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Winter Diet in Correlation to Sexual Dimorphism in Pennsylvania Coyotes (*Canis latrans*)

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Abstract

Coyotes (*Canis latrans*) have been rapidly expanding into the Northeastern Region of the United States since the mid 1900's most likely due to anthropogenic changes in their habitat. Several studies suggest that in addition to being top predators, coyotes are opportunistic feeders and are able to switch prey based on availability and density. Their generalist predation approach allows variation in their diets, and a widespread impact on the ecosystems in which they reside. In this paper, one hundred and seventy seven coyote stomachs were obtained throughout Pennsylvania from 2009-2012 and were dissected to define coyote winter diet. The contents were identified using *ad hoc* reference bone collections and a set of SEM hair images. Stomach contents were used to identify any correlation between sexual dimorphism and winter diets. It is hypothesized that if Pennsylvania's coyotes show sexual dimorphism, male diets may differ from females. Being able to hunt larger animals may provide males the benefit of a higher caloric return. As a by-product of this research we are detailing a list of prey items found in the winter diet of *C. latrans* arranged by sex and location.

Keywords

Coyote, Diet Composition, Stomach Dissection

1. Introduction

Coyotes (*Canis latrans*) have been expanding into the Eastern United States since the mid 1900's [1] [2] [3]. There are a number of factors that contribute to their success. One reason being that they are apex predators, which has allowed them to easily respond to changes in food availability [4] [5] [6]. This opportunistic feeding style allows them to switch potential prey items based on prey density and abundance [7]. Their foraging behavior gives them the ability to exist in different landscapes [8] [9]. Coyotes prefer landscapes that include fragmented areas such as human disturbed forests. These areas have the potential to host more prey items [2] [10] [11]. However, this human disturbance alone has not been responsible for all expansions; hybridization has contributed significantly as well [3]. As coyotes moved into areas occupied by grey wolf populations (*Canis lupus*) both species interbreed and this may allow for a much quicker colonization rate, facilitating their expansion [3] [11] [12]. *Canis latrans* mtDNA was found in wolf populations [13] [14] [15] and other studies have shown the opposite [3]. This documented hybridization has caused both morphological and behavioral changes within the northeastern species as a whole, including populations located within Pennsylvania [3] [16] [17] [18]. Those coyotes that have been hybridized show as an average larger skulls, larger muscle mass, overall larger body mass, and exhibit "pack-like" strategies when hunting [3] [16] [18]. In the mid/western United States females are found to be larger than males and vice versa in the northeastern region [19] [20]. The body mass of male coyotes is statistically larger than females [20] and this may be another consequence of previous hybridization [21]. These "newly acquired" physical features may help explain coyote behavior as a top predator in the eastern United States. It may also contribute to the possible alterations of diet when looking at sexual dimorphism in male and female eastern coyotes [3] [20].

In addition, the overall decrease in wolf populations in conjunction with the growing hybridized eastern coyote population may have provided coyotes with a unique opportunity to fill the apex predator niche in the Eastern United States Deciduous Forest [15] [22] [23] [24] [25] [26]. The current coyote role in PA resembles the apex predator role that wolves displayed in Yellowstone National Park in the 1990's [5] [18]. By suppressing smaller predators, coyotes in the Eastern USA are probably responsible for the prevention of a "mesopredator release" [25] [27]. A decrease in the coyote population may lead to a negative trophic cascade as it would allow an increase in mesopredators and therefore a numerical decrease on their prey species by pure competition [25] [27]. Studies have shown that coyotes have a positive indirect effect on rodent populations through the suppression of the middle-ranked species [17] [22]. Understanding the potentially different trophic interactions between predators and prey items is important when dealing with management of this species, specifically in understanding the impacts they have in the landscapes they reside [3]. In addition, an increasing population of coyotes must increase competition for resources within individuals of the same population. Due to this selective pressure, it is possible to imagine that sexual dimorphism evolved to exploit different food resources and reduce interspecific competition [28] [29].

