

Age and condition of deer killed by coyotes in Nova Scotia

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Abstract: Coyote (*Canis latrans*) predation is a major source of mortality for white-tailed deer (*Odocoileus virginianus*) in many areas of northeastern North America. However, if coyotes primarily remove deer that would have died of other causes in the absence of predation (compensatory mortality), the impact of predation would be minimal regardless of the number of deer removed. We examined the carcasses of 102 white-tailed deer consumed by coyotes during winter in southwestern Nova Scotia (Queens County) and on Cape Breton Island from 1992 to 1997. Sixty-nine deer were victims of predation, five died of other natural causes, two were killed in coyote snares, two were killed on the road, two were shot and not recovered during the autumn hunting season, and one was shot and abandoned in early winter. The causes of death of the remaining 21 deer could not be determined. Fawns were overrepresented in the sample of coyote-killed deer on Cape Breton Island, but the age distribution of deer killed by coyotes in Queens County did not differ significantly from that of local road-killed deer. Femur marrow fat reserves of deer killed by coyotes appeared to be as good as or better than those of road-killed deer in the vicinity of each study area. During winter, coyotes often killed deer in situations where deer were disadvantaged either by deep snow or by poor footing on frozen lakes. This may help explain the general lack of selection of weaker animals. Our data are consistent with the idea that mortality due to coyote predation was largely additive to mortality due to other factors. However, manipulative experiments are needed to verify this conclusion.

Résumé : La prédation par le coyote (*Canis latrans*) est une cause importante de mortalité chez le cerf de Virginie (*Odocoileus virginianus*) dans plusieurs régions du nord-est de l'Amérique du Nord. Cependant, si les coyotes soustraient de la population surtout les cerfs qui, en l'absence de prédation, seraient morts d'autres causes (mortalité compensatoire), l'impact de la prédation est minimal, quel que soit le nombre de cerfs retirés. Nous avons examiné les carcasses de 102 cerfs de Virginie mangés par les coyotes durant l'hiver dans le sud-ouest de la Nouvelle Écosse (comté de Queens) et l'île du Cap Breton en 1992–1997. Soixante-neuf cerfs ont été victimes de prédation, cinq sont morts d'autres causes naturelles, deux ont été capturés dans des pièges à coyotes, deux ont été écrasés sur la route, deux ont été tués à l'arme à feu et perdus pendant la saison de chasse en automne et un à été tué par arme et abandonné au début de l'hiver. La cause de la mort des 21 autres cerfs est inconnue. Il y a une surreprésentation de faons dans l'échantillon de cerfs tués par les coyotes à l'île du Cap Breton, mais dans le comté de Queens, la distribution des classes d'âges des cerfs tués par les coyotes est la même que celle des cerfs écrasés sur la route dans la région. Les réserves de graisse dans la moelle du fémur des cerfs tués par les coyotes semblent être aussi ou plus importantes que celles des cerfs tués sur la route dans les environs de chacun des sites d'étude. En hiver, les coyotes tuent souvent des cerfs qui sont en position vulnérable à cause de la profondeur de la neige ou de la surface gelée des lacs qui les fait déraiper. Cela peut expliquer le manque apparent de sélection des animaux plus faibles. Nos données appuient l'idée qui veut que la mortalité due à la prédation par les coyotes en grande partie s'ajoute à la mortalité due aux autres facteurs. Cependant, seules des expériences de manipulation permettraient de vérifier cette conclusion.

[Traduit par la Rédaction]

Introduction

Coyotes (*Canis latrans*) colonized Nova Scotia during the early 1980s (Moore and Parker 1992). In most forested areas of northeastern North America, white-tailed deer (*Odocoileus virginianus*, hereinafter referred to as deer) and the snowshoe hare (*Lepus americanus*) are the primary prey species of the eastern coyote (Messier et al. 1986; Parker 1986; Patterson et al. 1998). Coyote predation represents a major source of mortality for both adult deer (Whitlaw et al. 1998; Patterson et al. 2002) and fawns (Ballard et al. 1999). However, if coyotes primarily remove deer that would have died of other causes in the absence of predation (compensatory mortality), the impact of predation would be minimal regardless of the number of deer removed. Herein we document

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the age structure and condition of deer fed upon by coyotes in two areas of Nova Scotia from 1992 to 1997.

Study areas

The study was conducted in two forested areas of Nova Scotia. The Queens County study area (QC) was located in southwestern Nova Scotia (44°20'N, 65°15'W) and included the eastern half of Kejimikujik National Park (~200 km²) and approximately 300 km² of forested land directly to the east of the Park. The climate of this region was characterized by warm summers and cool winters averaging -5 °C in January (Dzikowski et al. 1984). This area generally did not receive winter accumulations of snow >20 cm, and therefore local deer did not show typical yarding behavior (MacDonald 1996; Lock 1997).

