A Comparative Ecological Study between Coyotes (*Canis latrans*) in a Protected and Urban Habitat: A Closer Look at Enteric Parasites and Diet between Florida Coyotes

by

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Denara Lynn Manning

ABSTRACT

Coyotes (*Canis latrans*) have inhabited Florida (USA) since the 1960s and are currently found throughout the state. The purpose of the present study was to obtain information on enteric parasites and diet of Florida coyotes from two different habitat types. Seasonal variation in diet was also examined. Fresh coyote fecal samples were collected from protected and urban habitats in Pinellas County, Florida (USA; 27^{o}54’ N, 82^{o}41’W) from May 2005 to March 2007. A standard fecal flotation examination and formalin-ethyl acetate sedimentation were utilized on fecal samples collected from the protected (n=40) and urban (n=50) habitats. Five novel (newly documented) parasites of coyotes were discovered; one cestode (*Hymenolepis* spp.), one nematode (*Ascaris* spp.), and three protozoa (*Balantidium coli*, *Blastocystis* spp., and *Entamoeba histolytica*). Novel parasites of Florida coyotes were also discovered; two cestodes (*Diphyllobothrium latum* and *Dipylidium caninum*), two nematodes (*Toxocara canis* and *Uncinaria stenocephala*), one trematode (*Paragonimus* spp.), and four protozoa (*Cryptosporidium* spp., *Giardia canis*, *Isospora* spp., and *Sarcocystis cruzi*). One cestode (*Taenia* spp.), three nematodes (*Ancylostoma caninum*, *Physaloptera* spp., and *Trichurus vulpis*), and one trematode

(*Alaria* spp.) were also recovered, all of which have previously been documented in Florida coyotes. Diet items were identified to the lowest possible taxonomic level by gross morphological characteristics and medullary configurations of dorsal guard hairs. A Poisson Regression was utilized to determine the relation between diet items and habitat, season, and interaction. In the protected habitat (n=49), vegetative matter (96%), Insecta (53%), and Rodentia (45%) were recovered most often, as opposed to berries (56%) and Lagomorpha (32%) in the urban habitats (n=71). Overall, vegetative matter, berries, and Lagomorpha were recovered most often from Florida coyote fecal samples. *Odocoileus virginianus*, Lagomorpha, and berries varied the most between wet and dry seasons. It is suggested that Florida coyotes are more susceptible to reinfection by novel parasites because of their rapid range expansion and lack of acquired immunity. Rapid habitat loss in Florida (i.e., urbanization) lowers survival of adult coyotes, increases the probability of transmission of disease between wild and domestic canids, and alters the diet of coyotes by lowering biological diversity of available prey items.

CHAPTER ONE: A COMPARATIVE STUDY BETWEEN ENTERIC PARASITES OF COYOTES IN A PROTECTED AND URBAN HABITAT

INTRODUCTION

Coyotes (*Canis latrans*) have inhabited Florida (USA) since the 1960s and are currently found throughout the state (Wooding and Hardisky, 1990; Maehr et al., 1996; Main et al., 1999; Main et al., 2000). To date, there has been minimal research conducted on these new Florida residents to determine what ecological effects they have on the communities they inhabit. Coyotes have been widely studied throughout North America, but due to vast differences of flora and fauna, it is unclear how well these studies apply to Florida coyotes (Seesee et al., 1983; Thurber and Peterson, 1991). Habitat loss in Florida (i.e., urbanization) lowers survival of adult coyotes and increases the probability of transmission of disease between wild and domestic canids (Grinder and Krausman, 2001). Furthermore, the overall health of individuals declines when heavy parasitic infections occur (Belden and Kiesecker, 2005).

Documentation of enteric (intestinal) parasites of Florida coyotes is important for a number of reasons. First, the health of the coyote population is directly affected by intestinal parasitic infection (Lindsay et al., 1997). Second, knowledge of parasite species which infect coyotes is essential in order to determine if any measures need to be taken to prevent transmission between coyotes and domestic animals (Arjo et al., 2003). Third, domestic animals and coyotes can act as reservoirs for infections to humans. When infected wild animals, such as coyotes, have increased interaction with areas frequented by humans, as is the case with dense human populations and drastic urbanization, the risk of infection to humans is increased. Humans can become infected with enteric parasites if they consume viable parasites or drink contaminated water (Rubel and Wisnivesky, 2005). Children, due to their close contact with the soil, are especially susceptible to consumption of parasites (Matsuo and Kamiya, 2005).

Although studies have been conducted on the intestinal parasites of coyotes elsewhere in the United States (Arther and Post, 1977; Conder and Loveless, 1978; Pence and Meinzer, 1979; Seesee et al., 1983; Arjo et al., 2003; Gompper et al., 2003), few studies have focused on Florida coyotes. Conti (1984) and Foster et al. (2003) conducted research on enteric parasites of Florida coyotes, but both studies were based on necropsies from coyotes in less densely populated counties. This present study is the first conducted on Florida coyotes using non-invasive fecal examination techniques. Specifically, we utilized standard fecal flotation and formalin-ethyl acetate sedimentation to compare enteric parasite species of Florida coyotes between two different habitats, protected and urban, in the most densely populated county in Florida (USCB, 2004).

The primary objectives of this study were to investigate differences in enteric parasites between coyotes from protected and urban habitats and to document any novel (i.e., newly documented) parasites. Specifically, we compared species richness, defined as the number of species, and composition of enteric parasites between study locations. Additionally, we documented any novel enteric parasites recovered, whether novel to *Canis latrans* (i.e., never been documented in coyotes before) or to Florida coyotes (i.e., never been documented in Florida coyotes before).

Species composition of enteric parasites:

Null hypothesis: Enteric parasites of coyotes in the protected and urban habitats will not differ significantly.

Alternate hypothesis: Enteric parasites of coyotes in the protected habitat will differ significantly from those parasites of coyotes in the urban habitat.

It is presumed that there will be several enteric parasites found in both habitats. However, we predict that there will be significant differences in parasite species composition between protected and urban habitats. Specifically, we predict that urban coyote samples will contain more parasites commonly found in domestic animals. This prediction is based on the increased probability that coyotes and domestic dogs utilize common areas in the urban environment and because of this coyotes in the urban habitat might have more enteric parasites that are normally documented in domestic dogs. This could result from an infected domestic dog defecating in an area, thus depositing viable parasite eggs in the urban environment. If an urban coyote were to come into contact with these viable eggs and consume them, the coyote could then become infected with parasites.

Novel enteric parasites:

Null hypothesis: All enteric parasites in Florida coyotes will have been previously documented.

Alternate hypothesis: Florida coyotes will be infected with novel enteric parasites.

Due to unique flora, fauna, and environmental conditions in Florida, it is also presumed that novel (i.e., newly documented) enteric parasites will be documented.

Specifically, we presume that novel enteric parasites of *Canis latrans*, which have not previously been documented in coyotes elsewhere in the United States may be discovered during the course of this study. Additionally, little research has been conducted on coyote populations in Florida. As such, little is known about what enteric parasites infect these animals. Therefore, we also predict that this research may discover novel parasites of Florida coyotes.

STUDY SITES

Pinellas County is the most densely populated county in Florida with over 1281 people per square kilometer (USCB, 2004). Two types of habitat were compared in Pinellas County during this study: protected and urban.

Protected Habitat

Brooker Creek Preserve (BCP; 27^{o}54' N, 82^{o}41'W) was used for the protected habitat (Bean et al., 2005). BCP is an 8500 acre wilderness area that is actively managed for natural resource protection. Located in the northeast corner of the county, the boundaries of BCP are shared with densely populated residential areas. The study site consists of extensive pine flatwoods and freshwater swamps. Fauna include white-tailed deer (*Odocoileus virginianus*), raccoons (*Procyon lotor*), armadillo (*Dasypus novemcinctus*), bobcat (*Lynx rufus*), otter (*Lutra canadensis*), wild turkey (*Meleagris gallopavo*), red-shouldered hawks (*Buteo lineatus*), wood storks (*Mycteria americana*), bobwhite quail (*Colinus virginianus*), and gopher tortoise (*Gopherus polyphemus*).

Urban Habitat

Different sites throughout Pinellas County were used for urban habitat. Sites were determined using GIS (ArcGIS v.8) to plot existing geospatial information including land-use categories, railroads, bike trails, and power lines throughout the county. Subsequently, a map revealing rural, sub-urban, and urban areas based on residential (land-use category) population density was generated. Sites were identified based on criteria expected to support urban coyotes. The sites were constrained such that they had land cover of urban sites similar to that of BCP, were traversed by power lines, bike trails, or inactive railroads, and were located in urban areas.

METHODS

Field Methods

Fresh coyote feces were collected over the course of two years (May 2005 thru March 2007) from trails, power lines, and bike trails in the protected (n=40) and urban (n=50) habitats. Paths were traversed on foot, bicycle, and by ATV three times a week during the course of this study. Each fecal sample was measured (length and diameter) and photographed in the field. Species origin of the fecal samples was determined by adjacent sign (tracks) and dimensions of feces. Upon confirmation of coyote scat, the sample was assigned a unique identification code and its longitude and latitude were recorded by use of a GPS unit. Finally, the sample was placed in its own paper bag. To avoid collecting bobcat feces, only those samples in excess of one inch in diameter were collected (Gompper et al., 2003). To avoid collecting domestic dog feces, only samples which contained hair and bone fragments and/or which were accompanied by coyote tracks were collected (Wooding et al., 1984).

Laboratory Methods

To determine the enteric parasites present in each sample, a standard fecal flotation (specific gravity = 1.25) examination was conducted within 12 hours of collection (Thornton et al., 1974). Two grams of the fresh sample was preserved in 10% formalin and stored at room temperature until analyzed (Gillespie et al., 2005). To allow for maximum recovery of ova, oocysts, and larvae, a formalin ethyl-acetate sedimentation technique was also utilized on each sample (Price, 1994). Parasites were identified based on measurements obtained by an ocular micrometer fitted to a compound microscope and review of morphological characteristics observed from photographs taken of each specimen (Zaman, 1984; Chessbrough, 1987).

Statistical Methods

Differences in enteric parasite composition between protected and urban habitats were tested using a 2 x 19 chi-squared contingency table. Specifically, the different types of enteric parasite species that infect coyotes in the protected habitat were compared to the types of parasite species that infect urban coyotes and a chi-square analysis was utilized to determine if the parasite species found in the different habitat types were significantly different. The contingency table utilized all parasite species that were recovered during the course of this study.

RESULTS

Ten helminth species consisting of three cestodes (*Diphyllobothrium latum*, *Hymenolepis* spp., and *Dipylidium caninum*), six nematodes (*Ancylostoma caninum*, *Ascaris* spp., *Physaloptera* spp., *Toxocara canis*, *Trichurus vulpis*, and *Uncinaria stenocephala*), and one trematode (*Paragonimus* spp.) were recovered from coyote fecal samples (n=40) collected from the protected habitat (Table 1). Seven protozoan species (*Isospora* spp., *Blastocystis* spp., *Entamoeba histolytica*, *Sarcocystis cruzi, Balantidium coli*, *Cryptosporidium* spp., and *Giardia canis*) were also recovered from coyote fecal samples found in the protected habitat (Table 1).

