Population Structure of Harvested Red Foxes (*Vulpes vulpes*) and Coyotes (*Canis latrans*) on Prince Edward Island, Canada

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An understanding of the population dynamics and habitat of wild Red Foxes (*Vulpes vulpes*) and Coyotes (*Canis latrans*) is a prerequisite to wildlife management. This information is also important in assessing the risk these wild canids pose to the public and domestic animals. On Prince Edward Island, information on age, sex, reproductive activity, and habitat use of 271 Red Foxes and 201 Coyotes was collected in the hunting and trapping season of 2004–2005. The estimated age of Red Foxes and Coyotes ranged from 0.5 to 13.5 years. A large proportion of harvested Red Foxes and Coyotes (58% and 48%, respectively) consisted of juveniles. The sex ratio was not significantly different from 1:1 for either species. Average litter size was 5.0 and 5.2 for Red Foxes and Coyotes, respectively. Number of placental scars ranged from 0 to 7 in Red Foxes and from 0 to 11 in Coyotes. Agricultural areas were the main habitat type (52%) of harvested Red Foxes. For harvested Coyotes, forest was the main habitat (44%), followed closely by agricultural areas (43%). Urban areas were a significant part (13%) of the habitat of Red Foxes. These data can be used to monitor population dynamics over time, provide information for wildlife management, and provide information on potential risk areas for disease transmission by wild canids.

Key Words: Coyote, *Canis latrans,* Red Fox, *Vulpes vulpes*, age, reproductive activity, habitat, Prince Edward Island.

The abundance of Coyotes (*Canis latrans*) on Prince Edward Island has increased rapidly since they were first observed in 1983, and Coyotes now occur throughout the island. Coyotes have been observed scavenging carcasses close to cattle, poultry, and hog farms (Field 2003). The role of Coyotes as a predator of domestic livestock is frequently cited as a justification for control of this species (Chambers 1992; Parker 1995; Mitchell et al. 2004). There is no published report regarding the population density of Coyotes in the province, but it has been estimated at 0.4 animals/km^2 (R. Dibblee, Prince Edward Island Department of Environment, Energy and Forestry, personal communication). In eastern Canada, several studies have documented specific aspects of Coyote demography. These studies, carried out in Quebec, Nova Scotia, and New Brunswick, focused on body condition (Poulle et al. 1995; Dumond and Villard 2000), productivity (Jean and Bergeron 1984), and social organization and space use (Patterson and Messier 2001). Two studies were previously carried out on Prince Edward Island (Field 2003; Gautreau 2004) to investigate the population ecology of Coyotes; however, the sample size in both studies was limited.

The Red Fox (*Vulpes vulpes*) is common on Prince Edward Island (Government of PEI, 2012). Many Red Foxes on Prince Edward Island have lost their fear of people, as they are often fed in campgrounds and urban areas. This proximity to people may pose a risk to human health. Red Foxes and Coyotes can be carriers of pathogens, such as the rabies virus (Constantine 1966) and the zoonotic parasites *Toxocara canis* (Smith et al. 2003; Wapenaar et al. 2013) and *Echinococcus* spp. (Eckert et al. 2000). Furthermore, Red Foxes and Coyotes can play a role in transmitting diseases, such as *Sarcocystis* spp. (Farmer et al. 1978) and *Neospora caninum* (Wapenaar et al. 2006), to livestock.

The density of Red Foxes in the province is estimated at 1 animal/km^2 (R. Dibblee, Prince Edward Island Department of Environment, Energy and Forestry, personal communication), comparable to densities of Red Foxes reported in metropolitan Toronto, Ontario (Voigt 1987; Rosatte et al., 1991). There are limited published studies of Red Foxes in eastern Canada. One report from Prince Edward Island described the Red Fox population from 1972 to 1980 (Curley 1983). Long-distance movement (170 km) of one Red Fox (Rosatte 2002) and the ecology and disease management implications of Red Foxes in Toronto (Adkins and Stott 1998; Rosatte and Allan 2009) have also been described. Voigt and Macdonald (1984) described significant variation in spatial behaviour of Red Foxes in rural Ontario and in Oxfordshire in the U.K. However,

the demography of Red Foxes on Prince Edward Island may have changed since 1980, and their behaviour there is expected to be different from that in an urban environment, such as Toronto.

