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Original Paper

The Diet of Foxes and the Availability of Anthropogenic Food on Prince Edward Island, Canada

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Abstract

It has been postulated that red foxes (Vulpesvulpes) inhabiting Prince Edward Island National Park (Canada) make very little use of natural food sources and that anthropogenic food play an integral part in their diet. The use of anthropogenic food sources has also been associated with an increased number of fatal fox vehicle-collisions in the park. The main goal of this study was to examine the composition of the diet of foxes inhabiting Prince Edward Island National Park and to compare this diet with foxes found in other areas of the island. In particular, we examined the importance of anthropogenic food items in foxes inhabiting the national park. We analyzed 38 stomachs from foxes killed by trappers or vehiclesduring late fall and early winter within and outside the national park. Our results showed that rodents and vegetation were the most common food items present in fox stomachs whether the animals were obtained from within or outside the park. Values of coefficient of variation of food items found in fox stomachs indicated a great diversity in diet composition. However, only six stomachs contained anthropogenic food items. Stomachs of foxes killed by vehicles contained twice the amount of anthropogenic food items than those that were collected from trappers. Overall, our findings indicate that anthropogenic food items are only a minor component in the diet of foxes occurring within the park, at least during the period of time examined in this study. Future studies should examine diet composition during other seasons when the quantity and quality of anthropogenic food sources is different.

Keywords

red fox, diet composition, anthropogenic food, national park, stomach analysis

1. Introduction

In Prince Edward Island (Canada), the red fox (*Vulpesvulpes*; herein called fox) was the largest mammalian carnivore species until the arrival of coyotes (*Canislatrans*) during the early 1980s. Although no studies have assessed the abundance of foxes on Prince Edward Island (PEI), it is commonly known that they occur throughout the whole province, including urban areas. Regardless of this widespread distribution, little is known about the ecology and behaviour of this species in PEI.

Food utilization is an important aspect in the study of mammalian carnivores since trophic resources dominate several aspects of their ecology (Macdonald, 1983; Bekoffetal., 1984; Silva et al., 2009; Faraz et al., 2019). Foxes are opportunistic animals known for having a diverse diet that allows them to survive in natural and human-altered habitats (O'Mahoney et al., 1999; Stuart & Stuart 2003; Dell'Arte et al., 2007; Savory et al., 2014; Handler et al., 2020). Common food items ingested by foxes usually include arthropods, rodents (e.g., mice, voles), birds and rabbits (Aryal et al., 2010; Dell'Arte et al., 2007). Several studies have shown that the importance of each food item in the diet of foxes varies depending on various factors, including habitat type and regional prey availability (Dell'Arte et al., 2007; MacDonald, 1977). For instance, anthropogenic food items may represent a large fraction of the items ingested by foxes in urban and suburban areas (Aryal et al., 2010; Contesse et al., 2004; Newsome et al., 2010; Savory et al., 2014; Handler et al., 2020).

Previous studies have found that in some areas on PEI, especially Prince Edward Island National Park (PEINP), foxes tend to select road and human-use areas for foraging during late fall and winter (Silva et al., 2009; Silva-Opps & Opps, 2011; Lambe, 2016). It has been hypothesized that foxes do this because they are fed by humans inhabiting houses or cottages located near PEINP, as well as by tourists (although this may be more important during the summer season) on roadsides. The consequences of fox-feeding on aspects of the ecology of foxes occurring in PEINP are unknown. According to Parks Canada, every year several foxes are killed by vehicles along roads traversing PEINP (D. Lajeunesse, personal communication). Thus, it is possible that fox-feeding has increased the probability for foxes to be killed or injured by vehicles. In addition, several studies have shown that an increase in the availability of food sources from human waste can have a profound effect on the reproductive success (Lewis et al., 1999; Reichmann & Saltz, 2005), home ranges and abundance levels of wild canids (Panez & Bresinski, 2002; Dolev, 2006; Lambe, 2016). Clearly, improving our knowledge of diet and food preference of foxes occurring in PEINP can help to elucidate the importance of anthropogenic food sources in the diet of these animals. It can also provide a better understanding of the adverse effects that fox-feeding may have on this mammalian predator in PEINP and other areas of the province (e.g., urban areas) where fox-feeding is a common activity.

The main goal of this study was to examine the diet composition of foxes in PEINP during late fall and

early winter. Specifically, our first objective was to determine the most common food items consumed by foxes within and outside PEINP during this time period. In particular, we were interested in quantifying the relative importance of anthropogenic food items for foxes. Based on previous studies (Silva et al., 2009), we predicted that consumption of anthropogenic food items would be higher in foxes occurring within PEINP than those outside the park. The second objective of this study was to explore the potential influence of various environmental factors on the diet composition of foxes. In particular, we were interested in examining the effects of climatic factors on the choice of food items during late fall and early winter.

