

The Feeding Ecology of Non-Native Red Fox (*Vulpes vulpes*) on an Atlantic Barrier Island

**by
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The Feeding Ecology of Non-Native Red Fox (*Vulpes vulpes*) on an Atlantic Barrier Island

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Abstract:

The Red Fox (*Vulpes vulpes*) is a non-native predator inhabiting most of North America and its dynamic ecosystems, such as Fire Island National Seashore (FINS), New York - an Atlantic Barrier Island that has more than 330 species of birds that are both migratory and resident. Almost nothing is known about red fox food habits on Atlantic Barrier islands. Therefore, our objectives were to assess red fox diet on FINS and compares diet between residential and “designated” wilderness areas and also to test for differences in diet among seasons. It was hypothesized that the increased decline of endangered and threatened birds is due to consumption by the red fox. Red fox feces were collected from February 2011 to October 2012. There were 90 red fox feces samples collected, washed, and dried. Prey items were classified into 6 major categories including: mammal, avian, crustacean, plant, fish, and unknown (with unknown being particles of soil and debris). Mammalian bones were identified to the species level, avian bones were identified to order and family, fish were identified to class, plants were identified to kingdom, and crustaceans were identified to subphylum. Based on a Binary Logistic Regression, there is no significant relationship between mammalian or avian prey selection with respect to season (fall, winter, spring, summer) or location (wilderness vs. residential) [p-values=0.619 & 0.569, respectively]. Red fox diet differed significantly with respect to mammalian prey items between 2011 and 2012 [p-value=0.030], with more mammalian prey consumed in 2011. There is no significant relationship with respect to avian prey selection and year (2011 & 2012) or location (wilderness vs. residential) [p-value=0.942]. No threatened or endangered birds were detected in or samples. This study is the first complete study on the diet of red fox inhabiting a dynamic barrier island and will be a valuable tool in creating a management plan for sensitive island ecosystems.

Introduction:

The Red Fox (*Vulpes vulpes*) is one of the most widely distributed carnivores in the world (Kamler and Ballard 2002). It can survive in a wide variety of habitats and is very versatile in its diet. It can forage on carrion, rabbits, and rodents, as well as plant matter. In Europe the red fox diet can be reduced into three main food groups that consist of: rodents, hare, and carrion (Jedrzejewski, Jedrzejewska, 1992). A study of red fox diet in Sweden concluded that outside of *Microtus*, hares were a major component in their diet (Angerbjorn, 1989).

Historically, native red fox could be found in the boreal regions of North America. The nonnative red fox (*Vulpes vulpes*) was introduced into the eastern United States from Europe, in the 1700's for hunting purposes. Nonnative red fox outcompeted the native red fox, quickly spreading westward and now inhabit a majority of the United States (Kamler and Ballard 2002). The remaining native red fox population can be found in a small isolated section of the Western United States, at higher elevations. The nonnative red fox thrives in human altered areas. Nonnative red fox can easily adapt to diverse landscapes and climates having negative impacts on fragile ecosystems. Nonnative red fox are generalist predators, consuming prey that are accessible as well as less abundant native species (Kamler and Ballard 2002).

The nonnative red fox is considered a threat to island ecosystems because of the significant damage they can impose on nesting shorebirds. Red fox directly decrease survival in chick and brood productivity through nest predation. In addition, Red fox indirectly cause nest abandonment through harassment of shorebird's nest sites (Petersen 1982). On Shaiak Island, Alaska, red foxes influence nesting sites for shorebirds by caching eggs throughout the island and killing young chicks (Petersen 1982). Indeed, this may have lead to the decline of the Tufted Puffins (*Fratercula cirrhata*) on this island. In South Manitou Island, Lake Michigan, the red fox's nocturnal disturbances cause nesting shorebirds to knock eggs out of their nests that red foxes then prey on. The eggs that are not consumed cool and embryo development ceases, causing low chick survival for these nesting shorebirds (Southern et al. 1985).