Descriptive baseline studies are required to better understand the population dynamics of Red Foxes and Coyotes to help monitor and provide evidence for appropriate wildlife management. Better understanding of wild canid populations makes managing the risk of disease transmission to humans and domestic animals more feasible. The objective of this study was to describe the population structure and habitat of harvested Red Foxes and Coyotes on Prince Edward Island.

Methods and Materials

Field sample collection

Red Fox and Coyote carcasses were obtained from 32 hunters and trappers on Prince Edward Island, Canada, between 19 October 2004 and 24 March 2005. All carcasses were sampled as soon as possible after death, varying from a few hours to five days. Sex, date of death, and the location where the animal was killed were recorded. Location was based on written or verbal information collected from hunters and trappers, who used names of villages or other landmarks nearby the place of harvest to identify the location.

A canine tooth was extracted from the lower jaw of each carcass for age analysis. Radiographs were made of the individual canine teeth to assess width of the pulp cavity to differentiate between a juvenile (<1 year old) and an adult animal (>1 year old) (Johnston et al. 1999). The age of adult animals was determined by counts of the annual growth zones in the canine tooth cementum (Grue and Jensen 1976). Most Red Foxes and Coyotes give birth in spring. Because sample collection was performed in fall and winter, the minimum estimated age recorded was 0.5 year and increased in 1-year increments.

Reproductive tracts were removed from female Red Fox and Coyote carcasses. Reproductive status was assessed based on the presence of placental scars in females older than 1 year of age. Only dark placental scars were considered in the estimation of litter size of the most recent breeding season; pale scars may have originated from a previous reproductive season (Martorell Juan and Gortazar Schmidt 1993).

Habitat characteristics

Foxes and coyotes were collected throughout Prince Edward Island, Canada. The present land surface of PEI ranges from nearly level in the west to hilly in the central region and to rolling hills in the east. The shoreline of PEI generally alternates between headlands of sandstone bluffs and sandy beaches. Close to 50% of the land on PEI has been identified as being highly productive farm land and the remaining habitat consists mainly of forest and a small proportion of wetland. Latitude and longitude of the locations where the animals were killed were recorded and entered into GIS software (ArcGIS 9.0) (ESRI Corp., Redlands, California).

Firstly, the habitat characteristics were defined by drawing a circle round the recorded location to represent the estimated home range (9 km^2 for Red Foxes and 50 km^2 for Coyotes). These estimates of home range size were based on previous studies (Harris 1977; Lloyd 1980; Voigt and Tinline 1980; Trewhella et al. 1988; Atkinson and Shackleton 1991; Field 2003; Gautreau 2004; Rosatte and Allan 2009).

The size of the home range of Coyotes reported previously varies considerably, ranging from 3 km^2 to 100 km^2, depending on the region, availability of food, human activities, reproductive season, and the technique used to calculate the home range. For example, home ranges are smaller in urban habitats than in rural habitats (Atwood et al. 2004). Because this study was performed in a rural area in winter, a large home range estimate of 50 km^2 was used.

Secondly, to determine the predominant land use type within the habitat of harvested Red Foxes and Coyotes, we derived land use data from field-validated aerial photographs of Prince Edward Island taken in 2000 (Government of PEI, 2013). These data were redefined into four general land use categories: forest, agriculture, wetland, and urban areas. Clear-cuts, abandoned land, and tree plantations were included in the forest category. Agriculture consisted of farmsteads, feedlots, fur ranches, orchards, pastures, and cropland. Swamps and marshes were considered wetland. Urban land types consisted of commercial, recreational, park, institutional, residential, greenbelt, and transportation land use. The percentage of each of these land types within the estimated habitat of individual Red Foxes and Coyotes was calculated using ArcGIS 9.0.