Nine helminth species, all of which are very common enteric parasites of domestic dogs, were recovered from coyote fecal samples (n = 50) collected in urban habitat (Table 2). Helminth species consisted of three cestodes (*Diphyllobothrium latum*, *Dipylidium caninum*, and *Taenia* spp.), four nematodes (*Ancylostoma caninum*, *Trichurus vulpis*, *Toxocara canis*, and *Uncinaria stenocephala*), and two trematodes (*Alaria* spp. and *Paragonimus* spp.) (Table 2). Two protozoan species, *Balantidium coli* and *Blastocystis* spp., were also recovered from the urban habitat (Table 2).

Of the 40 scat samples collected from the protected habitat, 47.5% contained three or more parasite species, while only 4.0% of the 50 scat samples collected in the urban habitat contained three or more species (Figure 1). When infected with parasites (Figure 1; zero values excluded), coyote scat in the protected habitat had an average of 2.6

parasite species/scat and those in the urban habitat had an average of 1.4 species/scat. The mean number of parasite species per infected scat (zero values excluded) was significantly greater in the protected than in urban habitat ($t = 3.84$, $df = 49$, $P = 0.0003$) (JMP, v.5.1.2, SAS Institute Inc.).

In addition to the 2 x 19 chi-square analysis ($X^2 = 29$, $df = 18$, $P < 0.05$), a 2 x 2 chi-square analysis ($X^2 = 4$, $df = 1$, $P < 0.05$) was also conducted with all expected values less than 5 combined. Both analyses indicated that the enteric parasite species that infect coyotes in the protected habitat do differ significantly from those parasite species that infect urban coyotes. Therefore, the null hypothesis that enteric parasites of coyotes in the protected and urban habitat would not differ significantly was rejected.

During the course of this study 19 different parasite species were recovered from coyote feces collected from protected and urban habitats. Only 9 parasite species that were found in the protected habitat were also found in fecal samples collected from the urban habitat. The fecal samples collected in the protected habitat contained eight parasite species that were not documented in fecal samples from the urban habitat. Two parasite species (*Taenia* spp. and *Alaria* spp.), both of which infect domestic dogs and have been previously documented for Florida coyotes, were recovered from fecal samples collected in the urban habitat that were not recovered from fecal samples collected in the protected habitat.

Of the parasites found in both habitats, two (*B. coli* and *Blastocystis* spp.) were novel to *C. latrans* (Table 3 and Figure 2) and five (*D. latum*, *D. caninum*, *T. canis*, *U. stenocephala*, and *Paragonimus* spp.) were novel to Florida coyotes (Table 4). Therefore, the null hypothesis that all enteric parasites in Florida coyotes will have been previously documented was rejected. Only two (*A. caninum* and *T. vulpis*) of the parasites found in both habitats had previously been documented in Florida coyotes (Table 5).

Three parasites found only in the protected habitat (*Hymenolepis* spp., *Ascaris* spp., and *E. histolytica*) were novel to *C. latrans* (Table 3 and Figure 2), four (*Cryptosporidium* spp., *G. canis*, *Isospora* spp., and *S. cruzi*) were novel to Florida coyotes (Table 4), and one (*Physaloptera* spp.) had been previously documented in Florida coyotes (Table 5).

Table 1. Parasites recovered from fecal samples of coyotes in the protected habitat (n=40).

	%	n
Cestoda		
Diphyllobothrium latum [2]	13	5
Dipylidium caninum [2]	5	2
Hymenolepis spp.[1]	8	3
Nematoda		
Ancylostoma caninum	20	8
Ascaris spp.[1]	20	8
Physaloptera spp.	5	2
Toxocara canis [2]	3	1
Trichurus vulpis	3	1
Uncinaria stenocephala [2]	3	1
Trematoda		
Paragonimus spp.[2]	13	5
Protozoa		
Balantidium coli [1]	15	6
Blastocystis spp.[1]	25	10
Cryptosporidium spp.[2]	13	5
Entamoeba histolytica [1]	23	9
Giardia canis [2]	8	3
Isospora spp.[2]	35	14
Sarcocystis cruzi [2]	20	8

[1] Novel parasites in *Canis latrans*

[2] Novel parasites in Florida coyotes

Table 2. Parasites recovered from fecal samples of coyotes in urban habitats (n=50).

	%	n
Cestoda		
Diphyllobothrium latum[2]	4	2
Dipylidium caninum[2]	4	2
Taenia spp.	4	2
Nematoda		
Ancylostoma caninum	24	12
Toxocara canis[2]	2	1
Trichurus vulpis	10	5
Uncinaria stenocephala[2]	2	1
Trematoda		
Alaria spp.	2	1
Paragonimus spp.[2]	2	1
Protozoa		
Balantidium coli[1]	4	2
Blastocystis spp.[1]	4	2

[1] Novel parasites in *Canis latrans*

[2] Novel parasites in Florida coyotes

Table 3. Novel parasite species of *C. latrans* found during the course of this study and the habitat they were found in. The table shows which habitat type (protected and/or urban) the coyote fecal samples were collected from.

Novel parasite species for *Canis latrans*	**Protected Habitat**	**Urban Habitat**
Cestoda		
Hymenolepis spp.	Yes	
Nematoda		
Ascaris spp.	Yes	
Protozoa		
Balantidium coli	Yes	Yes
Blastocystis spp.	Yes	Yes
Entamoeba histolytica	Yes	

Table 4. Novel parasite species of Florida coyotes found during the course of this study and the habitat they were found in. The table shows which habitat type (protected and/or urban) the coyote fecal samples were collected from.

Novel parasite species for Florida coyotes	Protected Habitat	Urban Habitat
Cestoda		
Diphyllobothrium latum	Yes	Yes
Dipylidium caninum	Yes	Yes
Nematoda		
Toxocara canis	Yes	Yes
Uncinaria stenocephala	Yes	Yes
Trematoda		
Paragonimus spp.	Yes	Yes
Protozoa		
Cryptosporidium spp.	Yes	
Giardia canis	Yes	
Isospora spp.	Yes	
Sarcocystis cruzi	Yes	

Table 5. Previously documented parasite species of Florida coyotes found during the course of this study and the habitat they were found in. The table shows which habitat type (protected and/or urban) the coyote fecal samples were collected from.

Previously documented for Florida coyotes	**Protected Habitat**	**Urban Habitat**	**Domestic Dog**
Cestoda			
Taenia spp.		Yes	Yes
Nematoda			
Ancylostoma caninum	Yes	Yes	Yes
Physaloptera spp.	Yes		Yes
Trichurus vulpis	Yes	Yes	Yes
Trematoda			
Alaria spp.		Yes	Yes

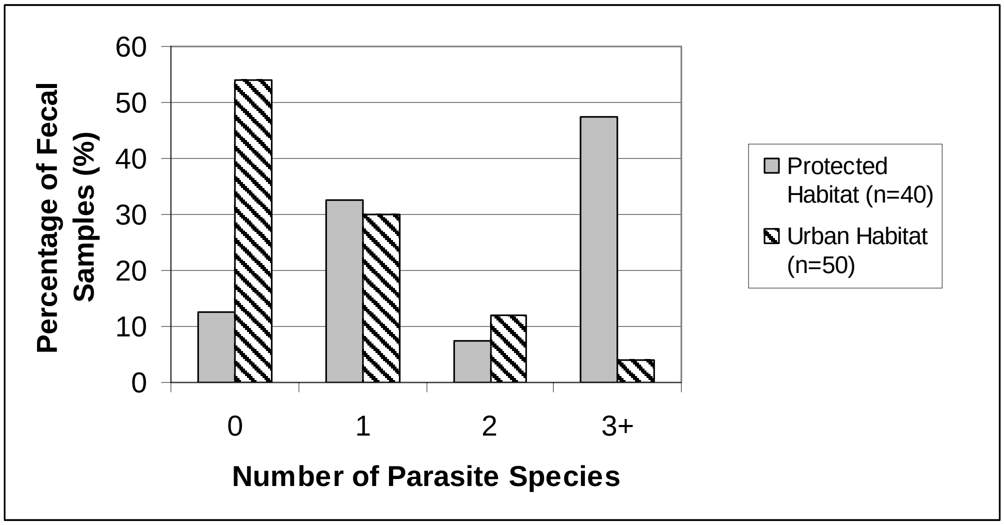

Figure 1. Distribution of the number of enteric parasite species identified per coyote fecal sample collected. Coyote scat collected in the protected habitat had an average of 2.6 parasite species/scat (zero values excluded) while scat collected in the urban habitat had an average of 1.4 parasite species/scat (zero values excluded).

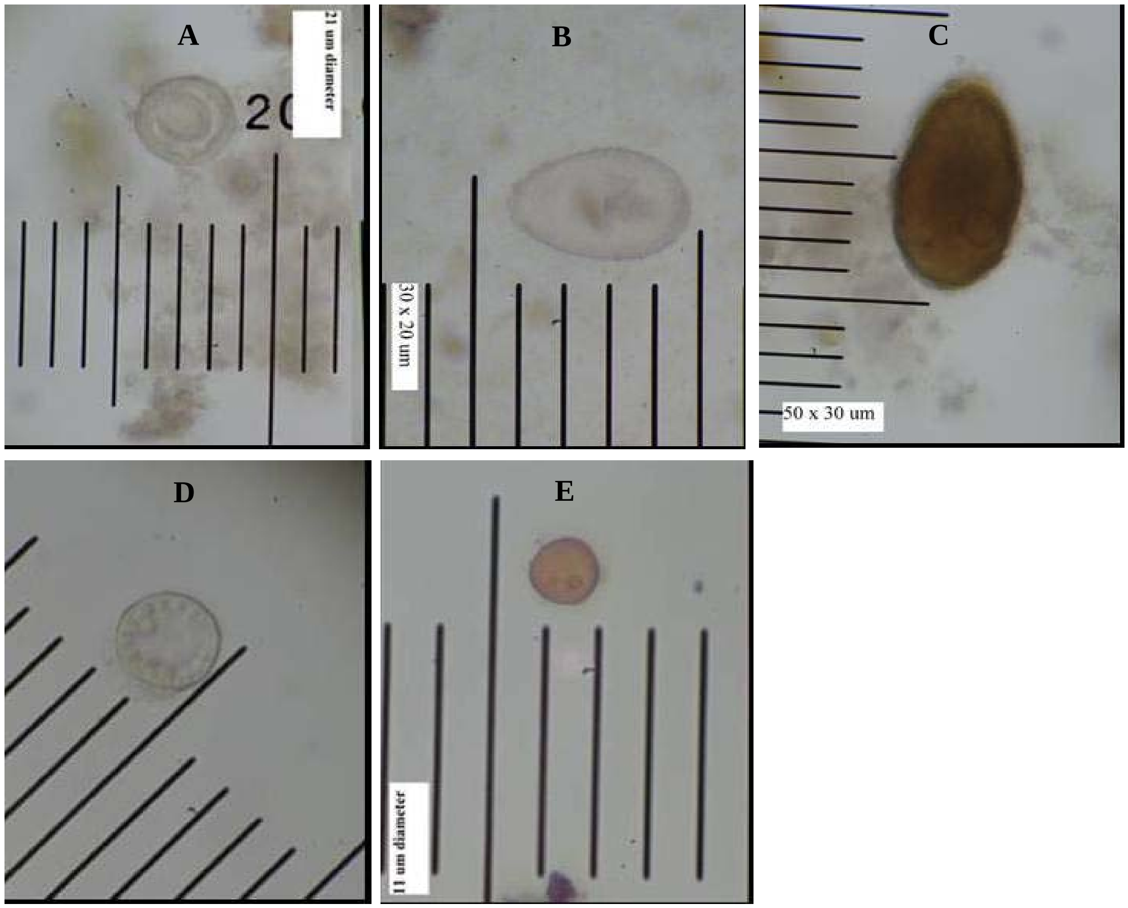

Figure 2. Novel parasites of *Canis latrans*. (A) *Hymenolepis* spp. (B) *Ascaris* spp. (C) *Balantidium coli* (D) *Blastocystis* spp. (E) *Entamoeba histolytica*

DISCUSSION

Enteric Parasites of Florida Coyotes in a Protected Habitat

All novel parasite species documented during the course of this study for *C. latrans* and for Florida coyotes were discovered in coyote fecal samples collected in the protected habitat. Additionally, protozoa were recovered more often from fecal samples collected from the protected habitat as opposed to those collected from the urban habitats. This is probably due to the fact that the protected habitat was a seasonal wetland and protozoa are easily transmitted through water.