2. Materials and Methods

2.1 Site Description

Prince Edward Island is located in the Gulf of St. Lawrence (Canada) and encompasses an area of approximately 5,660 km^2 (Weighs, 1995). The average yearly rainfall on PEI is 868 mm and the average yearly snowfall is 340 cm. Prince Edward Island winters are cold, ranging between -3°C and -11°C. Snowfall begins usually in November and may continue until April (National Climate Data and Information Archive, 2009). The original forest of PEI was the Acadian Forest that was characterized by the presence of hardwood tree species (Silva, 2001). However, much of PEI's natural habitats have been transformed into small forest patches enclosed by agricultural fields or human infrastructures mainly due to anthropogenic activities such as forestry, agriculture and urbanization (Majka et al., 2006; Silva et al., 2009). In addition, tourism (e.g., golf courses) has also contributed to the modification of PEI's landscapes and the alteration of the patterns of abundance and distribution of many mammalian species during the last decades (MacDonald & Jolliffe, 2003; Silva et al., 2009).

2.2 Stomach Collection and Content Analysis

A technique commonly used to examine diet composition in various species, including the fox, is the analysis of stomach contents. The value of this technique has been demonstrated with field and experimental studies that showed it can provide useful data regarding diet composition that can be integrated in species management programs (e.g., Harris 1981; Amundsen et al., 1995; Anthony et al., 2000; Contesse et al., 2004; Azevedo et al., 2006; Britton et al., 2006; Kidawa & Kowalczyk, 2011). Although we were initially interested in conducting the dietary analysis of this species for the whole year, we were limited to the late fall and early winter (November 2008 to February 2009) because all the fox stomachs that we were able to obtain were from animals that died or were trapped during this time period. Fox stomachs were extracted from animals that were opportunistically collected at two local sources (the Atlantic Veterinary College and a local taxidermy studio) that receive foxes that are either accidently killed by vehicles or caught by trappers. For each fox carcass, information regarding the date, location and cause of death as well as the sex was collected. Stomachs were extracted from animals and stored at -15°C until dietary analysis could be conducted (~3-4 weeks after their collection). For dietary analysis, stomachs were thawed for 48 hours at 2°C. Stomachs were then

opened and their contents were carefully rinsed with running water with a 0.5 mm sieve (see also Harris, 1981; Anthony et al., 2000; Azevedo et al., 2006; Britton et al., 2006). The rinsing water was then filtered through a 0.25 mm sieve (Contesse et al., 2004; Kidawa & Kowalczyk, 2011). Contents and filtrate were then transferred to petri dishes for air-drying (e.g., Anthony et al., 2000; Azevedo et al., 2006) in an Air Clean 600 Workstation. Contents were identified both during the transfer to the petri dishes and the drying process.

2.3 Data Analysis

Fox-stomachs were separated into two groups: those collected from animals trapped or killed at ≤ 5km from the boundaries of PEINP and those from animals trapped or killed at > 5 km from the boundaries of the park. A distance of 5 km was chosen because radio-telemetry data suggest that foxes travel as little as 0.4 km up to ~1.2 km during late fall and early winter on PEINP (Silva et al., 2009; Silva-Opps & Opps, 2011; Lambe, 2016), suggesting that a distance of 5km is sufficient to distinguish the foxes that occur within PEINP from those that are outside the park. Items present in fox-stomachs were classified into one of the following five food groups: invertebrates, vegetation (included apples), rodents (entire animal and/or animal fragments), feathers and anthropogenic food. No attempt was made to classify ingested rodent-items into taxonomic species since this was not considered to be essential for the purpose of this study.

