Research Note

Winter Forage Selection in White-Tailed Deer at High Density: Balsam Fir is the Best of a Bad Choice

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ABSTRACT We assessed winter forage selection by white-tailed deer (*Odocoileus virginianus*) on Anticosti Island, Quebec, Canada, using cafeteria-feeding trials. Winter habitat on Anticosti is degraded and free-ranging deer at high densities consume 70% balsam fir (*Abies balsamea*) and 20% white spruce (*Picea glauca*), even though spruce is much more available than fir. Deer ate 89.9% balsam fir and 10.1% white spruce when the availability of both trees was equal. Deer did not eat shredded twigs more than intact twigs. Fiber content and condensed tannins were greater in white spruce than in balsam fir. Deer preference for fir was not based on texture but, more likely, on plant constituents, so we concluded that deer will nearly eliminate fir before they use any significant amount of white spruce. Management actions, therefore, need to be undertaken to enhance balsam fir regeneration. (JOURNAL OF WILDLIFE MANAGEMENT 71(3):911–914; 2007)

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Forage selection by wild herbivores may be determined by the chemical composition of plants (Hanley 1982, Shipley et al. 1998) because the constituents of plant tissue, such as fibers, proteins, and secondary metabolites, can affect the digestibility and the palatability of forage (Robbins et al. 1987*a*, Berteaux et al. 1998). Plant secondary metabolites, such as condensed tannins, reduce dry matter digestibility and protein availability in ungulates (Robbins et al. 1987*a*, *b*), whereas terpenoids can be either deterrent or toxic (Harborne 1991, Vourc'h et al. 2002). The physical characteristics of plants (i.e., soft versus prickly or spiny tissue) may also influence the palatability of forage and, therefore, intake rate (Côté et al. 2004). Very little is known, however, on the effects of plant texture on handling time and food selection by ruminants, especially for coniferous browse. In boreal forests during winter, ruminants must feed on poor quality and well-defended plants with higher fiber content, lower protein content, and higher concentrations of plant secondary metabolites than summer forage.

Following the introduction of about 200 white-tailed deer (*Odocoileus virginianus*) on Anticosti Island, Quebec, Canada, in the late 1800s, the population erupted, and today, local densities of more than 20 deer/km^2 are common (Potvin and Breton 2005). Deer browsing gradually extirpated or severely reduced the abundance of all deciduous shrubs in the boreal forests of the island (Potvin et al. 2003, Tremblay et al. 2005). Before the introduction of deer, balsam fir (*Abies balsamea*) stands covered nearly 40% of the island's surface. Today, that number has declined to 20%, and fir stands are being replaced by white spruce (*Picea glauca*) stands (Potvin et al. 2003). Deer overbrowsing on seedlings is the main factor that contributed to the decline by suppressing regeneration (Potvin et al. 2003). Nowadays, deer can only feed on 3 plant species during winter on Anticosti: white spruce and black spruce (*P. mariana*), which are highly available, and balsam fir, which is now only available when trees or small branches are thrown down by wind (Tremblay et al. 2005).

Balsam fir is the staple food for white-tailed deer in winter on Anticosti, representing 70% of the diet, whereas white spruce represents about 20% of the winter diet (Huot 1982, Lefort 2002). Arboreal lichens complete the diet, and deer do not eat black spruce. Anticosti Island is at the northernmost fringe of the distribution of white-tailed deer and is the only known location where deer forage mainly on balsam fir and white spruce in winter. Mechanisms of forage selection between balsam fir and white spruce are important to understand because white spruce is gradually and rapidly replacing balsam fir across the whole island (Potvin et al. 2003).

We assessed the factors determining preference of white-tailed deer for balsam fir over white spruce in winter. Using cafeteria trials where availability of both forage was equal, we tested the effects of plant constituents and texture on deer preference. We hypothesized that 1) white spruce was more fibrous and more chemically defended than balsam fir and that 2) shredded plant matter (i.e., less prickly) would always be consumed in greater amounts than intact branches, especially for white spruce, which is much more prickly than balsam fir.

STUDY AREA

Anticosti Island (49°28′N, 63°00′W) is a 7,943-km^2 island located in the Gulf of St. Lawrence, Quebec, Canada. The maritime climate was characterized by cool summers and mild but long winters lasting from mid-November until April (Huot 1982). The boreal forest on the island was composed mainly of white spruce, balsam fir, and black spruce (Potvin et al. 2003).