The compiling effect of hybridization, increase in density, and a change in feeding behavior may be responsible for the way in which the population of northeastern coyotes are impacting a variety of landscapes from rural to suburban settings [30]. Their expansion into urban setting is increasing "human-coyote" interactions, making coyote competitors of humans for resources [22]. Hunters in particular are disturbed with the number of deer "attributed" to coyote's consumption, ultimately creating a serious conflict [22]. In the agricultural industry, there is concern for predation on livestock also attributed to coyote's opportunistic habits [1]. The impact on livestock does not only create another coyote-human conflict, but it presents a huge economical impact [31]. In 2005, it was estimated that $20 million dollars were lost due to the predation of cattle by coyotes in the Eastern US alone [31]. While not a common occurrence, there have been a number of reports of attacks on pets and even humans in suburban areas in the northeast such as Cleveland Ohio and other similar areas [23] [30].

As a consequence of this negative human interaction coyotes have been persecuted with no particular management goal [25]. Indiscriminated killings of this apex predator may prevent an efficient mesopredator control and an economical way to maintain a healthy level of middle-ranked carnivores and smaller-ranked species within an ecosystem [25] [27]. Furthermore, hunting as a control without a good knowledge of population dynamics may not always have an impact on the regulation of a species such as white-tailed deer [22]. If there is such a thing as an impact of coyotes on the populations of white-tailed deer, one will expect that the expansion of coyotes may decreased the amount of deer related accidents and may even have the potential to lower the risk of tick-borne Lyme's disease on humans by maintaining a lower deer population [22].

Since the northeastern coyote population has changed vastly from their western-counterpart, due to their adaptability and mostly to hybridization with grey wolves; it is important to have local data to understand their population dynamics [32]. Based on the work of Gittleman and Van Valkenburgh (1997) we assume that there is sexual dimorphism among the population of eastern coyotes in Pennsylvania and therefore, we correlate diet differences among sexes [33]. In this study, sexual dimorphism of Pennsylvanian Coyotes from eight counties is compared against their winter diet. This is examined to note the similarities in diets as the coyote expand its geographic range in the northeast where there is also a coincident decrease in grey wolf populations [3] [15]. It is hypothesized that male coyote diets may show a greater amount of larger prey items due to their larger body mass. If there are more differences in sexual dimorphism, then more differences in diets would also be expected. Combining hybridization with hunting behavior may explain the presence of more large items in the male's diet of the northeastern coyotes today due to the potential of a greater caloric return [34].

2. Materials and Methods

2.1. Study Sites

Coyote Stomachs were donated from 50 of Pennsylvania's 67 counties from hunts such as Mosquito Creek (41˚5'30.48", −78˚11'43.02"), Tunkhannock (41˚32'27.25", −75˚57'20.31"), Tubmill (40˚21'20.92", −79˚5'57.80"), and Cresson (40˚

29'3.89", −78˚36'19.36"). The stomachs were collected by Kyle Van Why (USDA-APHIS Wildlife Services) for four consecutive years from 2009-2012 in between January 30th and February 27th each year. A total of three hundred and ninety-nine coyote stomachs both male and female were donated from Pennsylvania coyote hunts for research, one hundred and seventy seven were analyzed for this study from eight different counties. The counties that had the most data available and were used for this study were from the Great Lakes, PA Wilds, Northeast Mountains, and Alleghany Mountain Regions including Bradford, Clearfield, Columbia, Erie, Lycoming, Montour, Susquehanna and Tioga Counties. Data provided to the university included the county and day that the coyote was harvested in addition to the weight and sex of the coyote, age of the coyote was not included. All stomachs were organized by county, year, and sex before they were frozen until dissection.