All empty stomachs were recorded, but excluded from all statistical analyses conducted in this study. In order to quantify the occurrence of each food group in the stomachs of animals from both inside- and outside-PEINP, we calculated the percentage frequency value (%F) for each food group as follows: $\%F = (N_i / N) \times 100$, where N_i*is* the total number of stomachs that had items from a given food group, and N corresponds to the total number of items from all food groups examined in this study (adapted from Weiss, 2004). Using all the %F values of the different food groups consumed by each animal, we calculated for each stomach a coefficient of variation in terms of diet composition. Coefficient of variation values were then used to compare (Chi-square goodness of fit tests; X^2 test) the diet (both composition and variety)of foxes from inside-PEINP and those from outside-PEINP as well as betweentrapped accidently vehicle-killed foxes. In addition, we also examined the effects of climatic factors on diet composition of foxes from inside- and outside-PEINP using One-Way ANOSIM (PRIMER-5, version 5.2.4) on the coefficient of variation values calculated above (Clarke & Warwick, 1994; Callaway et al., 2002). Climatic factors examined in this study included daily average temperature (°C) and total daily precipitation (mm). In addition, we calculated an indicator of evapotranspiration by multiplying daily average temperature and total daily precipitation values (*sensu* Francis and Currie 2003). Climatic data were obtained from Environment Canada.

3. Results

A total of 37 fox-stomachs were collected for this study. Seventeen stomachs were from foxes occurring inside-PEINP while 20 were from outside-PEINP (Figure 1).

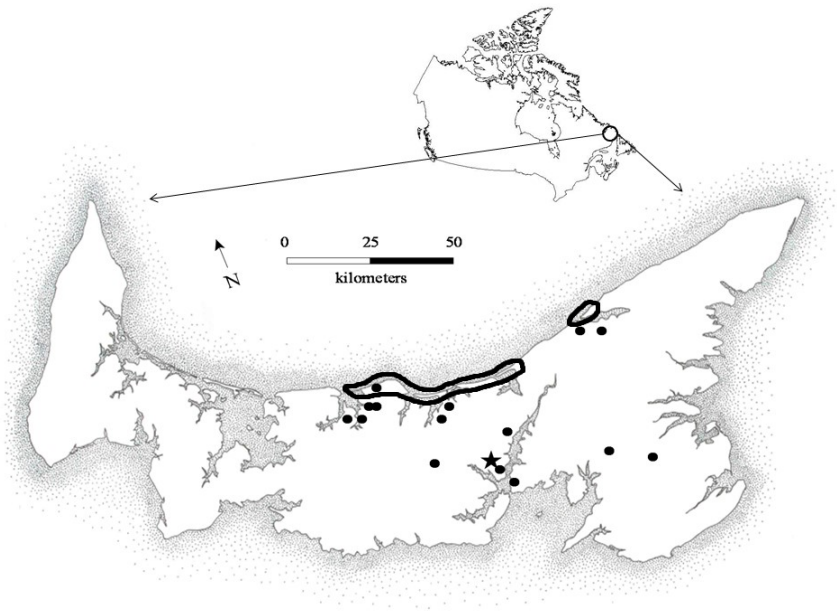

Figure 1. A map of Prince Edward Island (Canada) Showing the Location Where Red Fox Carcasses Were Collected. Star Indicates Charlottetown (the Capital City) and Circles Indicate Location Where the Carcasses of Eed Foxes Eere Obtained. The PEI National Park Is Highlighted on the North shore of PEI

Five stomachs (three from inside-PEINP and two from outside-PEINP) were empty and were therefore excluded from all statistical analyses. Values of coefficients of variation of food items were not only high, but also very similar for both fox groups (95.6 for inside-PEINP and 96.7 outside-PEINP). All stomachs used in the analyses contained natural food items, but only six of them (two from inside- and four from outside-PEINP) also contained anthropogenic food items. Anthropogenic food items found in fox stomachs included tin foil, coffee grinds, macaroni-cheese, cooked lobster and cooked chicken. No stomachs examined in this study contained exclusively anthropogenic food items.

X^2 test revealed significant differences in the frequency of food items consumed by foxes inside-PEINP and those from outside-PEINP (df = 5, X^2 = 12.451, p = 0.029). Although rodents were the most common food item consumed by both fox groups, %F values varied greatly between the two fox-groups(%F = 48.3% inside-PEINP and %F = 38.5% outside-PEINP; Figure 2), suggesting differences in diet composition.