Diet studies of red fox on Atlantic Barrier Islands are nearly nonexistent. One partial diet study was conducted on Assateague Island, Maryland as part of a red fox denning study (Krim, Bashore, Kirkland 1990). The study on Assateague Island focused primarily on denning behavior

with anecdotal information, non-diet revealing that 87% of the red fox diet consisted of mammals and 46% of the diet was avian.

This study is the first red fox diet analysis of an Atlantic Barrier Island, which shows the annual and seasonal diet of the red fox on Fire Island National Seashore (FINS), New York. The goal of this two-year study is to understand diet of red fox and compare diet between seasons. This study also investigates whether diet differs between residential and wilderness areas of the island. FINS is a prime nesting site of the Piping Plover (*Charadrius melodus*) and a potential nesting site for the Roseate Tern (*Sterna dougallii*), which are both federally listed as threatened and endangered, respectively (National Audubon Society 2004). The diet analysis investigated whether red fox are the main predators of these birds during the nesting season. From this study it is possible to make recommendations about how to augment current management plans for this non-native predator.

Methods:

Study Area:

FINS is a barrier island that stretches east to west off the southern coast of Long Island, New York (40 41' N, 73 00' W).



Figure 1. General map of Fire Island. Green areas represent NPS land and areas classified as wilderness areas. Beige areas are private residential communities on the island

FINS is approximately 55 km long and less than 0.5 km in width. The island is bordered by Fire Island Inlet to the west and Moriches Inlet to the east, and is separated from Long Island by the Great South Bay, Patchogue Bay, Bellport Bay, Narrow Bay and Moriches Bay.

FINS is 9,579 acres of both marine and terrestrial habitats. 1,380 acres make up the Otis Pike Fire Island High Dune Wilderness Area (Wilderness Area) and it is located at the eastern end of the island. The percentages of terrestrial habitats found at FINS include, 10% forested, 40% wetlands, 25% beach, swales and fields, and 25% developed lands (Trocki 2010).

FINS has a physiognomy of a typical Atlantic barrier island. Its topographic profile consists of flat beach by the ocean with a primary dune, interdunal swale, secondary dunes, maritime forest, and a salt marsh on the bayside of the island. Beach Grass (*Ammophila breviligulata*) is the common plant found on the primary dune. Woolly Beachheather (*Hudsonia tomentosa*), Seaside Goldenrod (*Solidago sempervirens*) beach plum (*Prunus maritima*), Northern Bayberry (*Myrica pensylvanica*), Virginia Creeper (*Parthenocissus quinquefolia*), and Poison ivy (*Toxicodendrum radicans*) are common plants found on the interdunal swale and secondary dunes. Highbush Blueberry (*Vaccinium corymbosum*), Black Chokeberry (*Aronia melanocarpa*) Black Cherry

(*Prunus serotina*), Pitch Pine (*Pinus rigida*), American Holly (*Ilex opaca*), Sassafras (*Sassafras albidum*), and Serviceberry (*Amelanchier canadensis*) are common plants found in the maritime forest. Smooth Cordgrass (*Spartina alterniflora*), Saltmeadow Cordgrass (*Spartina patens*), and Spike Grass (*Distichlis spicata*) are common plants found in the salt marsh (Trocki 2010).

FINS has a temperate maritime climate with an average high temperature during the winter of 4 C and 28 C during the summer. Average precipitation ranges from 74.4mm in July to 120.9mm in March.

Residential areas for this study include Talisman, Blue Point, and Watch Hill/Davis Park areas (shown in Figure 1). Residential areas were classified as areas that had both permanent and seasonal housing available. The Wilderness areas include the Otis Pike Fire Island High Dune Wilderness Area (OPWA), Bellport, and Old Inlet. Wilderness areas were classified as areas that were used just for recreation with no permanent or seasonal housing established and OPWA.