While some coyote fecal samples collected in the protected habitat were infected with helminths, protozoa infected them the most. The protozoa *Isospora* spp., *Blastocystis* spp., and *Entamoeba histolytica* were found in 35%, 25%, and 23%, respectively, of the samples collected from the protected habitat. No other parasites were recovered more often from fecal samples collected from the protected habitat.

While it is unknown, due to the current discovery of these novel parasitic infections of coyotes, what effect *Blastocystis* spp. and *Entamoeba histolytica* have on coyotes, it has been well documented that *Isospora* spp. infect coyotes. Coyotes from across the United States have been known to be infected with *Isospora* spp. For example, coyotes in Oregon (Dunbar and Giordano, 2003), Utah (Conder and Loveless, 1978), Colorado (Arther and Post, 1977), Texas (Thornton et al., 1974), and New York (Gompper et al., 2003) have been documented as being infected with *Isospora* spp.

Isospora spp. was found in 35% of the scat collected from Florida coyotes in protected habitat and from scat samples collected from coyotes in New York (Gompper et al., 2003), but only 3% of the scat samples collected during a study of coyotes in Colorado (Arther and Post, 1977) were infected. Based on necropsies of coyotes in Utah (Conder and Loveless, 1978) and Texas (Thornton et al., 1974), *Isospora* spp. infected 18% and 66%, respectively, of the animals examined.

Even though *Sarcocystis* spp. has not previously been documented for coyotes in Florida, it has been documented in coyotes in other states (Dunbar and Giordano, 2003). Coyotes are also known to be definitive hosts of the parasite (Dubey et al., 1989). Due to the current findings of *Sarcocystis* spp. in fecal samples collected from the protected habitat, the parasite has been listed as a novel parasite of Florida coyotes. Twenty percent of the fecal samples collected from Florida coyotes were infected with *Sarcocystis cruzi*. Likewise, 20% of the fecal samples collected from coyotes in Colorado were infected with *Sarcocystis cruzi* (Arther and Post, 1977). Results of *Sarcocystis* spp. (via fecal examination) from studies conducted on coyotes in Utah, Idaho, and New York are similar to those of the present study of Florida coyotes. Fourteen percent of the fecal samples collected from coyotes in Utah and Idaho were found to be infected with *Sarcocystis* spp. (Fayer and Johnson, 1975) and 27% of the fecal samples collected from coyotes in New York were infected with *Sarcocystis* spp. (Gompper et al., 2003). Necropsies preformed on coyotes in Georgia (Holzman et al., 1992) and Oklahoma (Cummings et al., 2000) showed that of the animals examined, 6% and 4%, respectively, were infected with *Sarcocystis* spp.

Water is a major vehicle for transmission of *Cryptosporidium* and the infective or viable stage of this parasite is prolonged in moist environments (Fayer, 2004). Thus, it is not surprising that 13% of the coyote fecal samples collected in the protected habitat, which supports a large number of seasonal wetlands, contained *Cryptosporidium*, while samples collected from the urban habitat did not. *Cryptosporidium* is of zoonotic importance due to outbreaks in drinking water and recreational water (Fayer, 2004). According to MacKenzie et al. (1994), the "defining recognition" of *Cryptosporidium* as a public health concern occurred in Milwaukee, Wisconsin in 1993, when the largest water-borne disease outbreak ever recorded occurred in the public drinking water supply and approximately 403,000 people contracted cryptosporidiosis.

Giardia is also of zoonotic importance because it is known to infect humans and cause disease. *Giardia* was first documented to infect coyotes in 2003 (Santin et al., 2003), when it was discovered that coyotes can serve as a reservoir for the parasite. Later that year, Gompper et al. (2003) discovered *Giardia* in 15% of the fecal samples collected from coyotes in New York. During the present study, *Giardia* was recovered in 8% of the fecal samples collected from the protected habitat.

Enteric Parasites of Florida Coyotes in Urban Habitat

While protozoa did comprise of some of the enteric parasites that infected coyotes in urban habitats, it was the helminth species that infected them the most. Helminth species, all of which were very common enteric parasites of domestic dogs, were recovered most often from coyote scat samples collected in the urban habitat. Thus, it is presumed that coyotes in the urban habitat could have received these parasites from infected domestic dogs. During the present study, protozoa may not have survived as long in the environment as helminths. Therefore, recovery and identification of protozoa in the urban habitat may have been limited.

Parasites may limit coyote population growth in a density-dependent way. *Ancylostoma caninum*, the common dog hookworm, for example, has been suggested as a regulator of coyote populations via increased neonatal mortality (Pence et al., 1988). Twenty-four percent of all fecal samples collected from the urban habitat were infected with *A. caninum*. No other parasite was found more frequently in the urban habitat. Additionally, twenty percent of the samples collected from the protected habitat were infected with *A. caninum*. Approximately 20% of the coyotes examined during a study in Kansas were infected with *A. caninum* (Ameel, 1955). In our study, the only other parasites found more often in the protected habitat were *Isospora* spp. (35% of the samples were infected), *Blastocystis* spp. (25% of the samples were infected), and *E. histolytica* (23% of the samples were infected), all three of which are protozoa.

The fact that dog hookworms were the most prevalent enteric parasites of coyotes in the urban habitat is very important for future densities of urban coyotes in Pinellas County and is of zoonotic importance. According to Radomski (1989), a threshold level of only >300 hookworm larvae/kg was needed to cause mortality in coyote neonates. Thus, a study on hookworm densities within coyotes of Pinellas County would give further insight into the health of urban coyotes and provide insight into the viability of their populations. *Ancylostoma caninum* is of zoonotic importance as well because infective stages of this hookworm can penetrate human skin causing cutaneous larva migrans (Traub et al., 2005). Thus, preventative measures that hinder transmission of parasites between coyote populations, domestic animals, and humans should be taken (Erickson, 1944; Traub et al., 2005).

Coyote fecal samples collected from the protected habitat had, on average, more parasite species per sample than those samples collected from the urban habitat. These averages, especially those of the protected habitat, are similar to those found in a study conducted by Holmes and Podesta (1968) in Canada. During their study of helminths, Holmes and Podesta (1968) found that the average number of parasites that infected coyotes in Canada was 2.0 parasite species per coyote. Increased numbers of enteric parasites weakens the condition of the intestines. This is important because pathogenic activities of parasites depend primarily upon the resistance of the host and the condition of the intestinal tract (Brown, 1975). Additionally, the ability of a host to acquire resistance to a parasite depends on immunity, nutritional state, and the condition of the intestinal tract within that host (Brown, 1975). While immunity can be built up, severe and prolonged exertion breaks down acquired immunity and renders the animal susceptible to reinfection (Olsen, 1974).

Novel Parasites of Canis latrans

Newly established coyotes in Florida would be expected to lack resistance to novel parasites due to recent exposure. In addition, rapid habitat loss in Florida, mainly due to urbanization, lowers survival of adult coyotes and increases the probability of transmission of disease between wild and domestic canids (Grinder and Krausman, 2001). It is suggested that Florida coyotes are more susceptible to reinfection by novel parasites because of their rapid range expansion and lack of acquired immunity. This is of importance for the species because the overall health of coyote populations declines when heavy parasitic infections occur (Belden and Kiesecker, 2005).

During the course of this study, five novel enteric parasite species were discovered which, to my knowledge, have not been previously documented in *Canis latrans*. Of these, one cestode (*Hymenolepis* spp.), one nematode (*Ascaris* spp.), and three protozoa (*Balantidium coli*, *Blastocystis* spp., and *Entamoeba histolytica*) were recovered, some of which are potentially pathogenic to humans (Abe et al., 2002). Biomolecular studies would need to be conducted on *Hymenolepis* spp., *Ascaris* spp., and *Blastocystis* spp. to determine which species were present. All of the novel parasites documented in this study for *C. latrans* were discovered in fecal samples collected from coyotes in the protected habitat. Two of these, *Balantidium coli* and *Blastocystis* spp. were also discovered in fecal samples collected from coyotes in the urban habitat.

Blastocystis has been reported in fecal matter of domestic dogs (*Canis familiaris*) and cats (*Felis cattus*) (Duda et al., 1998) as well as in cattle (*Bos taurus*), pigs (*Sus domestica*), and zoo animals (Abe et al., 2002). While *Hymenolepis* has more recently been documented in domestic dogs (Traub et al., 2005), it has been well known that *Entamoeba* (Jordan, 1967; Northway, 1975; and Wittnich, 1976), *Ascaris* (Traub et al., 2005), and *Balantidium* (Dikmans, 1948; Das, 1999) infect them.

Infection by all novel parasites of *C. latrans* discovered during the present study occurs through passive transmission (i.e., neither parasite nor host takes an active role in transmission) from contaminated sources, including soil and water. Additionally, autoinfection (i.e., proglottid disintegrates in the intestine reinfecting the host) can occur with *Hymenolepis* (Price, 1994).

While human infections of *Balantidium coli* are rare, *Ascaris*, *Blastocystis*, *Entamoeba*, and *Hymenolepis* are of zoonotic importance. *Ascaris* spp. is a very common nematode of animals and humans throughout the world, but rarely results in death. Originally, *Blastocystis* spp. was considered a nonpathogenic yeast, but in 1967, it was reclassified as a protozoan (Zierdt et al., 1967) and today it is known to be pathogenic to humans. *Blastocystis* spp. is frequently found in the intestinal tracts of humans (Price, 1994), causing diarrhea in immunosuppressed individuals (Zierdt, 1991), and reports of infection continue to increase. *Blastocystis* spp. and *Entamoeba* spp. are two of the few amoebas to infect humans (Price, 1994). *Entamoeba* spp. is ranked as an important parasite of humans due to its wide distribution and pathogenic properties (Olsen, 1974). While each parasite is cosmopolitan, *Entamoeba* spp. is more commonly found in warm, moist climates (Olsen, 1974). Infection by the tapeworm *Hymenolepis* spp. occurs through consumption of contaminated sources. Intermediate hosts are not required for certain species of *Hymenolepis*, but others utilize rodents, fleas (*Ctenocephalides* spp.), or cockroaches (*Periplaneta* spp.) (Price, 1994).

Novel Parasites of Florida Coyotes

In addition to the five novel enteric parasites discovered for *C. latrans*, nine enteric parasite species were discovered during the present study which have not previously been documented for Florida coyotes, but have been documented for coyotes in other states.

Of the novel parasites discovered for Florida coyotes, two cestodes (*D. latum* and *D. caninum*) were found in both the protected and urban habitats. During the present study, 13% of the fecal samples collected from the protected habitat were infected with *D. latum* while only 4% of the samples collected from the urban habitat were infected. Five percent (5%) of the coyotes examined by Holmes and Podesta (1968) in Alberta, Canada were infected with *Diphyllobothrium* spp. *Dipylidium caninum* has been known to infect coyotes (Ameel, 1955; Butler and Grundmann, 1954), dogs, and humans throughout the United States. While *D. caninum* is referred to as the "dog tapeworm," human infection can occur when the intermediate host (usually a flea) is consumed (Brown, 1975).

