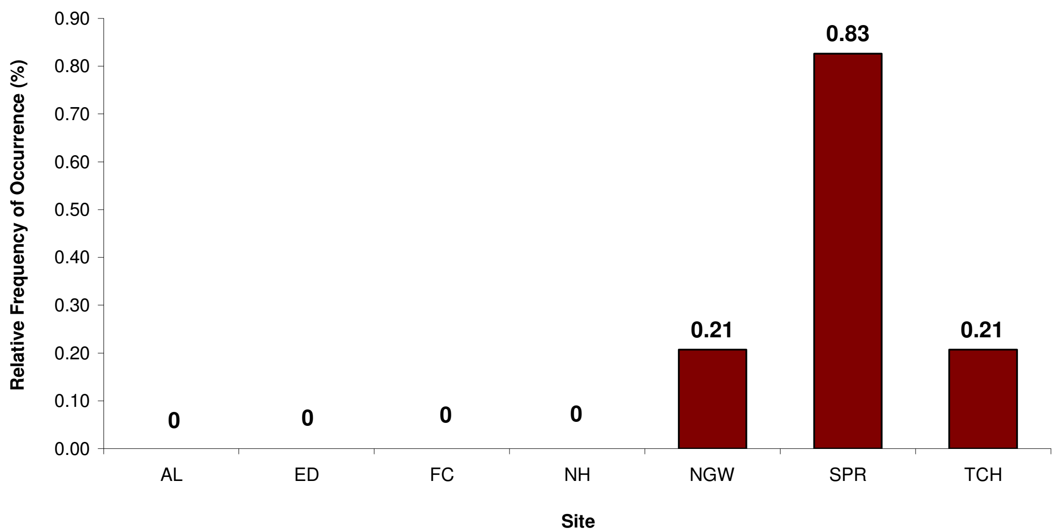
The human-related food categories (anthropogenic foods, domestic animals and crabapples) were of focal importance in our research, due to the potential link to human-coyote conflict (Lukasik and Alexander 2011). As such, we present these results separately. Sixty-eight of 484 scats (14.05%) contained anthropogenic food content (Figure 3a). Significant differences were found in the anthropogenic content (χ^2_6=1183, p<0.001) across sites, with AL having the greatest anthropogenic content. Difference in anthropogenic content between park sizes was found to be significant (χ^2_3=413.4, p<0.001), with the privately owned site and smallest parks having the most anthropogenic content. The amount of crabapples in scat was high, but varied significantly by site (χ^2_6=3700, p<0.001). Crabapples were most common at FC and were least evident at Nose Hill Natural Environment Park (NH). Crabapples were also significantly more common in small parks (χ^2_3=1427, p<0.001). Four of only six scats containing domestic animal content were collected in one site, SPR (Figure 3b), and five of six were found in small parks.

Percent Relative Frequency of Occurrence of Anthropogenic Foods by Site



a)

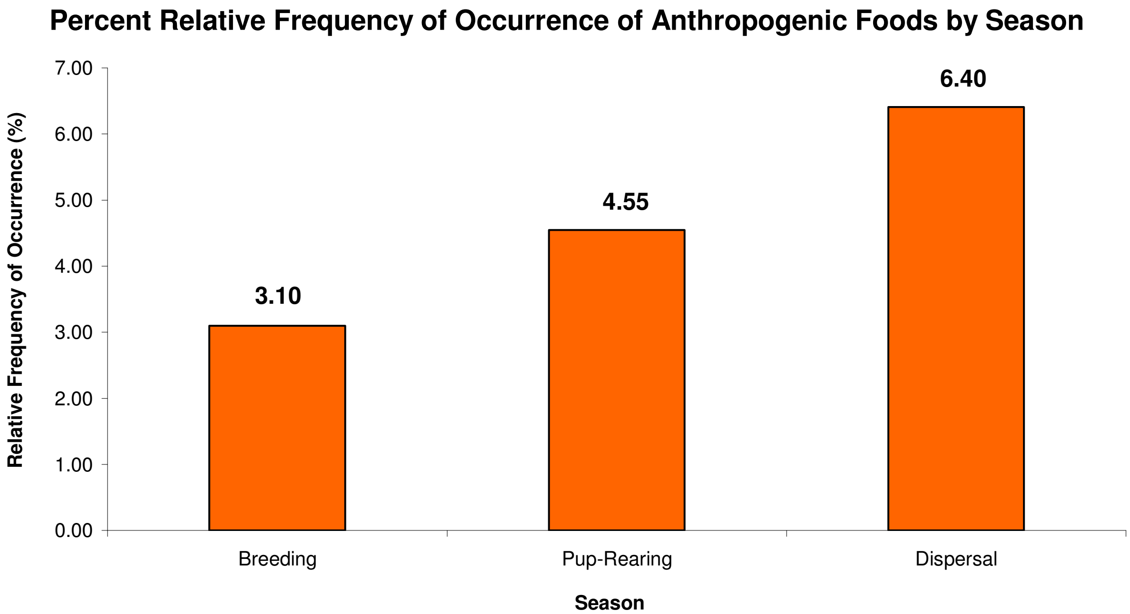
Percent Relative Frequency of Occurrence of Domestic Animals by Site