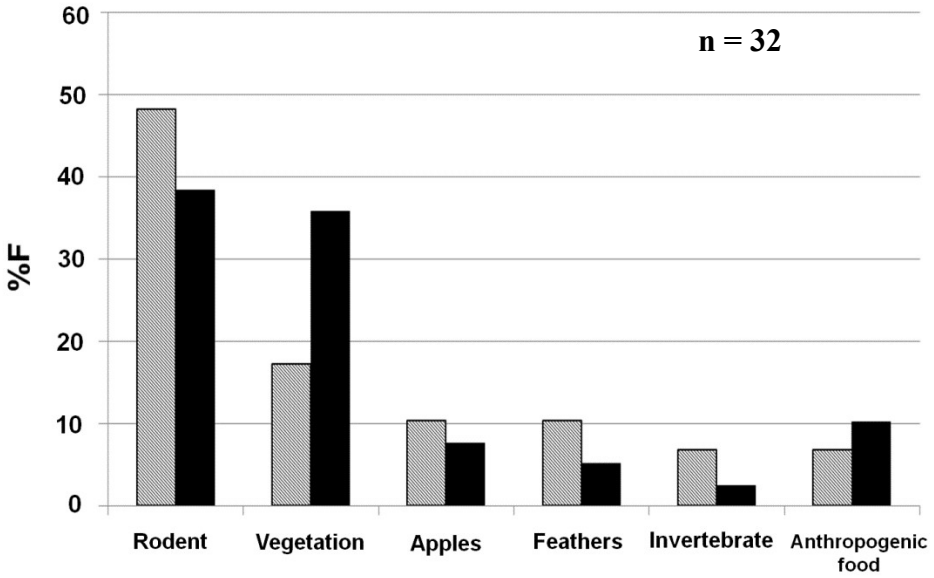

Figure 2. Frequency of Occurrence of Food Items Recovered from Stomachs of Red Foxes from Inside the PEINP (Hatched Bars) and outside the PEINP (Solid Black Bars), Collected between November 2008 and February 2009 in PEI

For instance, we found evidence for a difference in the consumption of anthropogenic food (inside-PEINP %F = 6.8 and outside-PEINP %F = 10.2). A significant difference was found between stomachs from trapped animals and those from animals killed by vehicle collision (df = 4, X^2 = 12.741, p = 0.012). Stomachs of foxes killed by vehicles (%F = 15.3) contained twice the amount of anthropogenic food items than those that were trapped (%F = 7.2) (Figure 3).

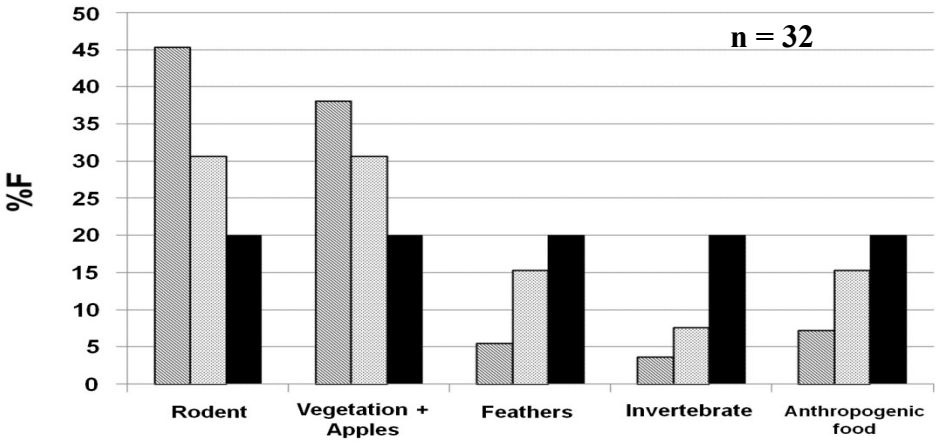

Figure 3. Frequency of Occurrence of Food Items Recovered from Stomachs of Red Foxes that Were Either Ttrapped (Hatched Bars) or Accidently Killed by Vehicle Collision (Dotted Bars), Collected between November 2008 and February 2009 in PEI and expected Values (Solid Black Bars)

No environmental factor examined in this study was found to have an influence on what foxes consumed. Similarly, no significant differences in stomach content (i.e., in %F values) were found between males and females for any of the fox groups (inside-PEINP, outside-PEINP, trapped foxes and vehicle-killed foxes) were found in this study.