FINS has more than 330 species of birds that are both migratory and resident. Of the 330 species, 67 breed on FINS (Mitra, Putnam 1999). FINS is also located along the Atlantic Migratory Flyway and is a prime nesting site of the Piping Plover (*Charadrius melodus*) and a potential nesting site for the Roseate Tern (*Sterna dougallii*), which are both federally listed as threatened and endangered, respectively. The Least Tern (*Sterna antillarum*) and the Common Tern (*Sterna hirundo*) are both listed as NYS threatened species and are known to have breeding colonies on FINS as well (National Audubon Society 2004). FINS has 21 resident species of terrestrial mammals some of which include, the Woodland Vole (*Microtus pinetorum*) Meadow Vole (*Microtus pennsylvanicus*), White-footed Mouse (*Peromyscus leucopus*), Eastern Cottontail (*Sylvilagus floridanus*), Eastern Gray Squirrel (*Sciurus carolinensis*), Common Raccoon

(*Procyon lotor*), White-tailed Deer (*Odocoileus virginianus*), Red Fox (*Vulpes vulpes*), Eastern Mole (*Scalopus aquaticus*), Muskrat (*Ondatra zibethicus*) and Norway Rat (*Rattus norvegicus*) (Trocki, 2010).

Field Methods:

Red fox feces were collected approximately twice a month from February 2011 until December 2012 with a total of 90 feces samples collected over the study period. Sample sizes between the 4 seasons, fall (September-October), winter (January-February), spring (March-May), and summer (June-August) were similar in 2012. Samples from our 2011 were only collected during fall and winter therefore they were not used for seasonal variation. Preliminary observations have shown that red foxes prefer to defecate on roadsides and boardwalks (Brunner, Amor, Stevens 1976). Therefore, feces were collected on boardwalks that are located throughout the island in both the Wilderness Area of Fire Island, as well as the eastern communities (Talisman, Blue Point, and Watch Hill/Davis Park) on Fire Island (Figure 5). All areas were surveyed for red fox feces twice a month.

Red fox feces were identified by length and diameter. Red fox feces are tubular and tapered at both ends, with a 12.7 to 15.9mm diameter and 76.2 to 152.4mm length (Murie 1982).



Figure 2. Red fox feces on the boardwalk at FINS

Signs of red tracks around feces found in sand along the boardwalk were also used in identifying the red fox feces. Red fox tracks show both 4 toes on the hind and fore paw with claws shown. The fore print measures 57.2mm in length and 50.8mm in width with a distinct inverted V shape (Murie 1982). The hind print for the red fox is 50.8mm long and 44.5mm in width, thus helping to distinguish the difference of red fox tracks from other mammals on FINS such as the Domestic Dog (*Canis lupus*), Domestic Cat (*Felis catus*), and Raccoon (*Procyon lotor*).



Figure 3. Red fox tracks in the sand on FINS

Individual feces were collected in brown paper bags. For each feces, location and date were recorded with a Global Positioning System (Trimble Navigation Limited, Sunnyvale, CA) and Garmin units (Garmin International Inc., Olathe, KS).

Laboratory Methods:

Dry weight of each fecal sample was recorded in grams. In order to separate the prey items within each fecal sample, a series of mesh sieves were used (78-700 Fieldmaster Sieves, Science First, Yulee, FL). Sieves were arranged in decreasing mesh size, with sieve layer 5 on the top and sieve layer 250 on the bottom. Sieve layer 5 (4,000 microns), sieve layer 10 (2,000 microns), and sieve layer 35 (500 microns) were kept in Pace University's Environmental Science Laboratory. Sieve layer 60 (250 microns), sieve layer 120 (125 microns), and sieve layer

250 (60 microns) were all sand based layers, which did not aid in diet analysis; therefore, they were discarded. Sieve layers 5, 10, and 35 were placed on labeled paper plates and left under the general chemistry fume hood in the laboratory to dry for approximately one week. Each sample was then put into separate, labeled plastic bags.