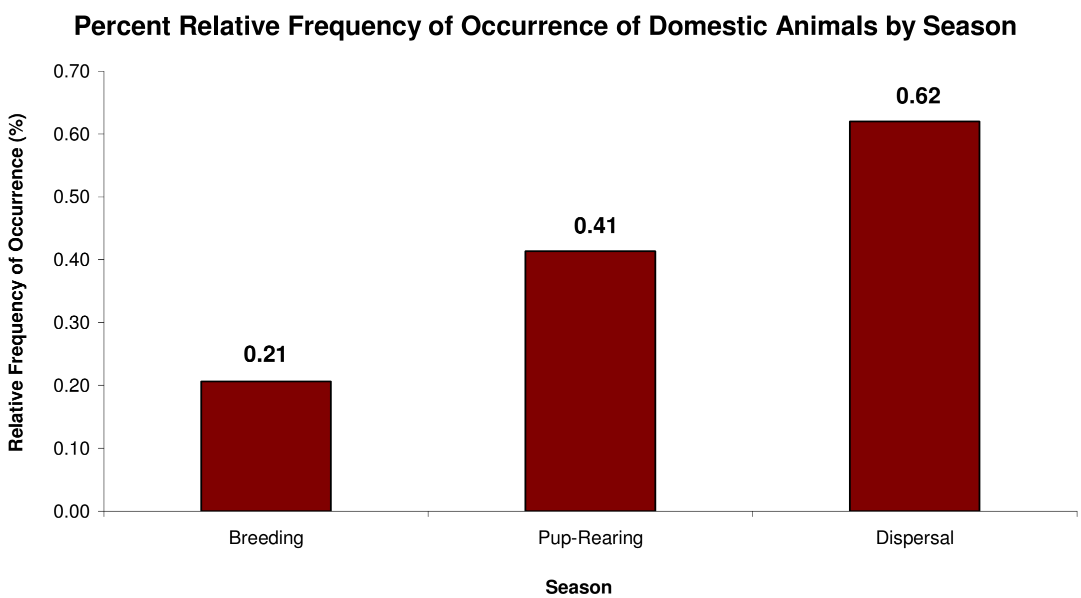
b)

Figure 3. a) Percent Relative Frequency of Occurrence of anthropogenic foods for each site; b) Percent Relative Frequency of Occurrence of domestic animals for each site. AL = Arbour Lake (n=92), ED = Edworthy Park (n=53), FC = Fish Creek Provincial Park (n=94), NH = Nose Hill Natural Environment Park (n=49), NGW = North Glenmore Park and Weaselhead Natural Wildlife Area (n=88), SPR = Stanley Park, Rideau and Erlton-Roxboro Natural Area (n=46), TCH = Tom Campbell's Hill (n=63).