Two nematodes (*T. canis* and *U. stenocephala*) novel to Florida coyotes were discovered in both the protected and urban habitats during the present study. *T. canis* recorded in the present study for Florida coyotes in protected (3%) and urban (2%) habitats is similar to that recorded for coyotes in New York (2%; Gompper et al., 2003) and Canada (1%; Holmes and Podesta, 1968), but lower than that recorded for coyotes in Utah (6%; Conder and Loveless, 1978). In the present study, *U. stenocephala* infections of Florida coyotes in protected (3%) and urban (2%) habitats are lower than those documented for coyotes in Montana (18%; Seesee et al., 1983), Canada (16%; Holmes and Podesta, 1968), and New York (6%; Gompper et al., 2003). While the effect of these parasites on Florida coyotes is not definitively known, it is presumed that they will not routinely be pathogenic to Florida coyotes. Additionally, *Uncinaria* infections in other carnivores are usually less severe than those of the dog hookworm (*Ancylostoma caninum*) (Bowman, 1999).

Paragonimus spp. is the only trematode documented in this study that is novel for Florida coyotes. Florida coyote scat collected from the protected and urban habitats were infected with this trematode. While *Paragonimus* spp. has been reported in fox (Bekoff, 1978), dogs (Bekoff, 1978), and coyotes outside of Florida, documentation of these parasites discovered via fecal examination is limited due to the location of the parasite within the host's body. *Paragonimus* spp. is a fluke that resides in the lungs of the infected animal (Brown, 1975). Detection of *Paragonimus* spp. in fecal samples would only result from the host swallowing parasite eggs (i.e., swallowing sputum) (Brown, 1975).

Conclusion

While this study has likely identified the majority of enteric parasites that infect Florida coyotes, there were significant differences in species composition of enteric parasites of coyotes between study locations. Some parasite species were recovered from both habitat types, but overall more protozoa were documented in the protected habitat (probably due to it being a seasonal wetland) and more helminths in the urban. Additionally, all of the helminths documented in the urban habitat are common parasites of domestic dogs. Another significant difference between study locations was the number of novel parasite species recovered. More novel parasite species were recovered from the protected habitat while more parasite species known to commonly infect domestic animals were found in the urban habitat.

My previous prediction that parasites recovered from the urban coyote scat samples would contain more parasites commonly found in domestic animals was supported by the findings that all of the helminths documented in coyotes in the urban habitat are common parasites of domestic animals. Therefore, it is presumed that coyotes in the urban habitat received these parasites from infected domestic dogs. Additionally, from a wildlife management perspective, domestic animals should not be allowed in nature preserves due to the heightened risk of wildlife becoming infected with parasites known to infect domestic animals. Pets could introduce new parasites into the protected area resulting in wildlife (i.e., coyotes) becoming infected.

While this study has shown that previous studies of coyotes from other geographical locations do apply to Florida coyotes, it has also documented novel parasites of the coyote in Florida. Optimum temperatures for helminths are 27 – 34^{o}C and with Florida being closer to the tropics, these temperatures are available throughout most of the year. Additionally, biodiversity of parasite species increases near the tropics. Therefore, the vast differences in climate, flora and fauna found in Florida, as opposed to other states, could be partly responsible for the recent discovery of these novel infections in the coyote.

Implications

One example of a preventative method that would hinder transmission of parasites between coyote populations, domestic animals, and humans is for pet owners to be more aware of their pet's behavior while in public areas. Specifically, pet owners should prevent their pet from coming into contact with feces previously deposited in urban areas. When infected canids (domestic dogs or coyotes) defecate in areas visited by domestic dogs, it is possible that dogs could become infected if they consume viable parasites. Thus, not allowing pets to come into contact with infected feces would help prevent infection.

Another preventative method that pet owners can take is to remove pet feces from urban/public areas. Removal of pet feces would result in fewer viable hookworms being present in these urban habitats. In theory, this could result in fewer coyotes being infected. Assuming that proper veterinary care (i.e., yearly fecal exams) is given to domestic animals, the severity of enteric parasite infections would be minimal. Conversely, coyotes do not receive such care. Thus, infection would pose a greater threat to their health.

A third example of a preventative method that humans should take is to perform sanitary behavior, such as frequent hand washing, especially for children. Parasites documented in this study remain viable outside of the host while in water and soil. Humans can also become infected with these enteric parasites if they consume viable parasites or drink contaminated water (Rubel and Wisnivesky, 2005). Children, due to their close contact with soil are more susceptible to infection.

These methods are especially critical due to the rapid disappearance of wild habitats. Areas frequented by wild canids, domestic canids, and humans overlap when dense human populations and vast urbanization are present, as is the case in Pinellas County, Florida (Canon et al., 2004). Hence, boundaries between wildlife and domestic animals become obscured and the risk of transmission of diseases increases (Tigas et al., 2002).

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CHAPTER TWO: A COMPARATIVE STUDY BETWEEN THE DIET OF COYOTES IN A PROTECTED AND URBAN HABITAT

INTRODUCTION

Diet is an important aspect of understanding the ecology of the coyote (*Canis latrans*). Different factors affect coyote reproduction such as the amount of available food and the degree of human exploitation (Windberg et al., 1997). As such, coyotes are very opportunistic and adaptable when it comes to meeting their nutritional needs (Stratman and Pelton, 1997). A coyote's diet is reflective of the habitat it utilizes and varies across geographical expanse. Previous research on the diet of coyotes has occurred throughout the United States (Wooding et al., 1984; Lee and Kennedy, 1986; Crossett and Elliott, 1991; Bartel and Knowlton, 2005). Most of the studies on the diet of coyotes have occurred in rural habitat (Lingle et al., 2005; Prugh, 2005; Azevedo et al., 2006). Relatively few studies have been conducted to determine the diet of coyotes in sub-urban habitats (MacCracken, 1982; Fedriani et al., 2001) or urban habitats (Quinn, 1997; Grinder and Krausman, 2001). Even fewer studies have been conducted on coyotes in Florida, a state with rapidly changing habitats (i.e., drastic urbanization). Wagner and Hill (1994) conducted a study of the diet of coyotes in four different states (Florida, Alabama, Mississippi, and Arkansas), but only evaluated the effect of coyotes on wild turkey (*Meleagris gallopavo*). Stratman and Pleton (1997) and Thornton et al. (2004) also conducted studies on the diet of Florida coyotes but these studies were conducted on military facilities in northwest and south-central Florida, respectively. This current study compares the diet of Florida coyotes in the most densely populated county in Florida, Pinellas County (USCB, 2004).

Coyotes are scavengers (Arjo et al., 2002) and opportunistic omnivores (Blanton and Hill, 1989). As such, they have a wide spectrum of dietary items they consume. It is important to study these animals throughout different geographical locations to document the great variety of food items consumed. Not only do coyote diets vary across their geographical range, but also seasonally. Lee and Kennedy (1986) conducted a study in Tennessee and found seasonal variation in coyote diet for rodents, insects, reptiles, amphibians, opossum (*Didelphis virginiana*), and persimmon (*Diospyros virginiana*). Wooding et al. (1984) found that livestock detection in coyote diet was highest in winter and spring in Mississippi and Alabama, while white-tailed deer (*Odocoileus virginianus*) remains were more frequent during the summer and winter.

Coyote diet varies across rural, sub-urban, and urban gradients as well. Fedriani et al. (2001) found that in the most urban area of their California study, anthropogenic foods comprised 25% of the coyote diet during the dry season and 14% during the wet. In contrast, they found that in the rural areas, anthropogenic foods accounted for 3% of their diet during the dry season and only trace amounts were detected during the wet season (Fedriani et al., 2001).

Coyotes are relatively new to Florida and little research has been conducted to determine their diet in this region of the country. In 1994, Wagner and Hill found wild turkey remains in only two scat samples from coyotes in Florida. Stratman and Pelton (1997) also conducted a diet study by collecting and analyzing the diet remains in scat samples and found that important diet items for coyotes in northwestern Florida were shrub/vine fruit (80%), beetles (55%), persimmon (27%), and white-tailed deer (15%). Deer occurred most often (29%) during the fawning season. Wild hog (*Sus scrofa*; 13%) was only recovered during the spring. Thornton et al. (2004) found that the majority of diet (via scat analysis) of coyotes in south-central Florida consisted of white-tailed deer, wild hog, and domestic cow (*Bos taurus*). Contrary to Stratman and Pelton's 1997 study, Thornton et al. (2004) recovered wild hog during every season. Also, coyotes observed in Stratman and Pelton's (1997) study consumed fruit more often than those in Thornton's (2004) study (80% vs. 24.5%).

The present study focuses on two aspects of coyote diet: diet diversity, defined as the different types of diet items consumed, and seasonal variation (wet season vs. dry season) in diet. The primary objective of this study was to investigate differences in diet between a protected and urban population of coyotes. More specifically, this study was designed in order to answer the following questions: Which habitat within this study (protected or urban) has higher diet diversity? Does the composition of diet items differ between protected and urban habitats? Does habitat type (protected or urban) and/or season (wet or dry) affect whether or not coyotes consume anthropogenic waste (as determined by presence/absence of anthropogenic waste in scat sample)? Does season (wet or dry) affect coyote diet in the protected and/or urban habitats?

Diet diversity:

Null hypothesis: Diet items consumed by coyotes in the protected habitat will not differ significantly from those diet items consumed in the urban habitats.

Alternate hypothesis: Diet items consumed by coyotes in the protected habitat will differ significantly from those diet items consumed in the urban habitats.

It is predicted that diet items consumed by coyotes in the protected habitat will differ significantly from those in the urban habitat. More specifically, coyotes in the protected habitat are expected to consume a wider variety of diet items as opposed to those in the urban habitat, which are expected to have a less varied diet, eating more of the same items consistently. This assumption is based on the protected habitat offering more variation in the types of diet items that coyotes could consume (i.e., more wildlife).

Seasonal variation in diet:

Null hypothesis: Coyote diet in protected and urban habitats will not differ significantly between seasons.

Alternate hypothesis: Coyote diet in protected and urban habitats will differ significantly between seasons.

It is predicted that seasonal variation (wet season vs. dry season) will affect the diet of coyotes in both habitats (protected and urban) due to changes in available diet items.

STUDY SITES

Pinellas County is the most densely populated county in Florida with over 1281 people per square kilometer (USCB, 2004). Two types of habitat were compared during this study: protected and urban.

Protected Habitat

Brooker Creek Preserve (BCP; 27^{o}54' N, 82^{o}41'W) was used for the protected habitat (Bean et al., 2005). BCP is an 8500 acre wilderness area that is actively managed for natural resource protection. Located in the northeast corner of the county, the boundaries of BCP are shared with densely populated residential areas. The study site consists of extensive pine flatwoods and freshwater swamps. Fauna include white-tailed deer (*Odocoileus virginianus*), raccoons (*Procyon lotor*), armadillo (*Dasypus novemcinctus*), bobcat (*Lynx rufus*), otter (*Lutra canadensis*), wild turkey (*Meleagris gallopavo*), red-shouldered hawks (*Buteo lineatus*), wood storks (*Mycteria americana*), bobwhite quail (*Colinus virginianus*), and gopher tortoise (*Gopherus polyphemus*).