Prey was classified into 6 major categories: mammal, avian, crustacean, plant, fish, and unknown. Hair samples were used to identify mammalian prey remains by mounting samples onto slides using the Carolina Hair Analysis Kit's Kleermount (Carolina Biological Supply Company, Burlington, NC). Hair samples were analyzed microscopically and the Adorjan and Kolenosky (1969) method of identification was followed to determine species by analyzing the distal, medial, and proximal portions of the known hair samples. Bones were used to identify mammalian, fish, and avian remains. These bone samples were also used to classify subadult versus adult mammalian prey items. Observing bone texture and observation of teeth confirmed adult versus subadult mammalian prey. Since DNA analysis was not used to identify fecal remains mammalian bones were identified to species, avian bones identified to order and family (Gilbert et al. 1979), and fish identified to class. Plants were identified to kingdom, and crustaceans were identified to subphylum. Our unknown category contained particles of soil and debris that could not be identified and most likely resulted from accidental ingestion while consuming the prey item.

Statistical Methods:

Prey categories were represented by calculating the relative frequency of occurrence: (number of times each prey item occurs among all samples/total number of occurrences of all prey) x 100 (Phillips, Winchell, Schmidt 2007). Logistic regression was employed for the analysis of data (Duxbury, 2008). Two separate analyses were done. The first analysis was

conducted for 2011 and 2012 combined (MINITAB, 2010). We took two factors: location and year, and created two dummy variables, one for the year and the other for location. The dummy variable for year is X_1 , taking values 0 for 2011 and 1 for 2012. The dummy variable for location is X_2 , taking values 0 for residential areas and 1 for the wilderness areas (Table 2).

The second analysis was conducted for 2012 (MINITAB, 2010). The 2012 fecal samples were tested for seasonal variation using the relative frequency of occurrence for mammalian and avian prey items. If the probability of presence of mammals in the diet is denoted by p , then we model its logistic transform (i.e., $\ln(p/(1-p))$) as a linear combination of season and location effect (Table 2). The same analysis was conducted for the response in presence of avian items in the diet.

Results:

No bones or feathers in the order and family of the Piping Plover (endangered species) that inhabit FINS were detected in red fox feces. Small mammals were most frequently preyed upon in both residential and wilderness areas (Table 1). The meadow vole was one of the most frequently consumed prey item, and red foxes tend to prey on the subadults of this species determined by (%) is the frequency of occurrence of that prey item (Table 1). There was no anthropogenic waste in any of the red fox samples.

Table 1. Diet items consumed by red fox in wilderness areas and residential areas on Fire Island. n is the number of times a prey item occurred in feces for the year and (%) is the frequency of occurrence of that prey item.

Diet Item	2011		2012	
	Residential n (%)	Wilderness n (%)	Residential n (%)	Wilderness n (%)
Mammalian	11 (44)	17 (45.9)	16 (31.4)	10 (18.2)
<i>Microtus pinetorum</i> (subadult)	0 (0)	3 (8.1)	1 (2)	0 (0)
<i>Microtus pennsylvanicus</i>	2 (8)	2 (5.4)	7 (13.7)	5 (9.1)
<i>Microtus pennsylvanicus</i> (subadult)	2 (8)	5 (13.5)	1 (2)	1 (1.8)
<i>Peromyscus leucopus</i>	2 (8)	0 (0)	2 (3.9)	0 (0)
<i>Sylvilagus floridanus</i>	2 (8)	4 (10.8)	2 (3.9)	2 (3.6)
<i>Sylvilagus floridanus</i> (subadult)	1 (4)	1 (2.7)	1 (2)	1 (1.8)
<i>Sciurus carolinensis</i>	0 (0)	1 (2.7)	0 (0)	0 (0)
<i>Procyon lotor</i>	1 (4)	0 (0)	0 (0)	1 (1.8)
<i>Odocoileus virginianus</i>	1 (4)	1 (2.7)	2 (3.9)	0 (0)
Aves	7 (28)	8 (21.7)	10 (19.6)	14 (25.5)
<i>Laridae</i>	1 (4)	1 (2.7)	4 (7.8)	4 (7.3)
<i>Anatidae</i>	2 (8)	0 (0)	3 (5.9)	4 (7.3)
<i>Passeriformes</i>	4 (16)	7 (18.9)	3 (5.9)	6 (10.9)
Plant Material	3 (12)	3 (8.1)	6 (11.8)	8 (14.5)
Osteichthyes	0 (0)	0 (0)	1 (2)	1 (1.8)
Crustacea	0 (0)	1 (2.7)	7 (13.7)	8 (14.5)
Unknown	4 (16)	8 (21.6)	11 (21.6)	14 (25.5)