A range of food items, from woody plants to small mammals to anthropogenic food items, was observed to be regularly consumed in all biological seasons. However, some food items were significantly different across these seasons. We tested each food type across seasons and organized our results by biological season rather than food type. We chose this organization due to the fact these seasons may more easily provide management targets. We also present non-significant food items for thoroughness.



a)



b)

Figure 1: a) Percent Relative Frequency of Occurrence of anthropogenic foods by season, b) Percent Relative Frequency of Occurrence of domestic animals by season. Breeding = Jan 1–April 30 (n=119), Pup-Rearing = May 1–Aug 31 (n=148), Dispersal = Sept 1–Dec 31 (n=217).

Only deer was consumed in greater frequently during the Breeding Season, however this difference was not significant (χ^2_2=2.250, p=0.325). During the Pup-Rearing Season woody plants (χ^2_2=998.0, p<0.001) were consumed significantly more than during other periods. During the

Dispersal Season we observed the following significant differences: Herbaceous plants (χ^2_2=89.273, p<0.001), crabapples (χ^2_2=5023, p<0.001), small mammals (χ^2_2=755.3, p<0.001), birds (χ^2_2=104.4, p<0.001), anthropogenic food sources (χ^2_2=183.9, p<0.001) and domestic pets (χ^2_2=31.417, p<0.001) were consumed significantly more often. Insects were also consumed significantly more during Dispersal season, though differences across seasons were only significant at the 0.005 level (χ^2_2=12.508, p=0.002). Figure 4 illustrates the percent relative frequency of occurrence of anthropogenic content and domestic animals across seasons.

We found a total of twenty-four food items across all scat samples, with individual scats containing between 1 and 7 different food items. Scat samples showed a mean of two food items per scat. The overall diversity index for all sites and seasons was 0.99, and ranged from 0.86 to 0.96 across sites, and 0.89 to 1.00 across seasons. A larger value represents a more diverse and less even diet. Hutcheson's t-tests (Zar 1999) indicated that some sites and seasons showed significant differences from overall diversity (Table 3).

Table 3. Shannon's diversity index values for each season, each site and all sites and seasons together ("Overall"). Table also includes the t statistic used to compare seasons and sites to the overall index, the degrees of freedom calculated (v) and whether the difference was significant at the 0.05 level. B=Breeding (Jan 1–Apr 30), P=Pup-Rearing (May 1–Aug 31), D=Dispersal (Sept 1–Dec 31). AL=Arbour Lake, ED=Edworthy Park, FC=Fish Creek Provincial Park, NH=Nose Hill Natural Environment Park, NGW=North Glenmore Park and Weaselhead Natural Wildlife Area, SPR=Stanley Park, Rideau and Erlton-Roxboro Natural Area, TCH=Tom Campbell's Hill.

		Seasonal Comparison			Spatial Comparison						
	Overall	B	P	D	AL	ED	FC	NH	NGW	SPR	TCH
Shannon's Diversity Index (H')	0.99	0.89	0.94	1.00	0.96	0.93	0.92	0.86	0.91	0.89	0.91
t statistic	---	-3.12	-2.11	-0.32	-1.14	-1.56	-1.98	-2.55	-1.96	-2.63	-2.33
v	---	416	868	1062	409	158	331	122	231	153	230
Significant Difference at α=0.05	---	Yes	Yes	No	No	No	Yes	Yes	No	Yes	Yes

Dietary breadth varied across sites. Sites with the greatest dietary breadth, but showing no significant difference from the overall breadth, were AL (0.96) and Edworthy (ED; 0.93). Sites that exhibited the least breadth and significantly less than the overall were NH (0.86) and SPR (0.89). Seasonally, dietary breadth was significantly lower than overall dietary breadth during the Breeding season (0.89) and highest (with no significant difference from the overall breadth) during the Dispersal season (1.00).

DISCUSSION

Our results yielded evidence that urban coyotes in Calgary eat primarily natural prey, such as rodents, vegetation, rabbits, deer and birds. Coyotes in Calgary preyed particularly upon voles and ground squirrels. These findings are consistent with other studies of both urban (Morey *et al*. 2007) and rural coyotes (Cunningham *et al*. 2006, McKinney and Smith 2007). Though our results represent only one year of data, a subsequent study which was conducted in Calgary from July 2009 – July 2010 has observed the same trends (Fortin-McCuaig unpub.). Morey *et al*. (2007) also found voles and mice to make up the highest frequency of occurrence in coyote scats in all seasons and sites in Chicago. Coyotes are well adapted to 'mousing' and Calgary's unique climate where snow cover tends to be shallow and intermittent during winter, may result in a situation where small rodents are easily accessible to coyotes throughout the year.