Statistical analyses

A one-sample proportion test was used to compare habitat proportions with the overall cover type distribution on Prince Edward Island. χ^2 analysis was used to investigate distribution of age, sex, and reproductive status. A Student's *t*-test was used to analyze the distribution of litter size between primiparae and multiparae Red Foxes and Coyotes. EpiTools epidemiological calculator (Sergeant 2009*) was used for the statistical analyses of the data.

Results

Descriptive data

We collected data on 271 Red Foxes and 201 Coyotes in Prince Edward Island during the period from October 2004 to March 2005. This sample size represented 34% of the Red Foxes (Government of PEI, unpublished data) and 59% of the Coyotes (Government of PEI, 2012) that were harvested during the 2004-2005 trapping and hunting season on Prince Edward Island. The method of kill for most Red Foxes (96%) (n = 261) and Coyotes (55%) (n =111) was trapping. Five Red Foxes and 2 Coyotes collected for

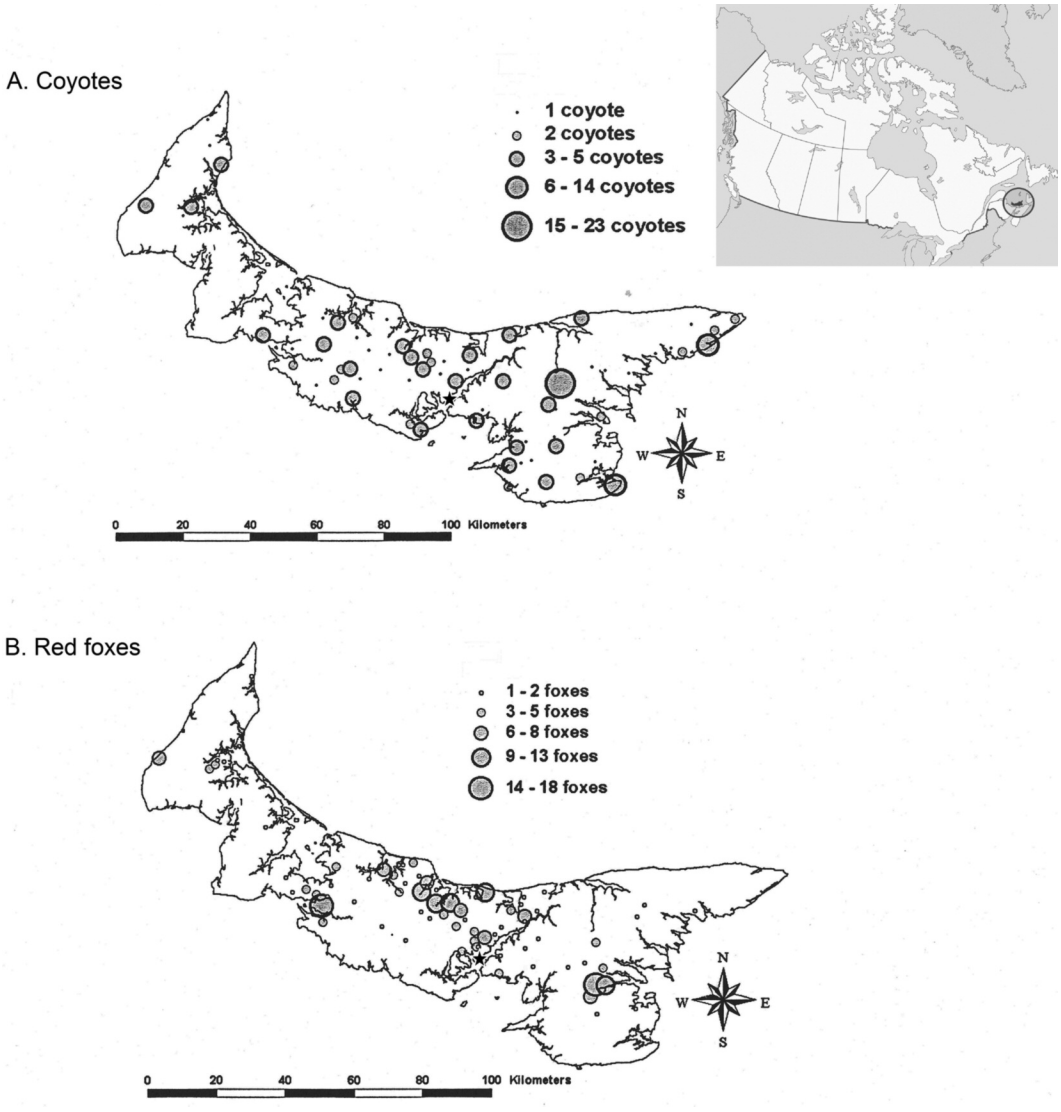

FIGURE 1. Graduated points of locations on Prince Edward Island, Canada (46° degrees latitude, -63° degrees longitude), where Coyotes (*Canis latrans,* Map A) and Red Foxes (*Vulpes vulpes,* Map B) were trapped or hunted in 2004–2005 (ArcGIS 9.0, ESRI Corp., Redlands, California). The capital Charlottetown is indicated by a black star.

this study were killed by motor vehicles and the remaining Red Foxes ($n = 5$) and Coyotes ($n = 88$) were killed by hunters.

Red Foxes were mainly collected in December; Coyotes were collected more consistently throughout the hunting and trapping season (approximately 30–40 Coyotes per month from November until March). Coyote harvesting was evenly distributed across Prince Edward Island, whereas Red Fox harvesting was mainly clustered in central Prince Edward Island (Figure 1). A high number of Red Foxes (35%) collected by one trapper contributed to this clustering. Sex was recorded for 246 Red Foxes (115 females and 131 males) and for 180 Coyotes (92 females and 88 male). The sex ratio was not significantly different from parity in Red Foxes ($P = 0.21$) or Coyotes ($P = 0.79$).