In 2012 neither location nor season showed significant differences with consumption of mammalian and avian prey items (Fig 4). When testing for the relative frequency of occurrence for mammalian prey items the p-value is 0.619. The independent variables are season and location. The dependent variable is 'presence' or 'absence' of mammals (or birds in the second analysis) in the diet. When testing, all the factor effects (i.e., season and location) are zero. When testing for the relative frequency of occurrence for avian prey items the p-value is 0.569. Thus we are led to the conclusion that in 2012 neither season nor location seems to be important factors for the presence or absence of birds or mammals in the red fox diet (Fig 5 & 6).

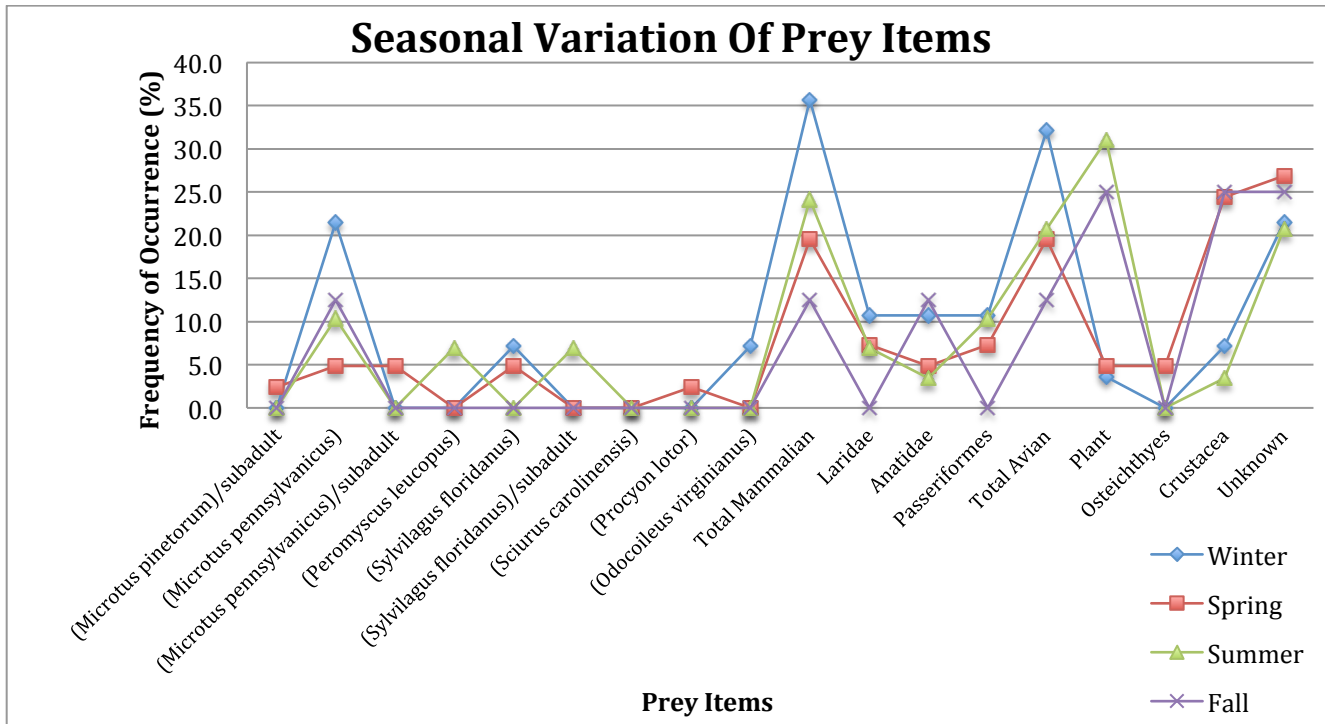


Figure 4. Diet items consumed in 2012 by red fox between the 4 seasons, fall (September-October), winter (January-February), spring (March-May), and summer (June-August) on FINS, New York.