While our work suggests coyotes in Calgary feed primarily on natural food items, there is evidence they consume substantial anthropogenic foods (14.05%) – not including crabapples - and while infrequent, they have eaten domestic dogs and cats (1.24%). Importantly, we cannot determine whether the cats and dogs found in the six of 484 coyote scats sampled, were preyed upon or scavenged by coyotes, though coyotes have been documented to kill cats in other areas (Grubbs and Krausman 2009). Chicago researchers similarly found that cats and anthropogenic food comprised between one and ten percent of the coyote diet at any given site (Morey *et al*. 2007). Conversely, coyote diet in Los Angeles County during a period of frequent human-coyote conflict, has been classified as "high in anthropogenic items" (Baker 2007), including a 40.9% occurrence of garbage in coyote scat, and 13.6% occurrence of domestic cat (Shargo 1988).

If the hypothesis that anthropogenic food content in coyote diet is linked to human-coyote attacks is correct (Carbyn 1989), our work suggests that the city of Calgary should be concerned with reducing coyote access to these food sources. Though we have no trend evidence to support this conclusion, other studies have found that coyote diet with elevated anthropogenic food content can predispose animals to conflict with people, related to food conditioning and habituation. Our dietary analysis can only reliably trace evidence of anthropogenic food that persists through the coyote's digestive tract, such as plastic and foil. Hence, our results may under-represent soft or digestible food items, such as meat or dog food. We suggest that 14.05% occurrence of anthropogenic food is likely a conservative estimate for Calgary. Importantly, our previous study quantifying reported human-coyote conflict in Calgary (Lukasik and Alexander 2011), showed that while human-coyote conflict is low in Calgary, it tends to be greater in sites where coyote scat contained highest anthropogenic food content. Specifically, coyote scats containing domestic cat or dog remains were found in NGW, TCH and especially (with the greatest frequency) SPR. The communities that reported the greatest human-coyote conflict from 2005–2008 were located in close proximity to SPR and TCH (Lukasik and Alexander 2011). Further research and long-term monitoring is needed to better understand these relations.

Coyote diet in Calgary differed among study sites, as well as across park size. Samples collected from the smallest sites, AL, TCH and SPR, had among the highest anthropogenic content detected in coyote diet, with AL having significantly more anthropogenic items in scat than any other site (χ^2_6=1183, p<0.001). Conversely, NH, FC and NGW had the lowest anthropogenic content in diet, and these were also the largest sites with natural habitat. Larger parks also tended to have scats with higher content of woody plants and deer. Although common at all sites, small mammals and deer were most prominent in coyote diet in NGW and FC, which are both large parks with good connectivity to the city border. Scats collected in AL had a predominance of small mammal content. Although this site was small and predominantly located on private property, a colony of ground squirrels and numerous small rodents were observed on the site during field work. Thus the availability of small mammalian prey at this site is likely high.

In theory, larger parks should yield higher diversity of species (Murphy and Wilcox 1986) and therefore coyotes living in larger parks may have access to a wider variety of food items. While we did not measure resource availability, prior research suggests the differences we observed likely relate to prey availability (Hernández *et al*. 2002, McKinney and Smith 2007), habitat types and level of human disturbance, all of which can affect coyote behaviour, activity levels and social dynamics (Kitchen *et al*. 2000, Fedriani *et al*. 2001, Atwood *et al*. 2004, Ditchkoff *et al*. 2006, Gehrt *et al*. 2011). We also suspect that coyotes with access to a large, more natural and homogenous habitat such as a large park spend more time in that park and are able to sustain themselves with the natural prey found there; White and Gehrt (2009) found that even in urban areas coyotes tended to spend more time in greenspaces and avoided humans, when possible. In contrast, small parks may not have enough natural habitat and prey species to sustain coyotes, forcing them to forage outside of the park. This likely would give them access to easily obtainable foods such as garbage, fruiting trees in people's yards and potentially domestic cats and dogs.