2.2. Dissection

Each frozen stomach was placed into a refrigerator to thaw for 24 - 72 hours. The stomach was cut from the esophageal to the pyloric sphincter along the greater curvature. All stomach contents were taken out of the stomach for thorough examination. The stomach was stretched to ensure that nothing was left behind or went undetected within the stomach folds. All contents such as hair, feathers, bones, plant matter, parasites, or other materials that could be used for identification were removed from the stomach. If a parasite was collected it was placed into a 1.5 mL microfuge tube and preserved with 70% alcohol. All other collected items were dried for at least one day before being separated and identified. If a bone was covered with tissues, it would go through bacterial maceration until they could be easily cleaned. After all stomachs obtained for each county were dissected, the collected materials identified.

2.3. Identification

The identification process varied based on what was found in each individual stomach. If distinguishable bones were collected they were compared to different species through books [35] and an *ad hoc* collection at Susquehanna University. Small mammal's teeth (mainly rodents) were also used as a method of identification. If identifiable bones were not present to help determine the species, hair samples were used for identification. All hair samples at the time of collection were cleaned, dried and placed into a 1 − 3/4 × 2 − 3/4 glassine envelope. Hair samples were identified by comparisons of scanning election microscope (SEM) images found within the Susquehanna University hair reference collection (**Figure 1**). To compare our hair samples to the SEM pictures the scale pattern of the hair was mounted onto a slide using Kores stencil correction fluid. The fluid was brushed on to a microscope slide, allowed to dry for up to two minutes, the hairs were placed onto the correctional fluid and pressed for at least two hours. The casts were observed under a light microscope. It showed the hair profile and aided in identification of that particular species.

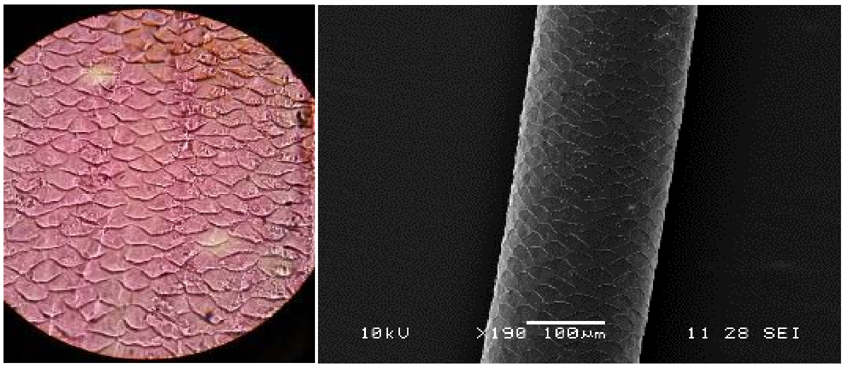

Figure 1. A White-tailed Deer (Odocoileus virginianus) hair pulled and mounted from a coyote stomach dissection viewed under a light microscope (Left) compared to a SEM hair sample from the Susquehanna University hair reference collection (Right).

2.4. Identification

Sexual dimorphism in western and northeastern coyotes was obtained from the literature ([20] [36]-[43]. In order to compare sexual dimorphism to coyote winter diet, a comprehensive list of all identified species and coyote weight was created. After dissection, each prey item was filed into a data sheet for the years 2009-2012 and the number of that individual was recorded. Prey items were divided into categorical groups based on size. Each sample was placed into the appropriate category after completing the identification. The groups consisted of cervids, noncarnivorous medium/large-sized mammals (greater than 3 kg), large carnivores (greater than 7 kg), small and medium-sized carnivores (less than 7 kg), small rodents (less than 3 kg), birds, and plant matter [44]. This allowed us to quantify avian individuals even if they could not be identified to species. The data was also broken down between males and females. Using the spreadsheets an analysis of the coyote diet in Pennsylvania could be completed. An unpaired t-test was run to find the body mass sexual dimorphism in Pennsylvanian coyotes. That data was then used as a comparison in their winter diets through the completion of a chi-square analysis of the categorical groups in which they were preying on.