Urban Habitat

Different sites throughout Pinellas County were used for urban habitat. Sites were determined using GIS (ArcGIS v.8) to plot existing geospatial information including land-use categories, railroads, bike trails, and power lines throughout the county. Subsequently, a map revealing rural, sub-urban, and urban areas based on residential (land-use category) population density was generated. Sites were identified based on criteria expected to support urban coyotes. The sites were constrained such that they had land cover of urban sites similar to that of BCP, were traversed by power lines, bike trails, or inactive railroads, and were located in urban areas. The wet season at both sites was defined as June 1 through October 31 and the dry season as November 1 through May 31 (Chen and Gerber, 1990).

METHODS

Field Methods

Fresh coyote feces were collected over the course of two years (May 2005 thru March 2007) from trails, power lines, and bike trails in the protected (n=49) and urban (n=71) habitats. Paths were traversed on foot, bicycle, and by ATV three times a week during the course of this study. Each fecal sample was measured (length and diameter) and photographed in the field. Species origin of the fecal samples was determined by adjacent sign (tracks) and dimensions of feces. Upon confirmation of coyote scat, the sample was assigned a unique identification code and its longitude and latitude were recorded by use of a GPS unit. Finally, the sample was placed in its own paper bag. To avoid collecting bobcat feces, only those samples in excess of one inch in diameter were collected (Gompper et al., 2003). To avoid collecting domestic dog feces, only samples which contained hair and bone fragments and/or which were accompanied by coyote tracks were collected (Wooding et al., 1984).

Laboratory Methods

Prey of the Florida coyote were identified to the lowest possible taxonomic category based on bone, teeth, nails, and hair that were recovered from each sample. After removing approximately 4 grams of the sample for parasite examination, the remaining sample was oven dried at 60–80^{o}C for at least 48h to kill any latent parasites

(Wagner and Hill, 1994). After desiccation, each sample was individually placed in the top of a combination of wire mesh sieves (Stratman and Pelton, 1997) and washed thoroughly with a garden spray hose attached to a sink faucet. The remaining diet items were then transferred from each sieve onto paper plates and allowed to dry overnight. After the contents on each paper plate (one for each sieve) were thoroughly dry, the remains were separated into the following categories: hair, bones, teeth, nails, feathers, reptile, insects, vegetative matter, berries, anthropogenic waste (i.e., trash, rope, plastic wrappers) and unknown. Dorsal guard hair was then separated based on gross morphological characteristics (i.e. color, color bands, and color band locations) and slides were made for prey identification. Hairs were identified based on gross morphological characteristics and medullary configurations (Wilkins et al., 1982). To aid in identification, hair, bones, teeth, and nails were compared with specimens housed at the Florida Museum of Natural History in Gainesville (Thornton et al., 2004).

Statistical Methods

Diet items were recorded and the percentage of coyote scat samples containing each item was determined. A Poisson regression, with the total number of diet items as the response variable, was utilized to determine the relation between diet items and habitat (H), season (S), and interaction (H*S) because the variable "diet items" is count data and follows a Poisson distribution. In order to determine if presence or absence of anthropogenic waste in coyote feces was in relation to habitat (H), season (S), or an interaction (H*S), a logistic regression was utilized because the diet item "Anthropogenic Waste" is a Bernoulli variable and follows a binomial distribution. Thus, a logistic regression was used to examine what effect, if any, H, S, or H*S had on coyotes consuming anthropogenic waste. In both the Poisson regression and the logistic regression, the habitat (H) response was controlled for the effects of season (S).

RESULTS

Forty-nine fecal samples were collected from the protected habitat and were used to determine the diet of coyotes in this habitat. Diet items recovered most often from coyotes in the protected habitat were vegetative matter (96%), Insecta (53%), Rodentia (*Sciurus carolinensis*, *S. niger shermanii*, *Sigmodon hispidus*, and *Geomys pinetis*) (45%), Cervidae (*Odocoileus virginianus*) (33%), berries (31%), and Lagomorpha (*Sylvilagus* spp.) (29%) (Table 1). Among all diet items, Aves (12%), anthropogenic waste (8%), Testudines (4%), and Felidae (2%) were recovered the least in the protected habitat (Table 1 and Figure 1).

In the urban habitat, 71 fecal samples were collected and were utilized to determine the diet of urban coyotes. The diet items recovered most often from urban coyote scat were berries (56%), Lagomorpha (32%), vegetative matter (25%), Rodentia (18%), and anthropogenic waste (18%; Table 2). In the urban habitat, Aves (7%), Insecta (4%), Didelphidae (*Didelphis virginiana*) (3%), Testudines (1%), Felidae (1%), and Procyonidae (1%) were recovered the least (Table 2 and Figure 1).

Analysis using a Poisson regression indicated that coyotes in the protected habitat had higher diet diversity than urban coyotes with a fitted regression of log(mean response) = 1.1386-0.6138H with a p-value = 0.0000. Thus, the diet of urban coyotes is less varied than that of coyotes in a protected habitat.

The logistic regression showed a very weak relationship between habitat and anthropogenic waste consumed by coyotes. The most significant term in the model was the interaction between habitat and season (H*S): logit(prob) = -2.0149+1.0594H*S with a p-value = 0.0821. Main effects of habitat was logit(prob) = -2.4204+0.9249H with a p-value = 0.1265. In the protected habitat, eight percent (8%) of the samples contained anthropogenic waste (Table 3). In comparison, eighteen percent (18%) of the samples collected from the urban habitat contained anthropogenic waste (Table 3).

While the Poisson regression showed that neither season (S) nor interaction (H*S) could be used to determine any changes in the number of diet items consumed by coyotes from either habitat, seasonal variation did affect the types of diet items consumed. In the protected habitat, Insecta and berries were found more frequently in the samples collected during the wet season while Lagomorpha, Rodentia, and Cervidae appeared more frequently during the dry season (Figure 2). It should also be noted that the only time Felidae was present in any of the collected samples from the protected habitat was during the wet season (Figure 2). Additionally, in the protected habitat, fawn *Odocoileus virginianus* were only consumed in the wet season while adult *O. virginianus* were only consumed in the dry season (Table 1 and Figure 3).

In the urban habitat, Didelphidae, Procyonidae, Felidae, Insecta, Aves, and Testudines were only recovered during the wet season (Figure 4). Berries and vegetative matter were recovered most often from the urban habitat during the wet season while Lagomorpha and anthropogenic waste were recovered most often during the dry season (Figure 4). During the wet season, 68% of the fecal samples collected from the urban habitats contained berries, but this number declined to 22% during the dry season (Table

2 and Figure 5). Conversely, during the wet season only 21% of the samples collected from the urban habitat contained *Sylvilagus* spp., but during the dry season this number rose to 67% (Table 2 and Figure 5).

When looking at seasonal variation among Florida coyotes (combining both protected and urban habitat data), season (wet vs. dry) affects consumption of certain diet items more than others. Overall, *Sylvilagus* spp., adult *O. virginianus*, and vegetative matter were recovered more often from fecal samples of Florida coyotes during the dry season while berries and fawn *O. virginianus* were recovered more often during the wet season (Figure 6). Additionally, when combining protected and urban habitat data to examine Florida coyote diet, vegetative matter (54%) and berries (46%) were recovered from more samples than any other diet item (Figure 7). The percentages of Florida coyote fecal samples containing Lagomorpha, Rodentia, and Insecta were 31%, 29%, and 24% respectively (Figure 7). Specifically, of the Rodentia recovered, *Sigmodon hispidus* was recovered most often from Florida coyote scat (Table 3).

Table 1. Diet items consumed by coyotes in protected habitat (n=49).

Diet Item:	Wet Season (n=27) %	n	Dry Season (n=22) %	n	TOTAL (n=49) %	n
Didelphidae	**0**	**0**	**0**	**0**	**0**	**0**
Didelphis virginiana	0	0	0	0	0	0
Lagomorpha	**22**	**6**	**36**	**8**	**29**	**14**
Sylvilagus spp.	22	6	36	8	29	14
Rodentia	**41**	**11**	**50**	**11**	**45**	**22**
Sciurus carolinensis	4	1	0	0	2	1
Sciurus niger shermanii	7	2	9	2	8	4
Sigmodon hispidus	30	8	36	8	33	16
Geomys pinetis	0	0	5	1	2	1
Cervidae	**30**	**8**	**36**	**8**	**33**	**16**
Odocoileus virginianus (fawn)	30	8	0	0	16	8
Odocoileus virginianus (adult)	0	0	36	8	16	8
Procyonidae	**0**	**0**	**0**	**0**	**0**	**0**
Procyon lotor	0	0	0	0	0	0
Felidae	**4**	**1**	**0**	**0**	**2**	**1**
Insecta	**63**	**17**	**41**	**9**	**53**	**26**
Vegetative Matter	**93**	**25**	**100**	**22**	**96**	**47**
Berries	**44**	**12**	**14**	**3**	**31**	**15**
Aves	**15**	**4**	**9**	**2**	**12**	**6**
Testudines	**4**	**1**	**5**	**1**	**4**	**2**
Anthropogenic Waste	**7**	**2**	**9**	**2**	**8**	**4**

Table 2. Diet items consumed by coyotes in urban habitats (n=71).

Diet Item:	Wet Season (n=53) %	n	Dry Season (n=18) %	n	TOTAL (n=71) %	n
Didelphidae	**4**	**2**	**0**	**0**	**3**	**2**
Didelphis virginiana	4	2	0	0	3	2
Lagomorpha	**21**	**11**	**67**	**12**	**32**	**23**
Sylvilagus spp.	21	11	67	12	32	23
Rodentia	**21**	**11**	**11**	**2**	**18**	**13**
Sciurus carolinensis	9	5	11	2	10	7
Sciurus niger shermanii	8	4	0	0	6	4
Sigmodon hispidus	4	2	0	0	3	2
Geomys pinetis	0	0	0	0	0	0
Cervidae	**0**	**0**	**0**	**0**	**0**	**0**
Odocoileus virginianus (fawn)	0	0	0	0	0	0
Odocoileus virginianus (adult)	0	0	0	0	0	0
Procyonidae	**2**	**1**	**0**	**0**	**1**	**1**
Procyon lotor	2	1	0	0	1	1
Felidae	**2**	**1**	**0**	**0**	**1**	**1**
Insecta	**6**	**3**	**0**	**0**	**4**	**3**
Vegetative Matter	**28**	**15**	**17**	**3**	**25**	**18**
Berries	**68**	**36**	**22**	**4**	**56**	**40**
Aves	**9**	**5**	**0**	**0**	**7**	**5**
Testudines	**2**	**1**	**0**	**0**	**1**	**1**
Anthropogenic Waste	**15**	**8**	**28**	**5**	**18**	**13**

Table 3. Diet items consumed by Florida coyotes (protected and urban habitats combined).