Age distribution and litter size

Canine teeth were collected from 271 Red Foxes and 184 Coyotes. The proportion of juvenile Red Foxes (58%) ($n = 158$) was significantly higher than the proportion of juvenile Coyotes (48%) ($n = 89$, $P = 0.04$). The age distribution ranged from 0.5 to 13.5

TABLE 1. Distribution of age and sex recorded for 246 Red Foxes (*Vulpes vulpes*) and 163[b] Coyotes (*Canis latrans*) collected in 2004-2005 on Prince Edward Island, Canada.

Age (years)	Red Fox				Coyote			
	Male		Female		Male		Female	
	N	%	*N*	%	*N*	%	*N*	%
0.5	84	64	57	50[a]	35	45	40	47
1.5	19	15	21	18	14	18	15	17
2.5	17	13	18	16	10	13	11	13
3.5	3	2	10	8	6	8	7	8
4.5	4	3	3	3	4	5	5	6
5.5–10.5	4	3	4	3	6	8	7	8
11.5–13.5	0	0	2	2	2	3	1	1
Total	131	100	115	100	77	100	86	100

[a] Significant ($P = 0.03$) difference between male and female juvenile Red Foxes.
[b] This is a subset of the total harvested number of coyotes, as both age and sex data were only available from 163 carcasses.

TABLE 2. Age-related reproductive status, average litter size (extrapolated from placental scars), and number of placental scars observed in 51 female Red Foxes (*Vulpes vulpes*) and 32 female Coyotes (*Canis latrans*) collected in 2004-2005 on Prince Edward Island, Canada.

			Average litter size (*n*)	Number of placental scars/female				
	n	Reproductively active (%)		0	1 or 2	3 or 4	5 or 6	7 to 11
Red Fox	16	50	4.9	8	0	4	3	1
	17	76	5.4	4	0	3	8	2
	10	70	4.7	3	1	2	3	1
	8	75	4.8	2	0	3	2	1
	51	66	5.0	17	1	12	16	5
Coyote	11	55	2.5[a]	5	3	3	0	0
	11	55	5.7	5	0	1	4	1
	3	100	7.0	0	0	1	1	1
	7	100	6.3	0	0	0	5	2
	32	68	5.2	10	3	5	10	4

[a] Significant ($P < 0.05$) difference between the extrapolated average litter size in primiparae and multiparae Coyotes.

years for both Red Foxes and Coyotes (Table 1). The median age was 0.5 years (mean 1.5) and 1.5 years (mean 2.1) for Red Foxes and Coyotes, respectively. Juvenile Red Foxes were more often male than female ($P = 0.03$) (Table 1); this skew was not present in Coyotes ($P = 0.60$). The oldest Red Fox was a 13.5-year-old female, and she had no dark or pale placental scars. Two Coyotes of 13.5 years of age were collected, a female with 5 placental scars and a male.