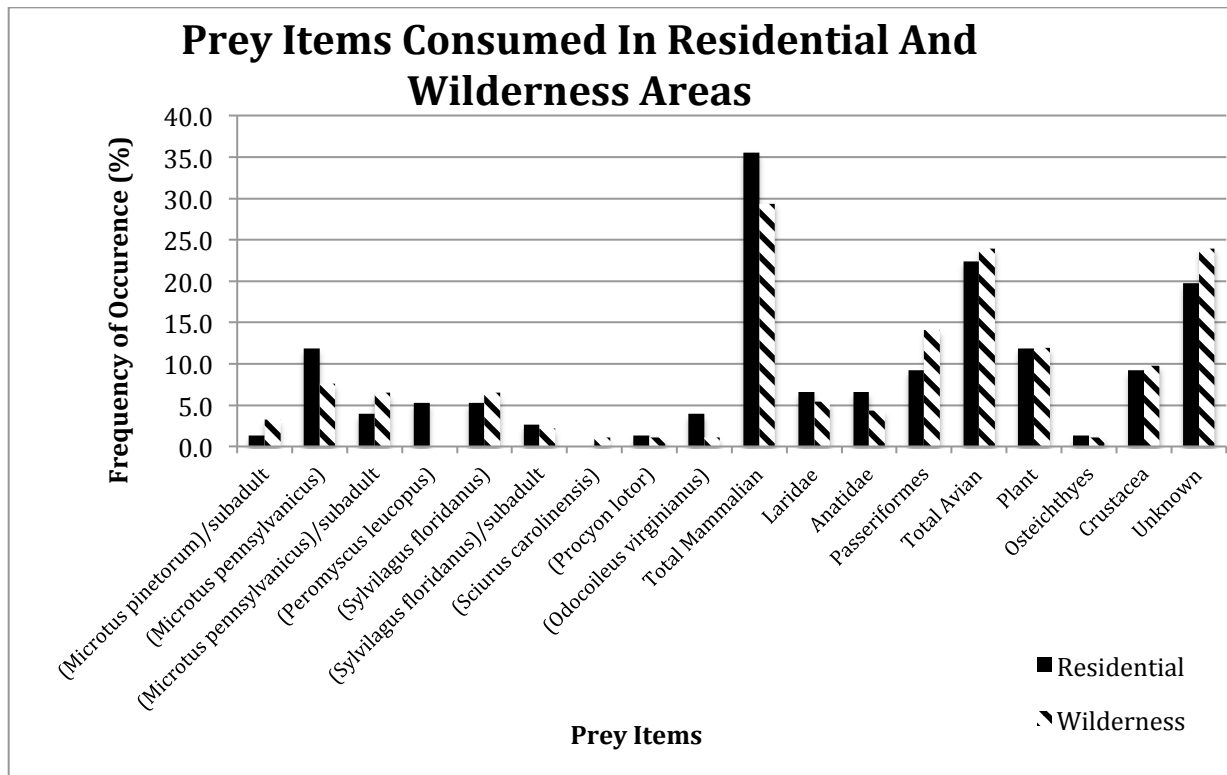


Figure 5. Diet items consumed by red fox in Wilderness areas (Otis Pike Fire Island High Dune Wilderness Area (OPWA), Bellport, and Old Inlet) and in residential areas (Talisman, Bluepoint, and Watch Hill/Davis Park) for 2011 and 2012 combined on FINS, New York.

When a logistic regression is carried out for the presence of mammals in the diet, the location effect is not statistically significant ($p=0.342$), but the year effect (2011) is statistically significant ($p=0.015$), with more mammalian prey consumed in 2011. If p is the probability of presence of mammals in the diet, then the logistic model is $\text{logistic}(p)=\beta_0+\beta_1X_1+\beta_2X_2$. The p -value for the likelihood ratio test for the probability of mammalian items in the diet, when both β_1 and β_2 are zero turns out to be 0.030.