Diet Item:	Protected (n=49) %	Protected (n=49) n	Urban (n=71) %	Urban (n=71) n	Combined (P+U) (n=120) %	Combined (P+U) (n=120) n
Didelphidae	**0**	**0**	**3**	**2**	**2**	**2**
Didelphis virginiana	0	0	3	2	2	2
Lagomorpha	**29**	**14**	**32**	**23**	**31**	**37**
Sylvilagus spp.	29	14	32	23	31	37
Rodentia	**45**	**22**	**18**	**13**	**29**	**35**
Sciurus carolinensis	2	1	10	7	7	8
Sciurus niger shermanii	8	4	6	4	7	8
Sigmodon hispidus	33	16	3	2	15	18
Geomys pinetis	2	1	0	0	1	1
Cervidae	**33**	**16**	**0**	**0**	**13**	**16**
Odocoileus virginianus	33	16	0	0	13	16
Procyonidae	**0**	**0**	**1**	**1**	**1**	**1**
Procyon lotor	0	0	1	1	1	1
Felidae	**2**	**1**	**1**	**1**	**2**	**2**
Insecta	**53**	**26**	**4**	**3**	**24**	**29**
Vegetative Matter	**96**	**47**	**25**	**18**	**54**	**65**
Berries	**31**	**15**	**56**	**40**	**46**	**55**
Aves	**12**	**6**	**7**	**5**	**9**	**11**
Testudines	**4**	**2**	**1**	**1**	**3**	**3**
Anthropogenic Waste	**8**	**4**	**18**	**13**	**14**	**17**

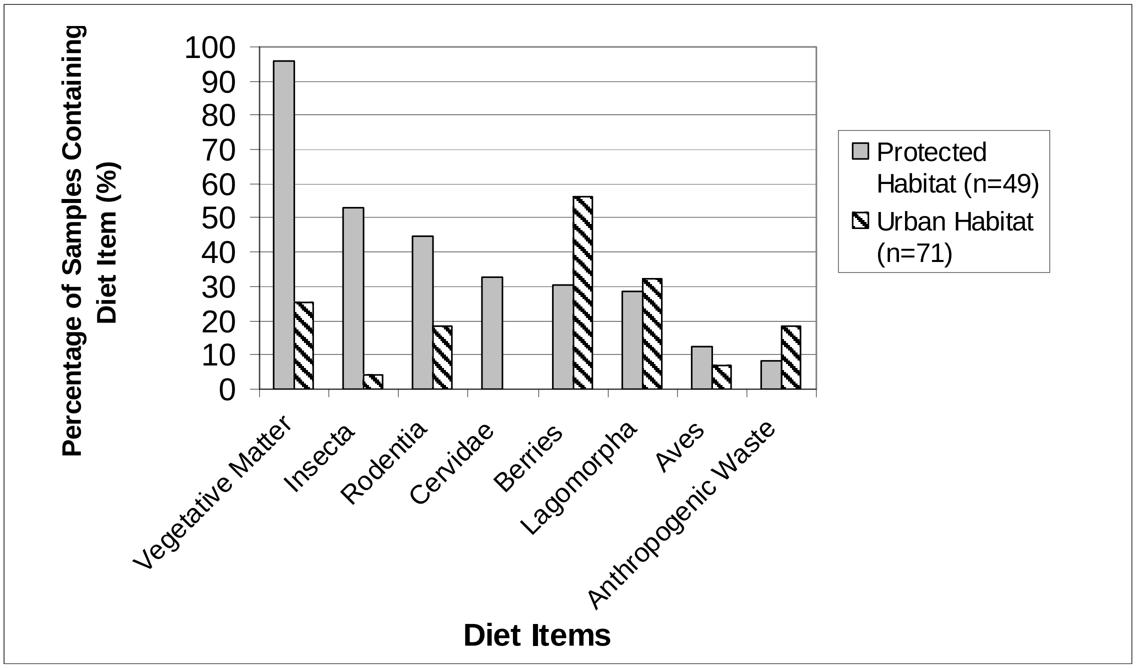

Figure 1. Comparison of diet items consumed between coyotes in protected and urban habitats.

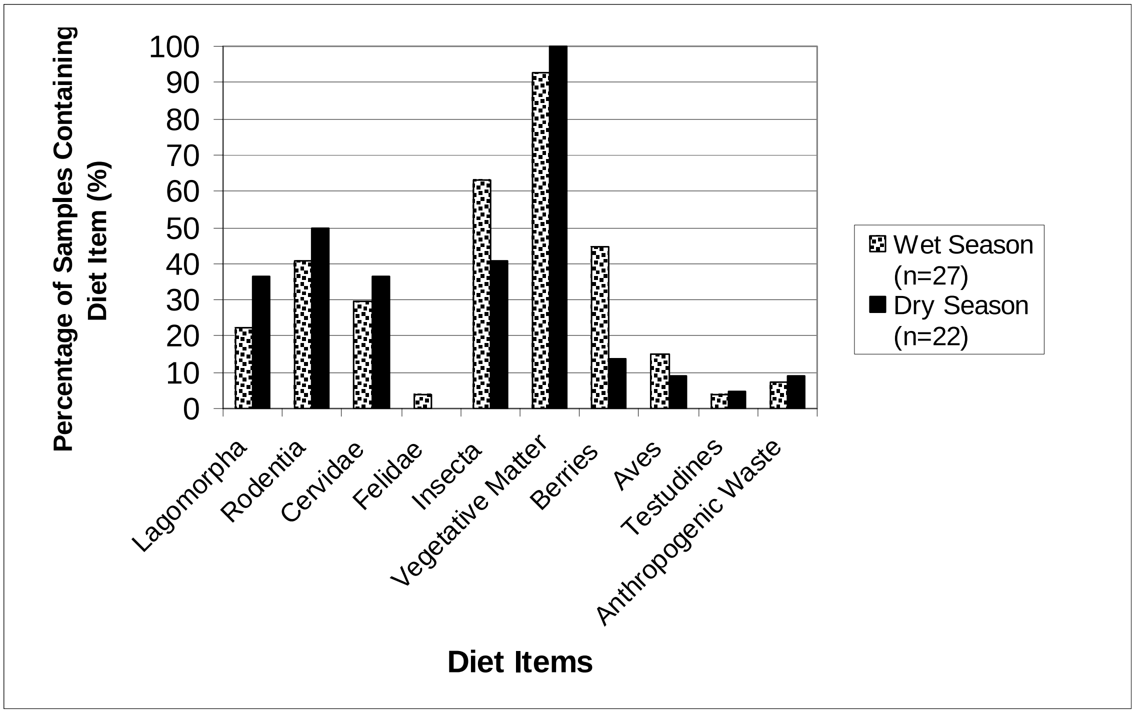

Figure 2. Seasonal variation in the percentage of coyote fecal samples collected in a protected habitat that contain each diet item.

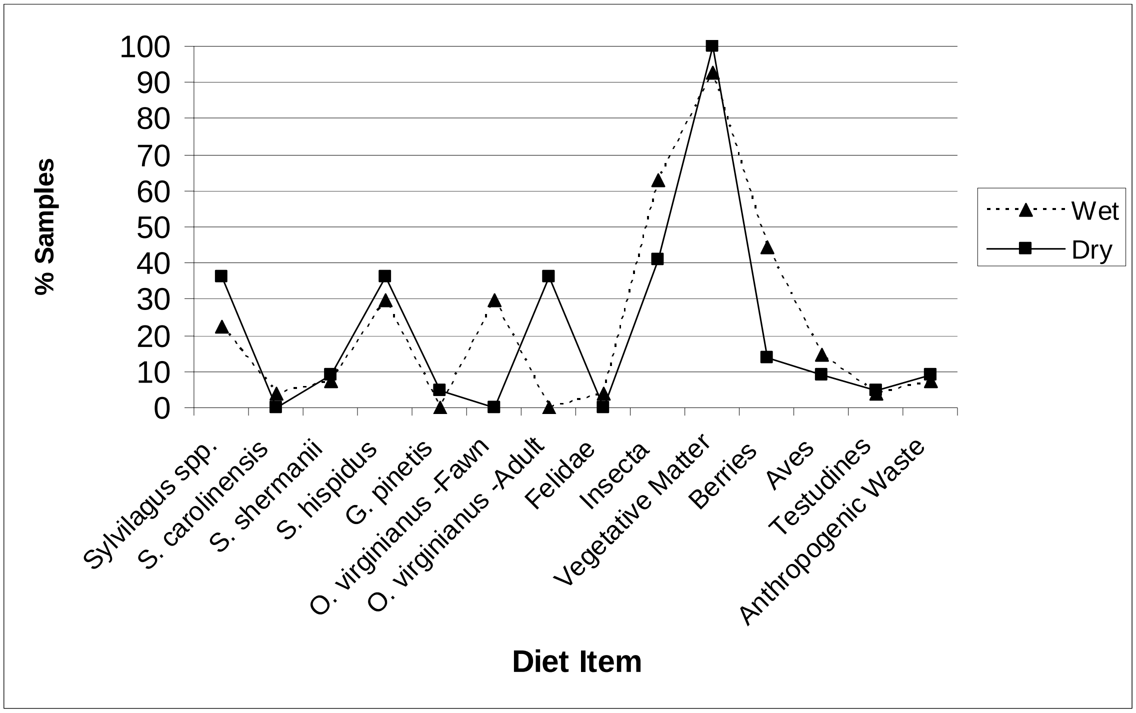

Figure 3. Seasonal variation in the percentage of coyote fecal samples collected in a protected habitat that contain each diet item (represented by the lowest possible taxonomic level).

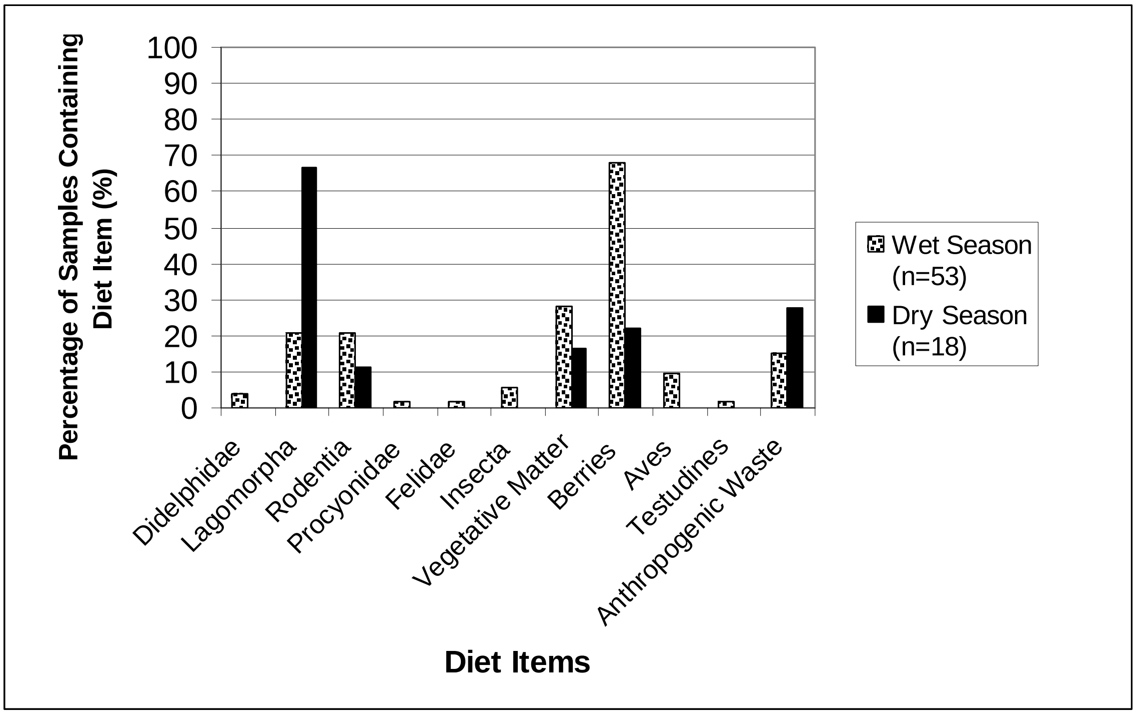

Figure 4. Seasonal variation in the percentage of coyote fecal samples collected in urban habitats that contain each diet item.