3. Results

An unpaired t-test was used to determine if sexual dimorphism was seen between Pennsylvania male and female coyotes. There was a statistical size difference between male and female coyotes ($p < 0.0001$; **Figure 2**). Multiple unpaired t-tests were completed to compare body weight across regions. Pennsylvania and the northeastern region only had slight variation in body mass (0.2 kg), whereas there was a statistical difference seen between the northeastern/ Pennsylvanian coyotes compared to the mid/western counterparts ([20], $p < 0.05$; **Figure 3**).

A Chi-Square was used to compare the categories of species the individual was preying on against their sex. A negative correlation was found in which there is no statistical similarity in the items that they were preying on in comparison to the coyote sex ($X^2 = 4.69$, df = 6, $p > 0.1$; **Table 1**).

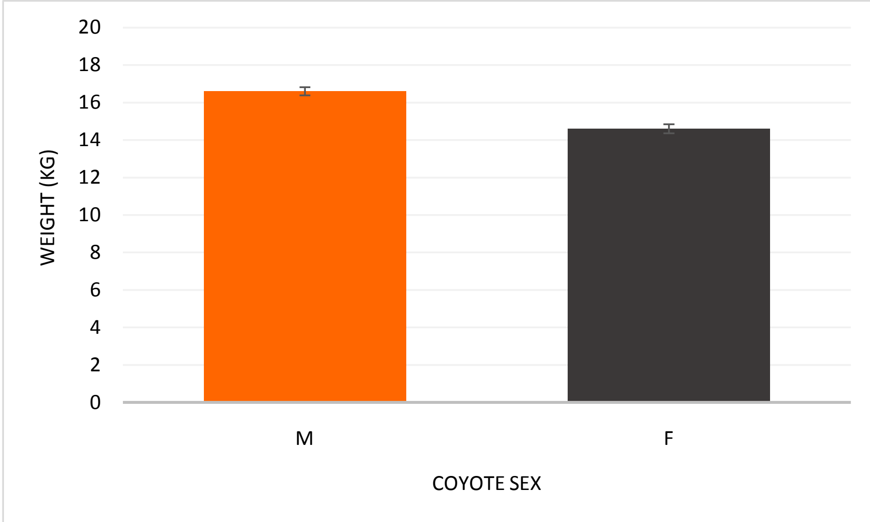

Figure 2. The average body mass difference between Pennsylvania male and female coyotes (N = 128). An unpaired t-test analysis showed that they were statistically different ($p < 0.0001$).

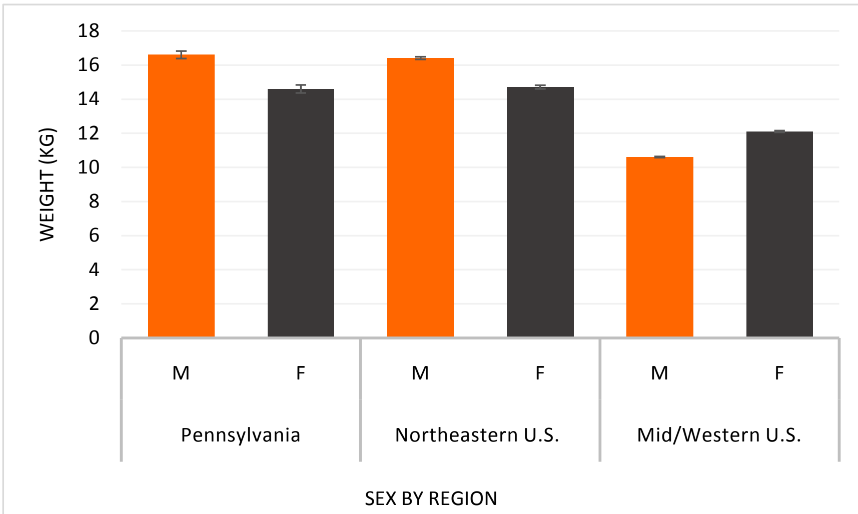

Figure 3. Average body mass between male and female coyotes across the United States. There was a statistical difference between the northeastern and the mid/western region ($p < 0.05$).