4. Discussion

Overall our findings showed that anthropogenic food items represented only a minor component of the diet of foxes either inside or outside PEINP during late fall and early winter. These results deviate from other studies that have found that anthropogenic food items play a major role in the diet of foxes during late fall or winter (e.g., Contesse et al., 2004; Savory et al., 2014). Furthermore, our results do not provide support for other studies conducted on PEI (Silva-Opps & Opps, 2011; Silva et al., 2009; Lambe, 2014) that suggested that anthropogenic food items are important components of the diet of foxes throughout the whole year, including the time period examined during this study. One possible explanation for our findings is that it is energetically more efficient for foxes to consume rodents and other natural resources instead of anthropogenic food items during late fall and early winter. According to the optimal foraging theory, organisms forage in such a way as to maximize their energy intake per unit time in order to achieve an optimal diet (e.g., Pyke, 1984; Castillo et al., 2011). Although humans inhabiting houses and cottages in close proximity to PEINP may still feed foxes during the period examined in this study, the absence of tourists may result in a significant decrease in both quantity and quality of anthropogenic food items. Other studies (Silva et al., 2009; Silva-Opps & Opps, 2011) and anecdotal information suggest that during the kit-rearing season (late spring and summer) foxes use human-use areas and roads where anthropogenic food items are abundant. During the kit-rearing season, the use of anthropogenic resources may not only be energetically more efficient, but also less risky for foxes. It is important to mention that in PEINP, fox-dens are located in the dunes which are situated in close proximity to human-use areas and a major road that traverses the park (Silva et al., 2009; Silva-Opps & Opps, 2011). It is, therefore, possible that potential temporal differences in the use of anthropogenic food items by foxes occurring in PEINP may be dictated by profitability and not necessarily encounter rate. Clearly, a study examining the diet of foxes inside and outside PEINP at other times of the year, especially during the kit-rearing season, would help elucidate these ideas.

We also found that despite small differences in diet composition, rodents and vegetation represented the largest portion of food items consumed by foxes both inside and outside PEINP. Interestingly, foxes involved in vehicle collisions in PEINP had a higher %F for anthropogenic food items than those trapped in PEINP, and lower %F for rodent and vegetation. This is an important finding because it would normally be expected that %F of anthropogenic food items would be higher in trapped foxes because these animals would have potentially consumed baits that usually include anthropogenic food resources. It is unclear why %F of anthropogenic food items were higher in foxes accidentally killed by vehicles, but one possibility is that at least a few of these animals were fed by humans along roadsides.

If this is true, our findings would provide support for the idea that foraging along roadsides is increasing the probability that foxes are killed by vehicles.

The coefficients of variation of food items calculated in this study were high for foxes occurring both inside and outside PEINP. This suggests that, at least during late fall and early winter, foxes in PEI are opportunistic animals. Given that opportunistic predators have a large dietary niche width, it is important to distinguish between the dietary niches of the individuals and that of the whole population (e.g., Amundsen et al., 1995; Drouilly et al., 2017). Populations with a broad dietary niche may be composed of individuals with narrow niches or wide niches, or a combination of the two. Therefore, it may be possible that the fox stomachs collected in this study were from a combination of specialist, generalist and opportunistic individuals, rather than strictly opportunistic individuals.

None of the climatic factors investigated in this study had a significant effect on the diet of foxes whether they occurred inside or outside PEINP. This finding was surprising because climatic factors are known to alter mammalian behavior and physiological processes (e.g., Christian, 1950; McNab, 1986; Stenseth et al., 2002; Santos et al., 2011). Although it is possible that effects of climatic factors on the diet of foxes may be more obvious during other times of the year (e.g., summer), the recovery of insect larvae from several fox stomachs examined in this study suggests that foxes are able to dig into old stumps or logs (where larvae overwinter) during warm days in late fall or early winter to find and consume the larvae. This finding also provides more support for the idea that foxes in our study area are opportunistic animals that are able to exploit a variety of natural resources when they become available.

4.1 Management Implications

In this study, we found evidence suggesting that in the study area foxes are opportunistic animals that can consume a variety of resources, including anthropogenic food. This finding is important because there is a common believe amongst local people that foxes depend upon anthropogenic resources to survive in PEI, especially during late fall and winter. Our findings clearly show that natural resources such as rodents and vegetation are the major source of food for foxes occurring inside-and outside-PEINP during late fall and early winter. Since we did not collect data for other periods of the year, it is clear that a long-term study that will investigate diet composition as well as foraging behaviour and movement of foxes throughout the whole year would be essential to elucidate the role played by anthropogenic food sources in the diet of foxes. A long-term study that would include other seasons of the year could help examine the response of fox populations to different abundance levels of anthropogenic food sources while also help understand the effectiveness and impacts of anthropogenic resource reduction on this species. Such long-term study would also be useful to determine the role of anthropogenic food on the abundance of foxes in PEINP and other areas of the province. It is commonly assumed that access to anthropogenic food sources is the main reason why fox densities in PEINP and other areas have increased significantly during the last decade.

Our findings also show that there is particular need for more research into the movement and habitat

selection of foxes. Foxes involved in vehicle collisions were found to consume more anthropogenic food items than foxes that were trapped. If foxes prefer to use roadsides for foraging, a long-term study that focuses on movement and habitat selection may provide essential information that could be incorporated in a management program for this species.

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