Neither the year effect nor the location effect is statistically significant for avian prey items. The p -value associated with the likelihood ratio test for the year effect and location effect when both β_1 and β_2 are zero turns out to be equal to 0.942 (see Figure 6).

Table 2. Estimates of the parameters (season and location) (Coef), standard errors (SE), z -values, the p -values for testing if each of the beta parameter is zero, and the odds ratios.

Predictor	Coef	SE	Z	P	Odds ratio
Constant	0.9802	0.4528	2.16	0.030	
Year	-1.1200	0.4598	-2.44	0.015	0.33
Location	-0.4201	0.4418	-0.95	0.342	0.66

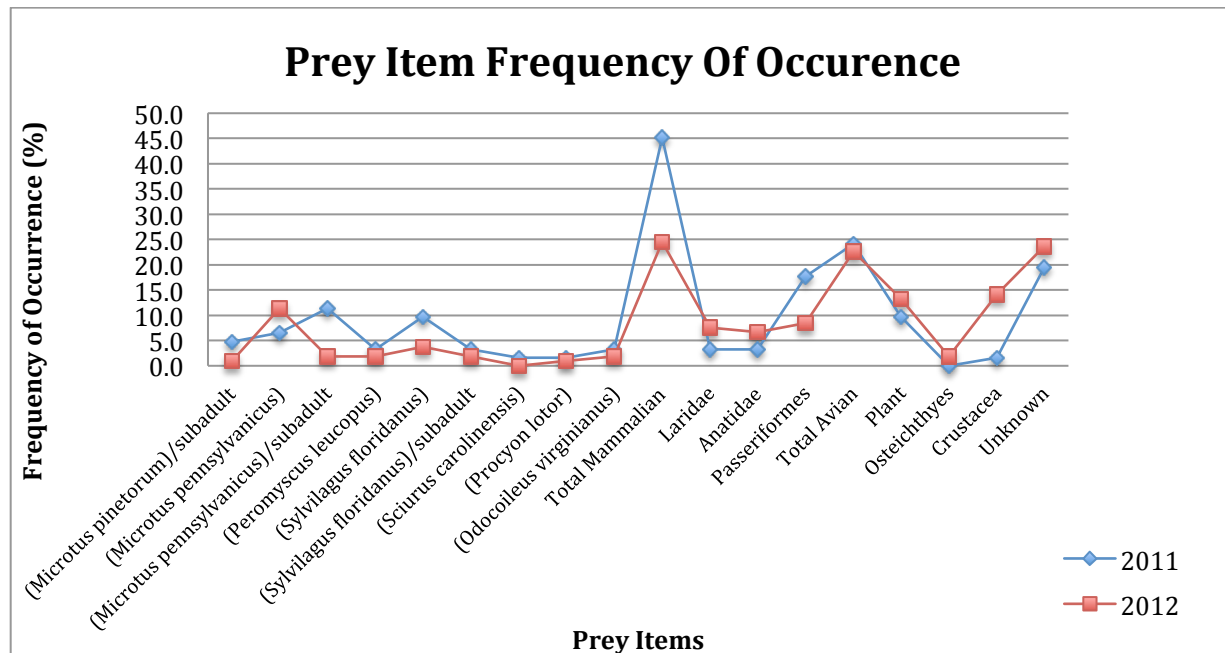


Figure 6. The frequency of prey items for the year 2011 and 2012.

Discussion:

Our results show that small mammals (meadow voles) are the main prey item for red fox on FINS, with significantly more mammalian prey consumed in 2011 then in 2012. Red fox on FINS tend to prey on subadult meadow voles more frequently then adult meadow voles; however, they preyed on a wide variety of items opportunistically throughout the year. Prey items were available during all seasons with the exception of migratory birds. Red fox on FINS did not scavenge or consume anthropogenic waste. The only scavenging that occurred was on whitetail deer carcasses.

Other studies demonstrate seasonal shifts in diet. For example, in the Swiss Jura Mountains, red fox prey more heavily on water voles during winter, wild fruits in autumn, and earthworms in spring (Ferrari, Weber 1995). During summer, red fox at the South San Francisco Bay consume mostly avian prey (63%), with the most important avian prey being waterfowl (Meckstroth, Miles, Chandra 2007). The red fox that were observed in Monterey County,

California, preyed heavily on voles during the spring and summer seasons (Meckstroth, Miles, Chandra 2007).