Table 1. A Chi-Square Analysis was used to determine if there was a correlation between sexual dimorphism and prey item preference (N = 177). Both males and females preyed on the same categories of species, there was no statistically different results ($X^2 = 4.69$, df = 6, $p > 0.05$).

	Cervids	Large Carnivores	Medium/Small Sized Carnivores	Noncarnivorous Small/Medium Sized Mammals	Small Rodents	Birds	Plants	Row Totals
Male	57	4	9	1	39	10	64	184
Female	49	3	4	7	32	8	54	157
Column Totals	.	7	13	8	71	18	118	341

A bi-product of this study was a list of the mammal species that the coyotes preyed upon in winter (**Figure 4**). Coyotes consumed a variety of prey species in their winter diets, but the majority (94%) was comprised of three main prey items: white-tailed deer (*Odocoileus virginianus*, 60%), voles (*Microtus spp*., 25%), and eastern cottontail (*Sylvilagus floridanus*, 9%).

4. Discussion

On the contrary of what was expected, the number of large mammals did not correlate with the larger size of male coyotes. This could be due to the timing of the sampling, in the winter hunting becomes more difficult and less cost effective [45]. While northeastern male coyotes weigh on average 2 kg more than females the physical and morphological differences between the two may not be strictly from evolutionary causes, but could instead be due to their hybridization with wolves [20] [46]. Through hybridization both sexes acquired larger body mass, more muscle mass, bigger skulls and larger jaws [3] [16] [18]. Due to this *Canis l. latrans* is clearly heavier than their nearest relatives (*C. l. thamnos*) from the Midwest [47]. Some literature on the other hand suggest that the larger size of the northeastern coyotes was primarily an evolutionary response to larger prey size [20]. However, white-tailed deer (*Odocoileus virginianus*) are more wide-spread than just the northeastern region of the United States [48]. The larger body mass of eastern coyotes may also be a consequence of the phenotypic plasticity in response to the abundance of prey [49]. It is also important to understand that mass is a variable factor and that variability can be attributed to fullness of stomach, health of the individual, season, and age [20]. In this study,