The 600-km² Cape Breton study area (CB) was located on Cape Breton Island (45°45'N, 61°15'W) and centered on the 24-km² Eden deer wintering area that typically contained ~200 deer from January through March (Patterson et al. 1998). Within this study area, the elevation rose abruptly from near sea level in the Denys Basin area to approximately 300 m in the Creignish Mountains. The higher elevations in the northern section of the study area received 250–300 cm of snow annually, whereas the lowland areas received 200–250 cm of snow annually (Gates 1975). Median duration of snow cover varied from 140 days at higher elevations to 130 days at lower elevations (Gates 1975). This contrasted with a median duration of snow cover of only 59 days in QC.

Patterson et al. (1998) presented data on the vegetation in each study area. Deer densities averaged 3–4/km² in CB, but reached as high as 9.8/km² in the Eden deer wintering area depending on winter severity (fewer deer migrated to the wintering area during mild winters). Estimates were consistently lower throughout QC, averaging 2.0/km² (Patterson et al. 1998). From May through November, track observations suggested that deer were evenly distributed within both study areas; however, in early winter, most deer migrated from the Cape Breton highlands to wintering grounds in the lowlands (MacDonald 1996; Patterson et al. 1998). Deer were legally protected from harvest in Kejimikujik National Park, whereas hunting of antlered deer only was permitted in all other areas during autumn from 1993 to 1997. Prior to 1993, all hunters were allowed one deer of either sex.

Methods

We investigated coyote–deer interactions while snow-tracking radio-collared coyotes and deer during December–March 1993–1997. We classified dead deer as coyote kills if there was evidence of attack or chase (i.e., blood-soaked fur or snow, bleeding observed around tooth puncture wounds). We collected a jawbone and femur from any deer killed or scavenged by coyotes to obtain information on age structure and physical condition of the deer. Deer were classified as fawn (<1 year old), yearling (>1 year old but <2 years old), adult (2–8 years old), or old (>8 years old) on the basis of tooth wear and development (Severinghaus 1949). Although the precise age of adult deer cannot be determined reliably from tooth wear and development (Gee et al. 2002), we be-

lieve this method was reliable enough to accurately place deer in one of the four age classes described above. Because deer can be accurately assigned to fawn and yearling age classes based on tooth eruption patterns (Severinghaus 1949), any errors in our classification would have been limited to the determination of whether or not a deer was “old”. Less than 10% of deer encountered during this study were placed in the old age category.

We examined whether coyote-killed deer were representative of the local deer populations by comparing the age distribution of deer killed by coyotes with that of road-killed deer using log-likelihood ratio tests (*G* tests) (Sokal and Rohlf 1995). O’Gara and Harris (1988) cautioned that road-killed deer may not be representative of the population structure of the herd in question because deep snows may force malnourished or otherwise debilitated deer to frequent road corridors. Given that winters were mild during this study and deer killed by both automobiles and predators were generally in good physical condition, we believe that the age structure of road-killed deer was representative of the respective populations in both study areas.

We used femur marrow fat (FMF) as an index of body condition (Neiland 1970). Although Mech and Delguidice (1985) cautioned that high FMF does not always indicate that an ungulate was in good physical condition, Lavigne (p. 155 of Lavigne 1992) concluded that “FMF levels approximating 80% or higher are closely associated with substantial reserves (e.g., ≥5 percent total body fat) of other body fat deposits that are characteristic of ‘good’ physical condition”. Deer with FMF <25% were classified as malnourished. We compared the numbers of healthy and malnourished fawn and adult deer killed by coyotes with those in the road-killed sample using *G* tests (Sokal and Rohlf 1995). If the *G* test led to the rejection of the hypothesis of homogeneity of age classes or relative conditions between coyote- and road-killed deer (see Neu et al. 1974), we used the Bonferroni *Z* test for proportions.

Results

We examined the carcasses of 102 white-tailed deer consumed by coyotes during winter (Table 1). Sixty-nine deer were victims of predation, five died of other natural causes (including two prime-aged bucks and one old female that died of malnutrition, and two old females that died of unknown but apparently natural causes, given the timing and location of their deaths), two were killed in coyote snares, two were killed on the road, two were shot and not recovered during the autumn hunting season, and one was shot and abandoned in early winter. The causes of death of the remaining 21 deer could not be determined. Considering only those deer for which the cause of death could be ascertained, 13.5% and 24.4% of deer consumed during winter in QC and CB, respectively, died of causes other than predation (Table 1).