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METHODS

From 1 December to 25 December 2003, we captured 6 wild white-tailed deer fawns (4 M and 2 F) for a companion study addressing the effects of winter nutrition on deer body condition (Taillon et al. 2006). We used Stephenson box traps, canon-nets, and dart guns with a mixture of Telazol® (4.5 mg/kg; Fort Dodge Animal Health, Fort Dodge, IA) and xylazine (2 mg/kg; Miller et al. 2003) to capture deer (Taillon et al. 2006). We sexed and weighed deer to the nearest 0.5 kg with an electronic scale. We marked all fawns individually with ear tags and relocated them to a 0.5-ha outdoor pen. We fed individuals their natural winter diet (i.e., a mixture of shredded balsam fir [80%] and white spruce [20%] twigs) until the beginning of the feeding trials. Laval University Animal Care Committee approved the experimental protocol and we met the principles and guidelines of the Canadian Council on Animal Care.

In March 2004, we isolated each deer in an outdoor pen of 0.5 ha and performed 6 preference-feeding trials that lasted 12 hours each. We conducted all 6 trials continuously during 3 days. During each trial, deer had access to 2 large plastic containers with 1,000 g of fresh food in each. We used the same quantity of food as during the pretrial period and the feeding troughs were located at the same site. We offered deer one of the following choices: 1) balsam fir and white spruce intact twigs, 2) balsam fir intact twigs and white spruce shredded twigs, 3) balsam fir shredded twigs and white spruce intact twigs, 4) balsam fir and white spruce shredded twigs, 5) balsam fir only (intact and shredded twigs), or 6) white spruce twigs only (intact and shredded). We offered 1 of the 6 different combinations (in random order) to each animal during a single trial. These combinations evaluated the selection between balsam fir and white spruce, and the effect of chipping twigs (i.e., removing the effects of texture) on winter food selection by white-tailed deer. We harvested trees <1 km from the pens in mature fir stands. We felled fir trees 1 to 2 days before testing and kept them outdoors in subzero temperatures. We harvested spruce twigs with pruning shears as needed. We shredded fir and spruce twigs separately in a wood chipper (Yard Machines 5-hp wood chipper; MTD, Kitchener, ON, Canada). We determined dry matter intake by subtracting the mass of orts from the initial mass of food placed in the troughs, corrected for the species-specific rate of water loss during the trials.

To evaluate the chemical composition of both tree species offered to deer, we collected 2 samples each of balsam fir and white spruce (annual shoots) in 8 different sites randomly chosen in mature balsam fir–white spruce stands ($\bar{x}$ area ± SE: 13.2 ± 2.6 ha) in mid-February 2004 for a total of 16 samples per tree species. We hand-collected the white spruce samples between 0.5 m and 3 m from the ground, whereas we cut fir branches with a 3-m tree pruner because no branches were accessible by hand because of deer browsing.

We kept half of all the samples (16 of 32) frozen in doubly sealed plastic bags, and we air-dried the other half at 50° C until constant mass and kept them at room temperature until analyzed. We shredded 16 air-dried samples in a Wiley mill (20 mesh size; Thomas Scientific, Swedesboro, NJ) and analyzed (8 samples for each species) them for neutral detergent fiber (NDF), acid detergent fiber (ADF), and acid detergent lignin (ADL; Goering and Van Soest 1970). We did NDF and ADF fiber analyses using an Ankom 200 fiber analyzer (Ankom Technology, Macedon, NY), whereas we determined ADL according to the method of Goering and Van Soest (1970). We analyzed all samples in duplicate. We determined nitrogen content of all air-dried vegetation samples in duplicates by the macro-Kjeldahl method and expressed results as crude protein content (nitrogen × 6.25).

We freeze-dried 8 balsam fir and 8 white spruce samples and ground them with dry ice in a Wiley mill (20-mesh size). We extracted total phenols and condensed tannins from 50 mg of plant material by placing each sample in a 70% (vol/vol) aqueous acetone solution for 24 hours in the dark and then centrifuging the solution for 10 minutes and removing the extracts (Yu and Dahlgren 2000). We assayed the samples for total phenol content using the Folin–Ciocalteu method and determined the concentration of condensed tannins using the HCl-butanol hydrolysis method (Yu and Dahlgren 2000).