Location (Residential vs. Wilderness areas) did not influence prey selection. One possibility is that human disturbance may not affect red fox eating habits. Therefore, red fox easily obtain prey from the residential and wilderness areas on the island. This could be a reason for the lack of anthropogenic waste in fox feces.

The red fox has been categorized as a threat to Alaska's Shaiak Island ecosystem, by caching eggs and killing chicks of the shorebirds (Peterson 1982). Predators, such as red fox, are known to kill surplus prey on islands (Southern et al. 1985). South Manitou Island in Lake Michigan is an example of predators killing more prey than needed. The red fox's nocturnal disturbances cause gulls to knock eggs out of their nest, which red foxes preyed on. The eggs that were not consumed cooled and embryo development ceased which caused low chick survival for these gulls (Southern et al. 1985). This is not the case on FINS. Piping Plover remains were not detected in our fecal samples. This may be due to the fact that Piping Plover nests on FINS have exclosures around them, hence protecting them from predators. However, the exclosures only protect the Piping Plover nests during incubation. Piping Plover chicks do not stay in the exclosure once they hatch. They are precocial and begin running around the beach soon after hatching, making them more visible and susceptible to predation. In other areas exclosures have been shown to act as targets for red fox, and although they dig and do not reach the eggs, they harass chicks and cause nest abandonment (Doherty & Heath 2011). Indirect red fox impacts, such as nest abandonment and harassment, could not be observed through a diet analysis. Through other methods, such as camera traps and behavioral observations, future studies could be conducted to understand indirect relationships.

While exclosures should still be utilized each season to deter red foxes from predating plover nests during incubation, red fox are not the only predator on the island. Indeed, some other potential predators include: Raccoon (*Procyon lotor*), Herring Gull (*Larus smithsonianus*), American Ghost Crab (*Ocypode quadrata*), and the American Crow (*Corvus brachyrhynchos*) (McIntyre, Heath, Jannsen 2010). These and other potential predators may be preying on the endangered shorebirds and their eggs.

A future FINS management plan should consider the impacts of all potential predators as well as a wide range of other factors affecting piping plover survival and productivity, including overwash from high tides and human disturbances. Closely monitoring the health of the red fox population could help determine the relationship between mange and predator/prey cycles on FINS. A similar study was conducted to determine the effect of mange in red fox on small mammal populations in Scandinavia (Lindstrom et al. 1994). The cyclic fluctuations of voles and small game decreases or disappears as mange strikes the red fox populations (Lindstrom et al. 1994).

One suggestion for further study would be to set camera traps on or close to the plover exclosures. Camera traps would aid in the detection of plover predators and create a population estimate for the red fox on FINS. Camera trapping for red fox abundance has been done successfully before in Serra da Malcata, Portugal (Sarmiento et al. 2009). Camera traps would also aid in the detection of other prey items the red fox could be consuming, if placed outside of red fox dens on FINS. No single technique is ideal for studying carnivores (Gompper et al. 2006). A combination of the above, supplemented by continuous fecal collection, may be helpful in further investigating the FINS red fox population and impacts to sensitive species FINS is concerned with.

FINS is one of the prime nesting sites of the endangered Piping Plover (*Charadrius melodus*) on the East Coast (National Audubon Society 2004). Since plovers nest on FINS for 4 to 5 months, it is imperative to collect red fox fecal samples more frequently during these summer months. To distinguish moderate effects in fecal samples, 94 samples would be the ideal number for a given period of time, according to a power test conducted in 2005 (Trites & Joy 2005). Instead of sampling 90 feces over 2 years (as we did during this study), approximately 90 samples should be collected for the 4 to 5 months that the Piping Plover inhabit FINS. This would provide a better picture of the summer diet for the red fox. If Piping Plovers are a main component of their diet it would be more prevalent during the months the Piping Plover populations are more abundant.

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