Statistically significant seasonal differences in food items were observed for aggregated diet data in all sites (versus comparing between sites across seasons). We discuss differences by biological season first and then by food item. Coyotes ate primarily small mammals, as well as herbaceous plants and crabapples during the Breeding season. While crabapples can persist well into winter, berries from many native fruiting trees do not, which would account for the minimal amount of woody plant content in coyote diet during this season. The Breeding season also had scats containing the least amount of anthropogenic and domestic animal food items across season. Typically, human activity outdoors is reduced in the winter months and as a result we suspect there may be lesser access to garbage both irresponsibly discarded, as well as deposited in park garbage bins, by park users at this time of year than others. Likewise, Morey *et al*. (2007) found that coyotes in Chicago consumed the least amount of anthropogenic foods during the Breeding season.

Scats showed that coyotes eat more herbaceous and woody plants, as well as small mammals, in the Pup-Rearing season than any other. Vegetation is more plentiful at this time of year than the others, with fruits especially available with exception to late-fruiting crabapples. In Chicago, Morey *et al*. (2007) found fruits to be most common food item during Pup-Rearing season. Coyotes also tend to exhibit more localized movements while denning (Pup-Rearing season), typically remaining closer to dens which tend to be located in natural habitat (Way *et al*. 2004). However, human use of parks tends to be highest in the summer, and pressure to feed coyote pups may lead coyotes to seek out easy sources of food (Carbyn 1989), including park garbage bins. It is possible that this leads to the increased anthropogenic food content observed at this time of year.

During the Dispersal season, crabapples were consumed to a greater extent than other seasons. The fruit of crabapple trees tend to persist well into autumn (Dispersal season), when other food items, such as saskatoon berries, may be less available. During the fall, crabapples may lie on the ground and are an easy food item for coyotes to consume. Crabapples are a high energy food source, which may be highly useful to dispersing coyotes that have not yet established a territory in which to hunt. Crabapples are largely domestic and associated with residential developments. Our findings signal that fruit bearing trees may provide an attractant to coyotes or lead to food conditioning. Crabapples are present on trees throughout the winter, and photographic evidence from one Calgarian source (Figure 5) showed that at least one coyote in Calgary is climbing trees in order to supplement its' diet with this fruit during winter months (Alexander, pers. comm. 2011).

Figure 5. Coyote climbing in crabapple tree in a Calgarian's backyard. © M. Morrison.

We observed a greater number of scats containing anthropogenically-associated food during the Dispersal season, as well as the highest domestic animal content. During Dispersal, juveniles tend to rely upon lower quality, easier to attain food sources until they have a good-quality territory of their own established (Carbyn 1989). For example, when coyote territory is lacking a good source of preferred (natural) prey, coyotes will take advantage of alternative food sources, such as those provided by humans (Morey *et al*. 2007). Morey *et al*. (2007) also found anthropogenic food items to be most prevalent during either the Pup-Rearing or Dispersal seasons. The weather in Calgary fluctuates greatly within seasons, which may lead to reduced variation in coyote diet across seasons (Foley 2006). Calgary experiences a warm weather pattern in winter – Chinooks – that cause unseasonably high temperatures for typically a few days at a time throughout the winter. During this time spring-like weather is experienced and snow usually melts. Furthermore, unseasonably cold weather (temperatures below freezing) is not uncommon in the spring and summer. Thus, coyotes in Calgary may have easier access to certain foods in winter that would otherwise be hindered by snow cover in most other parts of northern North America (see Crête and Larivière 2003).