We used randomized complete-block designs to analyze data, with individuals as blocks to take into account repeated measures on the same individual (PROC Mixed in SAS 9.1; Montgomery 2001). We first compared dry matter intake between the 6 tests. Then, we evaluated the effects of texture, plant species, and their interaction on percentage of dry matter intake. We tested all main effects with contrasts within blocks. We used 2-sided *t*-tests to compare vegetation parameters (NDF, ADF, ADL, protein content, total phenols, condensed tannins) between species. All data are presented as means ± standard error, and we used $\alpha = 0.05$ to accept significant differences.

RESULTS

All deer consumed both food types during the feeding trials, but total dry matter intake differed between tests ($F_{5,25} = 5.98$, $P < 0.001$). Post hoc multiple comparisons, however, revealed that dry matter intake was similar ($\bar{x} = 415 \pm 31$ g) for all 5 tests including at least one container with fir, but it was only 62 ± 31 g in the test comparing intact spruce with shredded spruce. Deer consumed >4 times more balsam fir than white spruce when we offered the 2 species simultaneously, irrespective of the texture of both foods ($F_{1,55} = 37.98$, $P < 0.001$; Fig. 1). Food texture did not influence selection for both tree species (texture: $F_{1,55} = 1.87$, $P = 0.18$; texture × species interaction: $F_{1,55} = 0.18$, $P = 0.67$; Fig. 1).

Fiber (NDF and ADF) and condensed tannins content were greater in white spruce than in balsam fir, but not acid detergent lignin (ADL; Table 1). There were no differences in total phenols and crude protein contents between balsam fir and white spruce (Table 1).

DISCUSSION

Our cafeteria-style experiments confirmed that white-tailed deer show a strong preference for balsam fir over white

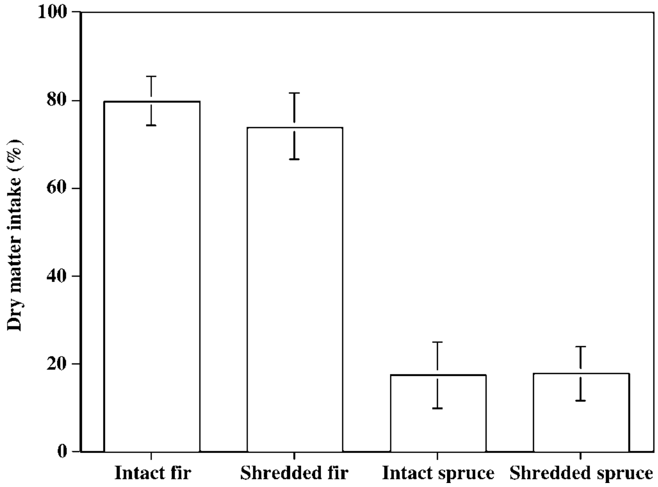

Figure 1. Percent dry matter intake of balsam fir and white spruce offered to white-tailed deer fawns from Anticosti Island, Quebec, Canada, during feeding trials conducted during March 2004. We offered different textures: shredded and intact twigs. Standard errors of the mean are reported.

spruce. These results are consistent with observations of food selection by overwintering, free-ranging deer on Anticosti Island (Lefort 2002), where the availability of balsam fir is very low and that of white spruce is high (Tremblay et al. 2005). Free-ranging deer also consume approximately 10% arboreal lichens (Lefort 2002). We did not specifically measure arboreal lichens in our trials, but we left those present on the branches that we fed to deer. Lichen biomass on balsam fir and white spruce trees >50 years old did not differ (Lefort 2002).

Chemical composition analyses revealed that white spruce was more fibrous than balsam fir. Because fiber content negatively influences dry matter digestibility (DMD; Robbins et al. 1987*a*), white spruce is likely less digestible than balsam fir. Studies of ruminants have shown that fibrous forage can reduce the rate of food intake by decreasing the rate of passage of food through the gut (Hanley 1982, Gray and Servello 1995, Tixier et al. 1997). Factors other than, or in interaction with, dietary fiber may also be involved in DMD (Robbins et al. 1987*a*, *b*) and thus in the selection we observed. Fiber may affect DMD in subtle ways, and only through in vitro or in vivo digestibility trials conducted with deer inoculum could these effects be teased out (Pearson et al. 1980, Côté 1998).