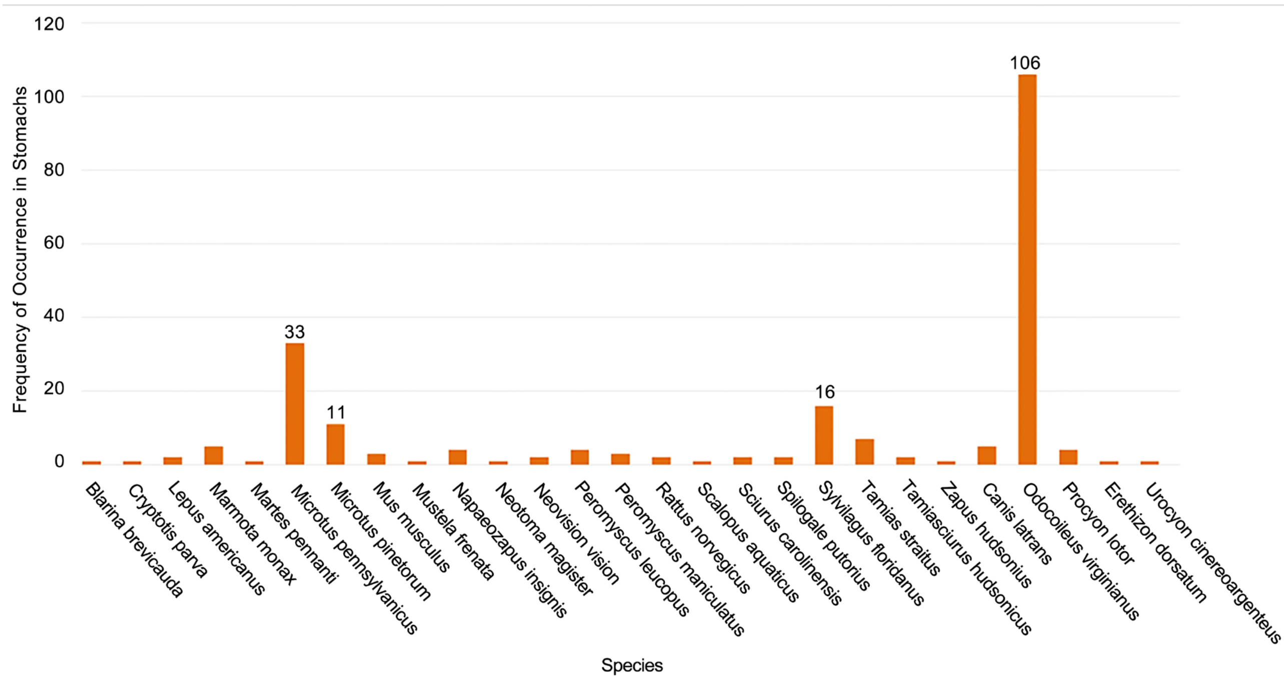

Figure 4. Comprehensive account of all mammals classified by species identified in coyote stomachs throughout all counties and years studied (N = 177).

there was not a difference between the fullness of stomachs between males and females.

We suspect that as coyotes are opportunistic predators that will prey on the species that is most readily available to decrease time spent foraging [50]. Using this generalist approach to prey on smaller mammals, insects, fruit, and plant matter can enhance the likelihood of survival in a variety of conditions and environments [32] [33] [49]. Coyotes may have larger home ranges to accommodate their nutritional need without overexerting themselves [20]. In this study, the three most common prey items observed were white-tailed deer, voles and cottontail rabbits. This diet correlates to that of most canid species in the northeastern region [24]. All prey items are in high abundance in the northeastern United States and therefore are preferred by and available to coyotes. Voles and rabbits are also seen in the winter diet of northeastern coyotes [51]. Our results support that idea as well as show insight in to how coyotes are preying on these species. For example, a small proportion of our stomachs had more than one individual within the stomach, in some cases up to as many as twelve voles were removed from a single stomach. Consuming more than one individual could have the same caloric return as eating a larger mammal as part of a pack [44]. Habitat can be a large influence on the predation rates of small mammals [52]. Coyotes in more developed areas tend to show more diverse diets and may prey upon anthropogenic food sources [52] [53]. Despite numerous studies involving coyote diets little has been documented long-term or in correlation with habitat types.

The most common item in the coyote winter diet was white-tailed deer. It was found in over half of the samples [22] [54] [55]. As coyotes moved into the northeastern region they became the apex predator. They were able to suppress the white-tailed deer population in order to prevent a mesopredator release [22], [23] [25]. It was suggested that larger body size on predators may be a consequence of large bodied prey species. While not statistically significant, our samples show a higher amount of white-tailed deer consumed by males than females, suggesting a trend that could be explained using sexual dimorphism.

The amount of deer found within our stomach samples could be overrepresented, as we do not know if the deer were killed by coyotes or eaten as carrion. In many cases, only deer hair was found inside the stomachs. Deer hair is quite durable and has the potential to last a very long time under the chemical effects of the stomach acids. Nevertheless, coyotes are still preying on both adult and juvenile deer and they may be exerting an impact on the local deer population [56] [57] [58] [59] [60]. To date the effects of coyote predation on deer populations has been understudied and therefore, it is not entirely understood [52].

Overall, coyotes are able to adapt their behavior based on environmental factors and therefore sexual dimorphism may not play an effect on their winter diets. Today coyotes in PA seem to have a diverse diet, including both small, medium, and large mammals, and probably are ultimately preventing a mesopredator release, influencing the overall health of our local ecosystems [25]. Few studies have been completed to understand the role of the coyotes within Pennsylvania and what impacts they have in this region. Many of what has been completed has been studied through scat samples or captive animals [32]. The predation tendencies of male and female coyotes within this study are important to understand their sexual dimorphism, diet, and responses to ecological factors such as habitat availability. As their diet changes by region and season this could help in understanding the population dynamics of this important species on local ecosystems.

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