Significant differences in dietary breadth were observed between some sites and seasons, though there was not a great range in values. Our analyses indicated that coyotes in the city of Calgary have a moderately varied diet. An overall Shannon diversity index of 0.99 is lower than the diversity index reported in Morey *et al*. (2007), with reported values ranging between 1.36 and 2.15. This indicates that coyotes in Calgary are either consuming fewer food items than those in Chicago, or a few food items dominate the diet of Calgary's coyotes relative to those in Chicago. There likely are differences in prey availability in the Chicago system when compared to Calgary, which would impact the breadth of coyote diet. Kozlowski *et al*. (2008) reported the diversity of coyote diets in the Great Basin Desert of Western Utah to be between 0.76 and 0.80, indicating that these coyotes had a less diverse, less even diet than those in our study as well as those in the Chicago study (Morey *et al*. 2007). This may be due to the fact that Kozlowski *et al*. (2008)

studied non-urban coyotes. The low diet diversity they observed may be due to a lower diversity of available food items, or a greater availability of preferred food items. Thus far, it appears that coyotes in an urban environment generally have a more diverse diet than their non-urban counterparts. Differences between dietary breadth did not vary greatly across sites, though some sites had significantly lower than the overall dietary breadth of 0.99. The greatest dietary breadth among study sites was found in AL (0.96) and ED (0.93), while the least diverse diets were in NH (0.86) and SPR (0.89).

Coyote dietary breadth was greatest during the Dispersal season and least during the Breeding season. Morey *et al*. (2007) also found diet to be least diverse during the Breeding season, though the most diverse diet varied among sites. Because Calgary experiences winter conditions throughout most of the Breeding season, there is likely lesser food available at this time of year. Conversely, a greater variety of foods is likely to be available during summer months (Pup-Rearing Season), which explains why dietary breadth would be higher for coyotes at this time of year. Dietary breadth was highest for Calgary coyotes during the Dispersal season. Calgary tends to experience mild weather in autumn, and consequentially many food items available in summer months are also available later in the year. As well, crabapples become more available at this time of year. Morey *et al*. (2007) found coyotes at only one of their four sites to have the greatest diversity during the Dispersal season.

CONCLUSION

Our research showed that during our year of analysis Calgary coyotes had a varied diet, composed primarily of natural food items such as small mammals and vegetation. However, coyotes in Calgary take advantage of human-associated food sources, including garbage (1 in 7 scats contained anthropogenic food items). Coyotes did prey upon domestic cats and dogs, but the incidence was very low (less than 1.5% of scats). Coyote diet varied seasonally and especially spatially, within Calgary. Large, natural parks appear to encourage coyote populations that depend upon a natural diet, consisting primarily of small mammals. Furthermore, coyote diet had the highest dietary breadth during the Dispersal season and this is the season during which the most anthropogenic food items are consumed. We suspect this may be due to a decreased availability of preferred prey during this season as compared to the Breeding and especially Pup-Rearing seasons (Morey *et al*. 2007). The level of anthropogenic food in coyote diet in Calgary indicated that at least some coyotes are already taking advantage of easy food sources provided both unintentionally and intentionally by humans. The diet of coyotes should continue to be monitored, as an increase in anthropogenic food sources in their diet may indicate that coyotes are becoming more habituated to humans, which is thought to lead to increased human-coyote conflict (Carbyn 1989). Any future increases in anthropogenic content in coyote scat should be regarded as an indication that better garbage management and public education about coyotes in the city is needed, whereas decreases in anthropogenic content may be a sign that the management steps taken are effective (Baker 2007, Lukasik and Alexander 2011). Our current work was intended to provide initial and comparative data on coyote diet in Calgary, for which estimates of selection were not necessary. This study will be complemented by a companion study completed by Fortin-McCuaig and Alexander (unpublished). Future studies investigating coyote food selection may help further explain under which circumstances coyotes become more dependent upon anthropogenic foods. In turn, that information may provide critical insights for management efforts. We suggest future research should incorporate measures of availability in order to more clearly identify preferences or selection of food items by coyotes.

We believe our findings provide a critical first 'snapshot' of urban coyote diet in Calgary, and underscores the importance of managing humans, residential waste and urban design (*e.g.,* what type of plants are chosen for yards) in Calgary and other urban areas. Our results can support management actions, and may be integrated into education campaigns encouraging citizens to limit coyote access to human foods and garbage.

APPENDIX A – Supplementary Figures

Figure A1. Location of scat samples collected in Calgary study sites (AL, ED, FC, NH, NGW, SPR, TCH). Samples displayed containing only natural food, containing some anthropogenic foods (*i.e.,* garbage), and those containing domestic animals (cats, dogs).

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