Our results also showed that protein content was similar between balsam fir and white spruce. Crude protein content for both tree species was <6%, the dry matter minimum threshold for the maintenance of a healthy rumen flora and fauna proposed by Owens and Zinn (1993). Brown et al. (1995) found that prolonged protein restriction negatively influences ruminal digestible energy in white-tailed deer, although deer diet in their study included ≥7% crude protein (i.e., above the 6% proposed threshold). It appears, therefore, that wintering deer on Anticosti Island are protein deprived, as the only other constituents in their diet, arboreal lichens, are low in proteins (Robbins 1988).

Our results suggest that total phenols cannot explain

Table 1. Chemical composition of balsam fir and white spruce twigs from Anticosti Island, Quebec, Canada, during the winter of 2004. Dietary fibers (neutral detergent fiber [NDF], acid detergent fiber [ADF], and acid detergent lignin [ADL]) and protein content are expressed as percent dry matter, whereas total phenols and condensed tannins are expressed in mg/g dry matter.

Chemical components	Browse species					
	Balsam fir		White spruce			
	$\bar{x}$	SE	$\bar{x}$	SE	t_{30}	*P*-values (2-tailed)
NDF	39.7	1.2	45.9	1.2	3.63	0.001
ADF	33.0	0.5	34.6	0.6	3.24	0.003
ADL	16.8	0.5	16.4	0.4	0.66	0.5
Crude proteins	5.3	0.2	5.2	0.2	0.32	0.8
Total phenols	2.1	0.1	2.2	0.07	0.87	0.4
Condensed tannins	0.098	0.002	0.11	0.003	2.32	0.03

balsam fir selection over white spruce for white-tailed deer on Anticosti Island. However, the content of condensed tannins was slightly, but significantly, greater in white spruce than in balsam fir, which may partly explain the selection for fir over spruce by deer. Although tannins are known to be antinutritive for ruminants (Robbins et al. 1987*b*, Silanikove et al. 2001), deer from the *Odocoileus* genus produce proline-rich proteins in their saliva that bind with tannins, thus negating, at least in part, the adverse effect of tannins on protein digestibility (Hagerman and Robbins 1993). It remains possible, however, that we did not observe an effect of total phenols on food selection by deer because determining the dose of specific phenols in forage is difficult, which limits the interpretation of the effects of these compounds on food preference and digestibility (Mole and Waterman 1987*a*, *b*).

We hypothesized that deer might prefer balsam fir over white spruce because the physical texture of fir is less abrasive and prickly than spruce and would, therefore, require less handling time to process or at least be more palatable than spruce. There were no significant differences in dry matter intake between the intact and the shredded twigs for both species, suggesting that the preference for balsam fir over white spruce by deer is based on the chemical composition of plants rather than on their mechanical properties.

That white-tailed deer preferred balsam fir to white spruce appears to be the best of a bad choice because both forage types were of low quality. Although NDF, ADF, and condensed tannin contents were lower in balsam fir than in white spruce, we cannot rule out that other factors may be involved in the strong preference of deer for balsam fir. Further studies should concentrate on the determination of other chemical constituents of balsam fir and white spruce, such as terpenes, to assess the strong selection observed for balsam fir. Von Rudloff (1972) identified camphor as an abundant monoterpene in white spruce, whereas it is not found in balsam fir (Hunt and von Rudloff 1974). Camphor is known to be deterrent in red deer (*Cervus elaphus*), snowshoe hare (*Lepus americanus*), and voles (*Microtus* spp.; Harborne 1991, 2001) and could also be involved in the preference for fir over spruce for white-tailed deer on Anticosti Island.

MANAGEMENT IMPLICATIONS

Our results suggest that to regenerate balsam fir stands, fir seedlings need to be protected from deer browsing. Because we found that deer preference for fir was not based on texture but more likely on plant constituents, it seems that deer will nearly eliminate fir before they use any significant amount of white spruce. Management actions, therefore, need to be undertaken to enhance balsam fir regeneration. One option is to fence cutblocks and reduce deer density inside enclosures by sport hunting to decrease the browsing pressure on fir seedlings (Côté et al. 2007).

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