We examined a winter sample of road-killed deer in the counties containing the study areas from January–March 1994–1997. The age distribution of deer killed by coyotes in CB differed significantly from that of the local deer population ($n = 136$ road-killed deer, $G = 6.74$, $P = 0.03$); fawns were overrepresented in the sample of coyote-killed deer

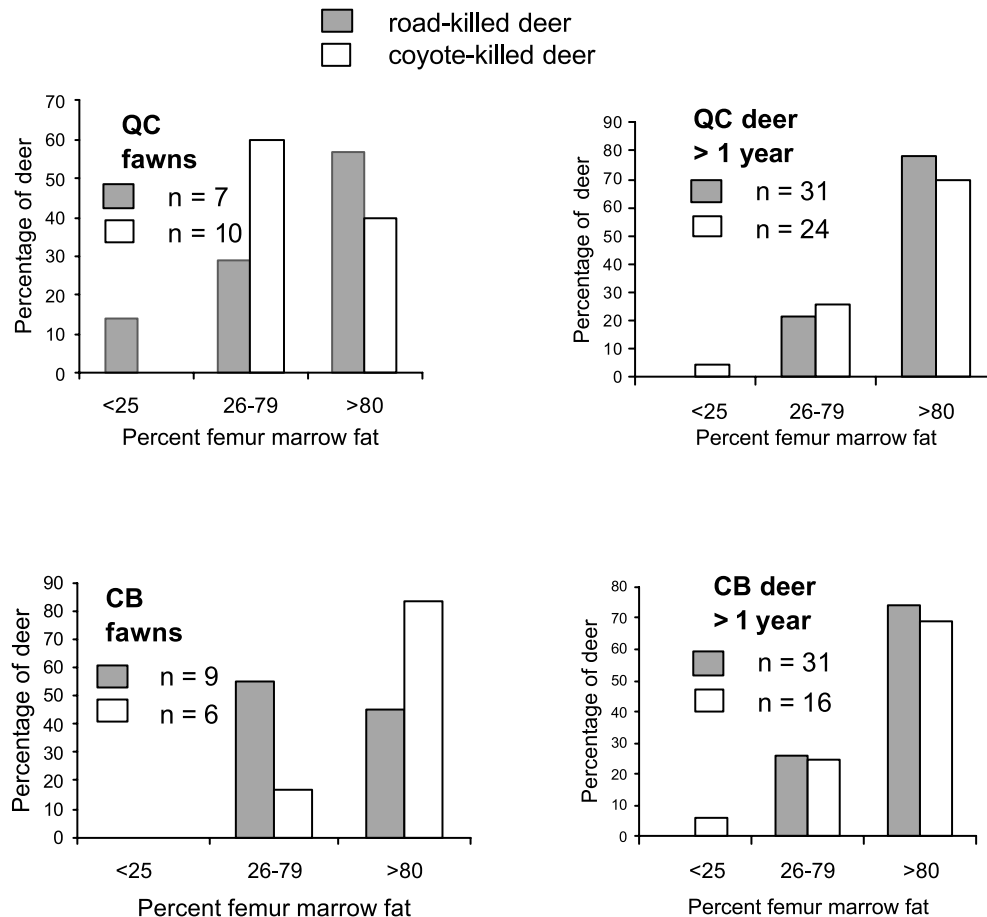
Table 1. Age and causes of mortality of 102 white-tailed deer (*Odocoileus virginianus*) consumed by coyotes in the Queens County (1992–1997) and Cape Breton (1994–1997) study areas, Nova Scotia, Canada.

| | Queens County | | | | | | Cape Breton | | | | |
|--------------------------------|---------------|--------------|--------------|-------------|----------|--------------|--------------|-----------|--------------|--------------|-------------|
| | 1992–1994 | | | 1995–1997 | | | 1994–1997 | | | | |
| | Fawn | ≤8 years old | >8 years old | Age unknown | Fawn | ≤8 years old | >8 years old | Fawn | ≤8 years old | >8 years old | Age unknown |
| Predation | 9 | 10 | | | 5 | 10 | 4 | 13 | 16 | | 2 |
| Natural mortality ^a | | 1 | 1 | | | | | | 2 | 1 | |
| Other causes ^b | | 2 | | | | | | 1 | 4 | | |
| Uncertain | | 2 | | 8 | 1 | 4 | 2 | | 2 | | 2 |
| Total | 9 | 15 | 1 | 8 | 6 | 14 | 6 | 14 | 24 | 1 | 4 |

^aIncludes two prime-aged bucks and one old female that died of malnutrition, and one old female that died of unknown causes.

^bIncludes two deer killed in coyote snares, two deer killed on the road, two deer wounded during hunting season, and one deer shot and abandoned after the hunting season.

Fig. 1. Percent femur marrow fat of adult (>1 year old) and fawn white-tailed deer (*Odocoileus virginianus*) killed by coyotes in the Queens County (QC) and Cape Breton (CB) study areas, Nova Scotia, Canada, winters 1994–1997, in relation to road-killed deer.