Uteri were not available from all female Red Foxes and Coyotes, due to autolysis of carcasses that made placental scar counts unreliable. Placental scar counts were performed on the uteri of 51 adult female Red Foxes and 32 adult female Coyotes. Thirty-four of 51 (66%) adult female Red Foxes and 22 of 32 (68%) adult female Coyotes were reproductively active (Table 2). Fifty percent of Red Foxes and 55% of Coyotes of 1.5 years of age were reproductively active.

The average litter size for Red Foxes and Coyotes, extrapolated from placental scar counts, was 5.0 (95% CI, 4.5–5.5) and 5.2 (95% CI, 3.9–6.4), respectively. Number of placental scars ranged from 0 to 7 in Red Foxes and from 0 to 11 in Coyotes (Table 2). In Coyotes, the litter size of primiparae was smaller than for multiparae ($P = 0.001$). This significant increase in litter size in multiparae was not observed in Red Foxes ($P = 0.36$).

Habitat characteristics

Habitat characteristics were estimated for 266 harvested Red Foxes and 185 harvested Coyotes for which the location of kill was recorded. For both canids, agricultural areas were important habitat types, comprising 52% of the habitat of Red Foxes and 43% of the habitat of Coyotes. Forest was the largest habitat type for Coyotes, comprising of 44% of their habitat (Table 3). The estimated habitat of harvested Red Foxes contained a higher percentage of urban (13%) and agricultural (52%) land types than the distribution of these land types on Prince Edward Island as a whole (Table 3).

Discussion

To our knowledge, this is the first descriptive report on age, sex, litter size, and habitat of harvested Red Foxes and Coyotes on Prince Edward Island. A small proportion consisted of remarkably old animals, with

TABLE 3. Distribution of land types on Prince Edward Island compared to the distribution of land types in the estimated habitat of harvested Red Foxes (*Vulpes vulpes*) (n = 266) and Coyotes (*Canis latrans*) (n = 185) collected in 2004-2005 on Prince Edward Island, Canada.

	Habitat type		
	On Prince Edward Island	Of Red Foxes	Of Coyotes
Forest (%)	47	29[a]	44
Agriculture (%)	39	52[a]	43
Wetland (%)	8	6	7
Urban (%)	6	13[a]	6

[a] Significant difference ($P < 0.01$) between the percentage of land type in the habitat of harvested Red Foxes and the distribution of the same land type on Prince Edward Island.

one Red Fox and two Coyotes of 13.5 years of age. A Coyote of 16.5 years of age has previously been reported in New Brunswick (Dumond and Villard 2000). This is the first published report of a wild Red Fox of 13.5 years of age in eastern Canada.

A high proportion of harvested Red Foxes (58%) were juveniles. This may represent the actual age ratio, but it could also be explained by less experienced juvenile Red Foxes being easier to trap. High juvenile counts are common when trapping Red Foxes and Coyotes: a previous study reported that juveniles comprised 64% of a mainly trapped Red Fox population studied on Prince Edward Island between 1972 and 1980 (Curley 1983). The high proportion of juvenile Red Foxes could also be attributed to the abundance of food, as an increase in food supply would support better body condition and survival rates for young individuals (Voigt 1987; Dumond and Villard 2000).

The average and median ages of Red Foxes were lower than for Coyotes. Eighty-five percent of Coyotes in 14 North American studies were under 3 years of age (Parker 1995), which is similar to 76% of the harvested Coyote population in this study. However, age estimates vary greatly among studies: in nearby northeastern New Brunswick, an unusually high average age of 5.6 years has been observed in Coyotes (Dumond and Villard 2000).