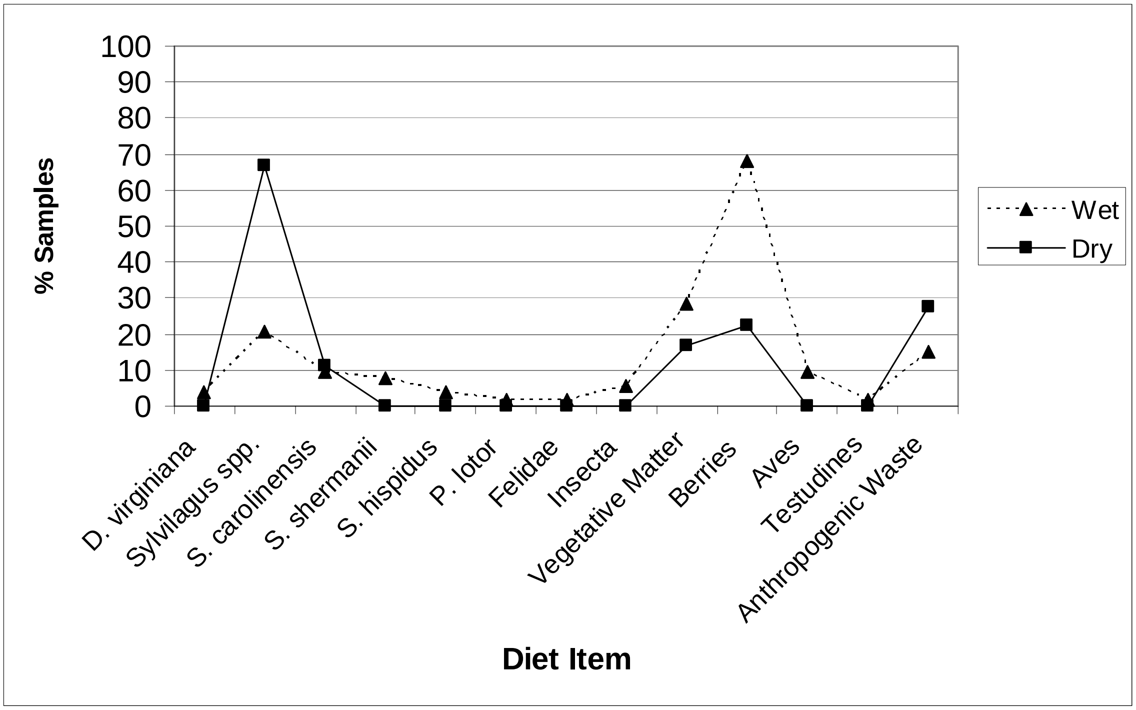

Figure 5. Seasonal variation in the percentage of coyote fecal samples collected in urban habitats that contain each diet item (represented by the lowest possible taxonomic level).

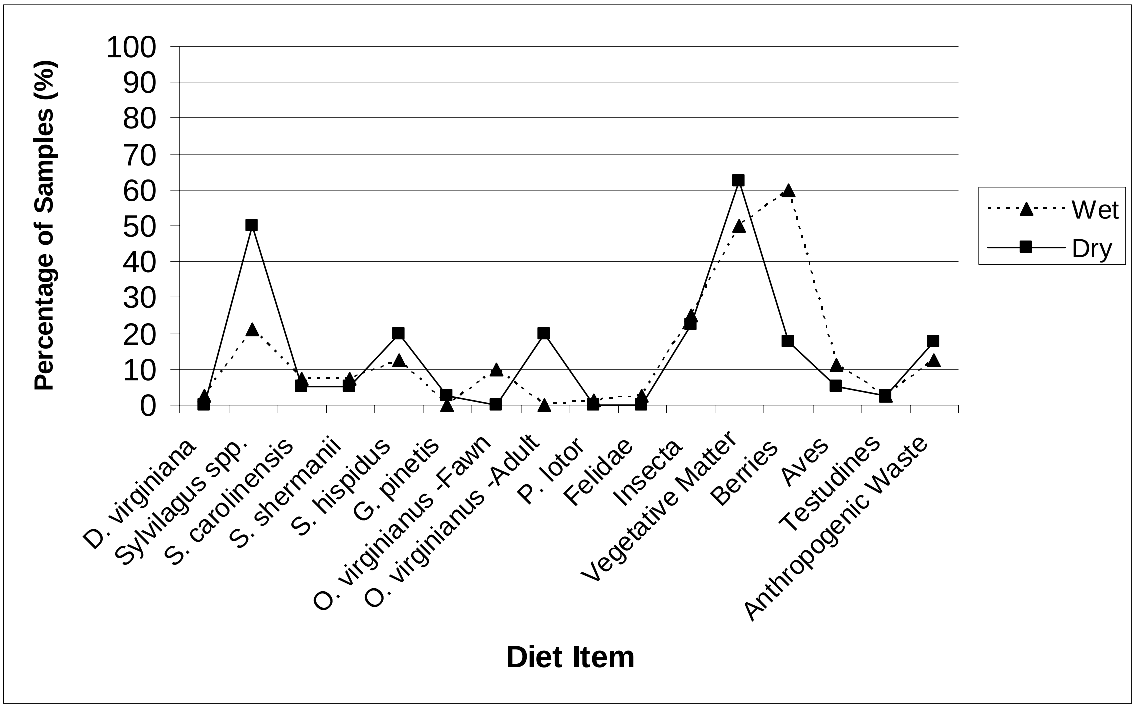

Figure 6. Seasonal variation in the percentage of fecal samples collected from Florida coyotes (protected and urban habitats combined) that contain each diet item (represented by the lowest possible taxonomic level).

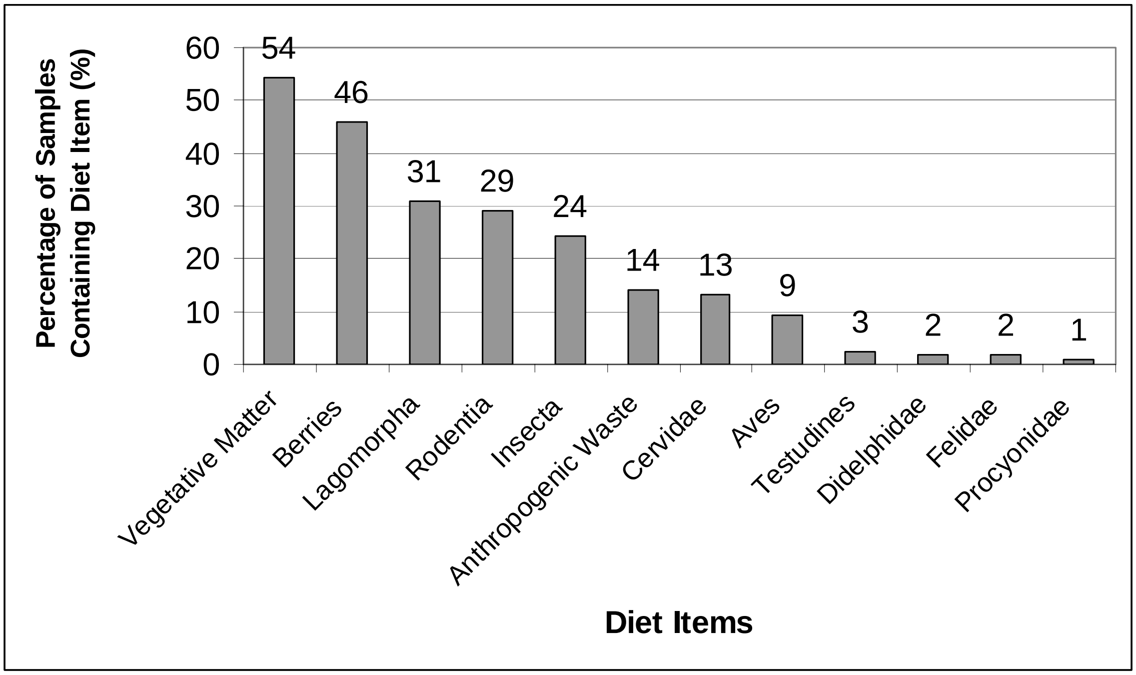

Figure 7. Florida coyote diet (protected and urban habitats combined) (n=120).

DISCUSSION

Diet of Coyotes in Different Habitat Types

Results indicate that my prediction that the diet of coyotes in the protected habitat would differ significantly from that of coyotes in the urban habitat was correct. Coyotes in the protected habitat consumed a wider variety of diet items (higher diet diversity) than the urban coyotes. This is likely attributed to the protected habitat offering more diverse wildlife species available for consumption. Of the diet items consumed in both habitat types, *Sylvilagus* spp. was the diet item that varied the least between urban (32%) and protected (29%) habitats, while vegetative matter was the diet item that varied the most (96% protected, 25% urban). It should be noted that a limitation to this study is that it only represents a snapshot in time. For example, the results do not indicate what percentage of coyote diet consists of each diet item, but rather what percentage of samples contains specific diet items.

Deer were recovered in the protected habitat from more samples than berries or *Sylvilagus* spp. Adult deer were recovered in the protected habitat from as many fecal samples as fawns. It should be noted that the percentage of deer found in coyote fecal samples from the protected environment is likely an over-representation of deer mortality caused by coyotes (Stratman and Pelton, 1997). Coyotes are scavengers and opportunistic carnivores which allows them to obtain food without expending much energy (Arjo et al., 2002). Thus, coyotes may scavenge carrion or feed on one kill for multiple days (Stratman and Pelton, 1997).

However, it is interesting that 8% of the coyote fecal samples collected in the protected habitat contained anthropogenic waste. The protected habitat is largely surrounded by dense urban housing. Thus, the question of how these coyotes obtained anthropogenic waste is of importance. While it is possible that anthropogenic waste could have been obtained from within the borders of the protected habitat, it seems more likely that the coyotes obtained it from the neighborhoods surrounding the habitat. During the course of this study, coyote tracks were identified outside gates and fences lining the parameter of the protected habitat. Additionally, while obtaining scat samples in the protected habitat, areas were discovered where coyotes had dug, and were actively utilizing as passageways, areas under the fence that surrounded the study site. It appeared that these passageways were being actively utilized as an egress from the protected habitat to the surrounding neighborhoods and then later as an entryway back into the protected habitat. Further studies of the movements of coyotes could address this question.

While the origin of the anthropogenic waste recovered from coyote fecal samples collected in the protected habitat cannot be determined, it is assumed that some of it was obtained from the neighborhoods surrounding the study site. This assumption is supported by a comparable study (Fedriani et al., 2001) in which only 3% of the coyote samples contained anthropogenic waste, as opposed to 8% of the samples in the present study. Because coyote scat samples were collected in the protected habitat over the course of this study and relatively few samples contained anthropogenic waste, it can be assumed that if the coyotes were leaving the protected habitat it was probably for short durations of time. Additionally, the results of the present study indicate that the diet of coyotes in the protected habitat is reliant on and maintained by the biological diversity within the preserve rather than by human influence in the surrounding neighborhoods.

Areas with higher human population densities would also have higher amounts of anthropogenic waste. Therefore, it is not surprising that anthropogenic waste was recovered over twice as often from coyote fecal samples collected in the urban habitat as opposed to those collected in the protected habitat. Eighteen percent (18%) of the fecal samples collected in the urban habitat contained anthropogenic waste, as opposed to 8% in the protected habitat. It is presumed that even fewer fecal samples collected in the protected habitat would contain anthropogenic waste if coyotes remained in the protected habitat, as opposed to venturing out into the surrounding urban neighborhoods.