($Z = 2.24, P = 0.02$). In contrast, the age distribution of deer killed by coyotes in QC did not differ significantly from that of local road-killed deer ($n = 165$ road-killed deer, $G = 3.56, P > 0.10$). However, considering the 1992–1994 and 1995–1997 periods separately (based on differences in winter severity and coyote feeding behavior; see Patterson et al. 1998), fawns were overrepresented in the sample of coyote-killed deer examined in QC during 1992–1994 ($Z = 2.52, P = 0.01$), whereas deer ≥ 8 years old were overrepresented

in the sample of coyote-killed deer examined in the same area during 1995–1997 ($Z = 3.11, P = 0.002$).

FMF reserves of fawn and adult deer killed by coyotes appeared to be as good as or better than those of road-killed deer in the vicinity of each study area ($G < 5.02, P > 0.08$; Fig. 1). Only 1 of the 56 coyote-killed deer that were assessed had FMF levels of <25%. Seven percent of the deer had FMF levels between 26% and 50%, 25% of the deer had FMF levels between 51% and 79%, and the remaining 66%

of the deer had FMF levels of $\geq 80\%$ (Fig. 2). Most of the deer exhibiting depleted FMF levels were killed in the CB area, which had the greatest snow depths encountered during this study.

Discussion

Fawns represented a greater proportion of deer in the coyote-killed sample than in the local population in CB and QC (winters 1992–1994 only). Similarly, fawns predominated among deer killed by coyotes during relatively severe winter conditions in southern Québec and northern New Brunswick (Messier et al. 1986; Parker and Maxwell 1989). In contrast, coyotes in the Gaspé region of Québec killed proportionately fewer fawns than available in the local population during mild winter conditions (Pouille et al. 1993). Winter conditions were relatively severe in QC during 1993 and 1994 and were generally more severe in CB than in QC (MacDonald 1996; Lock 1997). Given the relatively small size of fawns, we suspect that greater snow depths increase the relative vulnerability of fawns to predation.

Deer killed by coyotes during this study had FMF levels as high as or higher than deer in the general populations (Fig. 1). Furthermore, examination of the carcasses of deer killed by coyotes revealed no signs of arthritis or other debilitations that may predispose ungulates to predation (Mech et al. 1995). Although at least four of the deer killed by coyotes during winter in QC were ≥ 8 years old, we have no evidence that these deer were disadvantaged by their age. Similarly, Lavigne (1992) determined that 50%–70% (depending on age class) of the deer in a sample of 863 deer killed by coyotes in Maine were in good physical condition (based on FMF levels of $>80\%$). Because nearly half of these deer were mature, Lavigne (1992) suggested that losses to coyotes may be additive to mortality due to other factors. Messier et al. (1986) and Brundige (1993) also reported that deer killed by eastern coyotes during winter were probably in a condition as good as or better than that of the general population.

Over time, variation in factors such as winter severity, relative deer density, and density of alternate prey may also influence selection of deer based on age or condition. For example, in a deer–wolf system in southwestern Québec, wolves preyed mainly on prime-aged deer when deer were scarce but selected fawns and older animals when deer were more abundant (Potvin et al. 1988). In situations like this, predation may have little effect on deer populations when deer densities are high, but it may have a major limiting, and thus destabilizing, effect when deer densities are low (Potvin et al. 1988). Our study and studies of others (Messier et al. 1986; Parker and Maxwell 1989; Pouille et al. 1993) demonstrate that winter severity may differentially affect the vulnerability to predation of different age classes of deer. Previously, we demonstrated that killing of deer by coyotes was inversely related to the abundance of snowshoe hares (Patterson et al. 1998; Patterson and Messier 2000). Although we noted a general lack of selection of deer based on age or condition, we predict that coyotes should be more selective (i.e., prey primarily on the weakest members of the population) when the relative availability of alternate prey is high.

During winter, coyotes often killed deer in situations where deer were disadvantaged either by deep snow or by poor footing on frozen lakes (Patterson and Messier 2000). We also noted several cases where deer were ambushed in their beds and subdued before they could escape. These findings are similar to those reported for coyotes in the Adirondack Mountains of New York (Brundige 1993) and may preclude strong selection of weaker individuals (very young or old deer) under normal conditions. Overall winter conditions were relatively mild during this study, and coyotes preyed largely upon prime-aged deer in apparently good physical condition. Although manipulative experiments are needed to definitively demonstrate additive mortality (e.g., Bartmann et al. 1992; White and Bartmann 1998), our data are consistent with the idea that mortality due to coyote predation was largely additive to mortality due to other factors during this study.

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