The extrapolated average litter size of Red Foxes corroborates the findings from a previous study performed on Prince Edward Island, where a litter size of 5.2 was observed (Curley 1983). A mean litter size of 4.7, 3.3, and 8.0 was observed in studies of Red Foxes around Bristol, U.K. (Harris and Trewhella 1988), in northeastern Spain (Martorell Juan and Gortazar Schmidt 1993), and in Ontario (Voigt and Macdonald 1984), respectively. The differences in climate and habitat between Europe and Prince Edward Island are significant and may have influenced the difference in litter size.

The percentage of reproductively active female Coyotes (68%) is higher than previous findings of 54% on Prince Edward Island (Field 2003). In a study in New Brunswick, only 41% of adult female Coyotes were reproductively active, and on average 6.6 placental scars were present in females older than 5 years (Dumond and Villard 2000).

Litter sizes of Coyotes generally vary between 3 and 4 per litter in established populations, whereas litter sizes in harvested populations of Coyotes vary between 5 and 8 pups per litter (Field 2003). In this study, an increasing litter size for multiparae Coyotes was observed (Table 2). Data from only one hunting season were available, so it was not possible to compare our findings to pre-harvest data and it is therefore not feasible to assess the effect of harvesting on the population. Continued annual data collection would provide valuable information on changes in litter size.

It is important to note that the presence of placental scars is most commonly used in wildlife to indicate the number of young born in the most recent litter. However, counting placental scars is a crude measure of reproductive success, because it fails to account for resorption of embryos, aborted foetuses, or pup or kit mortality. Therefore, our findings may be an overestimate of actual litter size derived from counting pups at a den site. A study of fetal viability in captive wild-caught Coyotes found that 75–85% of the placental scars represented live pups in most years, although lower percentages were observed among younger and older females (Green et al. 2002).

A previous study indicated that the relative abundance of Red Foxes and Coyotes on Prince Edward Island was uniform throughout the island (Field 2003). Coyotes were collected in an even distribution over the island in the current study, and the findings from the harvested Coyotes may therefore be representative of the general Coyote population. However, there are the limitations associated with using harvesting records to infer population demography. A previous study investigating harvesting records of Red Grouse (*Lagopus lagopyus scoticus*) determined that the sample population poorly reflected the true age and sex ratio of the wild population (Bunnefeld et al. 2009).

The habitat of harvested Red Foxes and Coyotes was estimated by placing a buffer of 9 km^2 and 50 km^2, respectively, round the point of capture. These zones may not have accurately represented the true habitat of the Red Foxes and Coyotes, as some of these animals may have been tracked for some time before they were killed. In addition, the method of kill for 96% of the collected Red Foxes was trapping, in contrast to 55% for the Coyotes. Trapped animals were expected to be

trapped in their natural habitat; however, one trapper was responsible for 35% of harvested Red Foxes, and this may have biased the results and therefore limits application of the findings of the harvested population to the wild Red Fox population on Prince Edward Island. On the other hand, it is common for trappers to trap in areas where they expect many Red Foxes, and the current sample of Red Foxes may therefore be representative of their distribution. Similarly, a study investigating Red Grouse demonstrated that the number of Red Grouse shot did reflect the actual density (Bunnefeld et al. 2009). Comparative research with radiotelemetry or multiple recapture data was not feasible within this study but is required to determine whether the estimated distribution and habitat preferences are truly representative of the natural habitats of these wild canids.

This study described the characteristics of harvested Red Fox and Coyote populations on Prince Edward Island with a high proportion of reproductively active females and a high litter size, particularly in multiparae Coyotes. Agricultural areas for both Red Foxes and Coyotes and urban areas for Red Foxes were an important part of the habitat, indicating that there is ample opportunity for these animals to transmit disease to humans and domestic animals. Gathering additional data on population dynamics over time would be valuable to inform appropriate wildlife management and provide information on potential risk areas for disease transmission by wild canids.

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