While there are noticeable differences between the amount of anthropogenic waste consumed by coyotes in the protected and urban habitats, the logistic regression showed a weak relationship between habitat and anthropogenic waste. It is suggested that the weak relationship shown by the logistic regression may be due to coyotes in the protected habitat consuming anthropogenic waste from the surrounding urban neighborhoods (urban habitat). Thus, rather than a complete delineation between protected and urban habitats as main effects, the urban neighborhoods surrounding the protected habitat may have caused interference in the protected habitat data, resulting in a higher p-value.

While the Poisson regression showed that season could not be used to determine any changes in the number of diet items consumed by coyotes from either types of habitat, seasonal variation did affect the types of diet items consumed. Diet items in the protected habitat most affected by seasonal variation were white-tailed deer, *Sciurus carolinensis*, *Geomys pinetis*, and Felidae. Fawn was only recovered from coyote fecal samples collected in the protected habitat during the wet season, while adult deer was only recovered during the dry season. Additionally, *S. carolinensis* and Felidae were only recovered during the wet season from fecal samples collected in the protected habitat while *G. pinetis* was only recovered during the dry season.

Seasonal changes were also recognized for other diet items recovered in coyote fecal samples collected in the protected habitat. For example, berries, Insecta, and Aves were recovered more often during the wet season. Berries were recovered from over three times as many samples collected in the protected habitat during the wet season (44%) as opposed to those collected during the dry season (14%). Insecta was recovered from 63% of the samples collected in the wet season, but only 41% of the samples collected during the dry season contained Insecta. Fifteen percent (15%) of the fecal samples collected in the wet season, as opposed to 9% of the samples collected in the dry season, contained Aves.

Remains of *Sylvilagus* spp. were recovered more often during the dry season from coyote fecal samples collected in the protected habitat. Thirty-six percent (36%) of the fecal samples collected during the dry season from the protected habitat contained *Sylvilagus* spp., as opposed to only 22% of the samples collected in the wet season. While more coyote fecal samples collected in the dry season (9%), as opposed to the wet season (7%), from the protected habitat contained anthropogenic waste, the difference was negligible. Fedriani et al. (2001) found similar results for seasonal variation of anthropogenic waste recovered from coyote fecal samples collected in rural areas of California. Fedriani et al. (2001) found that 3% of the fecal samples collected in the dry season contained anthropogenic waste, but only trace amounts of anthropogenic waste were recovered during the wet season.

Diet items in the urban habitat that were affected the most by seasonal variation were *Didelphis virginiana*, *Sciurus niger shermanii*, *Sigmodon hispidus*, *Procyon lotor*, Felidae, Insecta, Aves, and Testudines, all of which were only recovered during the wet season. No diet items were recovered during the dry season that were not also recovered during the wet season from fecal samples collected in the urban habitat. Therefore, in regards to the type of diet items consumed, the diet of urban coyotes changed the most during the wet season.

Other diet items consumed in the urban habitat were also affected by seasonal variation. The percentage of coyote fecal samples collected during the wet season (68%) from the urban habitat that contained berries more than tripled when compared to that of the dry season (22%). *Sylvilagus* spp. was recovered from more than three times as many samples collected from the urban habitat during the dry season (67%) as opposed to the wet season (21%). Additionally, half as many fecal samples collected during the dry season (11%) contained Rodentia as compared to those collected in the wet season (21%) from the urban habitat.

Anthropogenic waste was also found in only half as many samples collected during the wet season (15%) as opposed to the dry season (28%) from the urban habitat. The results of the present study for seasonal variation of anthropogenic waste in urban coyote fecal samples are very similar to those of Fedriani et al. (2001). Fedriani et al.

(2001) conducted a study on coyote diet in an urban area of California and found that during the wet season only 14% of the fecal samples contained anthropogenic waste, but during the dry season this number rose to 25%.

Diet of Florida Coyotes

When combining protected and urban habitat data to examine Florida coyote diet, most of the fecal samples contained vegetative matter (54%) and berries (46%). While Stratman and Pelton (1997) found that fruit accounted for 80% of the coyote diet in northwestern Florida, the present study recovered berries from only 46% of the fecal samples collected. Rabbits were recovered from 31% of the fecal samples of Florida coyotes. Rabbits appeared in more samples of Florida coyotes (31%) than samples of coyotes in Kentucky (22%) (Crossett and Elliott, 1991).

Rodentia and Insecta were recovered from 29% and 24%, respecitively, of the fecal samples collected from Florida coyotes. Specifically, of the Rodentia consumed, *Sigmodon hispidus* was recovered most often (15%). Only seven percent (7%) of the fecal samples collected from coyotes in Florida contained *S. niger shermanii* (Sherman's fox squirrel). Even so, it should be noted that the Sherman's fox squirrel is ranked by Florida Fish and Wildlife Conservation Commission (FWC) as a Species of Special Concern (SSC) (FWC, 2004). Species are ranked as SSC when there is future risk of extinction or, as is the case with the Sherman's fox squirrel, may already meet criteria for being classified as a threatened species, but conclusive data are limited or lacking (FWC, 2004).

Felidae was only recovered from 1 (2%) coyote fecal sample collected in the protected habitat and 1 (1%) sample collected in the urban habitat. When combining samples from both habitats, Felidae was recovered from only 2% of Florida coyote fecal samples. The results of the present study reveal dramatically less consumption of Felidae than other studies on coyote diet. Crossett and Elliott (1991) found remains of Felidae in 13% of the stomachs examined during necropsies on coyotes in Kentucky. It should be noted that it was not possible to differentiate, based on gross morphological characteristics and medullary configurations, whether the remains in feces classified as Felidae were those of bobcat, domestic cat, or feral cat. Additionally, it is not possible to determine whether the remains of prey in coyote feces are the result from the coyote scavenging carrion or actually killing the prey. Therefore, it is likely that the one scat sample collected in the protected habitat that contained Felidae hair was actually a large (>1 inch diameter) bobcat scat. Genetic analysis of scat samples would need to be conducted to determine if samples were indeed deposited by coyotes, or rather by bobcat or even domestic dogs. The results of the present study indicate that cats are not a diet item frequently recovered from coyote scat in either habitat. These findings do not support the popular opinion among many of the general public that coyotes are a major threat to domestic cats.

In regards to the importance of white-tailed deer for the diet of Florida coyotes, the results of the present study are similar to previous studies conducted on the diet of Florida coyotes (Stratman and Pelton, 1997; Thornton et al., 2004). This study concluded that white-tailed deer was recovered from 13% of the fecal samples collected from

Florida coyotes. Similarly, Stratman and Pelton (1997) found that white-tailed deer accounted for 15% of the diet of coyotes in northwestern Florida.

Seasonal variation (wet vs. dry) did occur in the diet of Florida coyotes. Even so, some diet items were affected more than others. For example, the remains of adult white-tailed deer were only recovered from fecal samples of Florida coyotes during the dry season. However, fawns were only recovered during the wet season. These results are similar to those of other studies in which fawns were consumed more frequently (as carrion) during the same time of year (Cook et al., 1971; Salwasser, 1974; Berg and Chesness, 1978; Litvaitis and Shaw, 1980).

It has previously been documented that much of the large prey consumed by coyotes is indeed carrion (Berg and Chesness, 1978; Hugel, 1979; Weaver, 1979). Arjo et al. (2002) documented coyotes scavenging large prey carrion, as opposed to capturing and killing large prey. Due to coyotes being scavengers, it is difficult to determine if diet items recovered from a coyote's feces were the result of the coyote killing the prey or simply scavenging the carrion. Thus, the frequency of coyote predation on large mammals should not be predicted by the frequency of large mammal remains found in coyote scat.

Sylvilagus spp. and berries were other diet items of Florida coyotes that were dramatically affected by seasonal variation. When comparing the wet and dry seasons, Florida coyote fecal samples containing *Sylvilagus* spp. more than doubled in the dry season. *Sylvilagus* spp. was recovered from 50% of the fecal samples of Florida coyotes collected during the dry season, but only from 20% during the wet season. These results are similar to previous findings in which *Sylvilagus* spp. were reported as major diet items of coyotes during the winter months (Clark, 1972; Wagner and Stoddart, 1972). Similarly, when comparing the wet and dry seasons, the amount of Florida coyote fecal samples containing berries tripled in the wet season. In the wet season berries were recovered from 60% of the fecal samples, but less than 20% of the samples collected in the dry season contained berries.

Conclusion

Coyotes are relatively new inhabitants of Florida. Therefore, little is known about how Florida coyotes and other flora and fauna coexist. As opportunistic animals, coyotes are able to find available resources in disturbed landscapes. Even so, they still rely on natural diet items (Riley et al., 2003). While coyote diets are reflective of the habitats they inhabit, they also vary across geographical expanse. The present study documented that habitat and season interact to affect diet, further complicating interpretation of coyote diet.

Coyotes in the western United States have been vilified as major predators (Mitchell et al., 2004), but this negative connotation does not appear to be sufficient for coyotes in Florida, as evident by deer recovered from fecal samples of Florida coyotes. Over the course of the present study, deer was recovered from only 13% of all coyote fecal samples examined. Most reports (Gese and Grothe, 1995; Hugel and Rongstad, 1985; Ozoga and Harger, 1966) of coyotes capturing and killing large prey have occurred when there was sufficient amounts of snow on the ground, which hinders the prey's ability to successfully escape predation (Arjo et al., 2002). Due to the climate in Florida, snow is not a factor. Deer was only recovered from fecal samples collected in the protected habitat which had high deer densities. When deer densities are high, predation by coyotes has little effect on deer populations due to coyotes being more selective (i.e., primarily prey on weak individuals) (Patterson and Messier, 2003). Due to the lack of snow in Florida and high deer densities in the protected habitat, it is presumed that coyotes mainly consumed carrion and/or diseased or older individuals as opposed to killing healthy prey.

Determining what diet items are consumed by Florida coyotes and if seasonal variation occurs in the diet could support future resource management plans. The results of the present study indicate that the prediction that the diet of coyotes in the protected habitat would differ significantly from that of coyotes in the urban habitat was correct. This prediction was based on the notion that in the urban habitat the amount of different diet items is limited while the protected habitat offers more variation (biological diversity) in the types of diet items that coyotes could consume (i.e., more wildlife).

The present study found remains of the Sherman's fox squirrel, which is a SSC, in only 8 coyote fecal samples. It is highly unlikely that Florida coyotes pose a major threat to the continued existence of the Sherman's fox squirrel. It is suggested that continued urbanization poses a greater threat to the future survival the squirrel rather than predation by coyotes. This suggestion is supported by the FWC. According to the FWC, the Sherman's fox squirrel is a SSC because it "has a significant vulnerability to habitat modification, environmental alteration, human disturbance, or human exploitation which, in the foreseeable future, may result in its becoming a threatened species unless appropriate protective or management techniques are initiated or maintained" (FWC, 2004).

While increased urbanization, habitat fragmentation, and complete habitat loss are inevitable, one of the most serious threats to biological diversity worldwide is the destruction of habitat (Wilcove et al., 1998). Documenting the diet of coyotes in protected and urban habitats is essential in order to develop a better understanding of the effects of habitat type on diet. These methods are especially critical due to the rapid disappearance of protected Florida habitat from urbanization.

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