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Michael T. Pruss
University of New Hampshire - Main Campus

Peter J. Pekins
University of New Hampshire - Main Campus, pete.pekins@unh.edu

EFFECTS OF MOOSE FORAGING ON BROWSE AVAILABILITY IN NEW HAMPSHIRE DEER YARDS

Michael T. Pruss and Peter J. Pekins
Department of Natural Resources, University of New Hampshire, Durham, NH 03824

ABSTRACT: Food habits of moose (*Alces alces*) and white-tailed deer (*Odocoileus virginianus*) overlap in northern New Hampshire during autumn and winter. High moose and deer densities in deer yards, where deer may be confined for extended periods, could result in competition for limited deciduous forage. The purpose of this study was to investigate possible impacts by moose on browse availability in deer yards, and the potential effects on deer. Fifteen deer yards were studied in northern New Hampshire during spring and fall, 1990-91. Unbrowsed and browsed deciduous twigs, and deer and moose pellet groups were counted on 900 permanent plots to measure seasonal browse use and population density of deer and moose. Twig biomass availability and removal were estimated for each season in all areas.
Combined data from all deer yards showed that unbrowsed biomass increased between spring 1990 and autumn 1990, and decreased between autumn 1990 and spring 1991. Moose browsed 7.2% of available food during autumn 1989 and winter 1990, 7.7% during autumn 1990, and 3.8% during winter 1991, accounting for 26.3%, 81.1%, and 17.6% of browsed biomass, respectively. One-year-old clearcuts adjacent to wintering areas were heavily browsed, particularly during the winter. Preferred moose foods during autumn were quaking aspen and mountain maple. Pin cherry and nannyberry were removed relative to availability. Moose have the potential to substantially reduce the availability of preferred deciduous browse (e.g., maples) of deer, and thus reduce the carrying capacity of deer yards. Specialized management in areas of high moose density may be warranted where clearcuts adjacent to deer yards provide the essential winter forage of deer.

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White-tailed deer in northern regions reduce winter energy expenditure by occupying a specific winter concentration area or deer yard in response to low food availability, poor food quality (Mautz 1978), and harsh weather conditions including low ambient temperature, high wind, and deep snow (Severinghaus 1953, Verme and Ozoga 1971). The availability and use of deer yards is a primary focus of deer management in northern New Hampshire. Deer yards in New Hampshire are characterized by mature softwood stands of primarily spruce (*Picea* spp.) and/or balsam fir (*Abies balsamea*), with a mixture of eastern hemlock (*Tsuga canadensis*) and northern white-cedar (*Thuja occidentalis*) (Strong 1977). Proximate openings and early successional stands provide shrub and regenerating tree browse (Gill 1957, Verme 1965, Strong 1977). Deer require access to browse during winter to meet energy demands for survival until they disperse in the spring (Mautz 1978). Important winter browse species of deer are also utilized by moose, which inhabit mature coniferous stands in all seasons (Peterson 1955), particularly browsing in and around such areas during late summer and fall (Pimlott 1953, Dodds 1955, Telfer 1967, Kearney and Gilbert 1976).

New Hampshire's deer and moose populations increased continually throughout the late 1980's. While, the deer density in northern New Hampshire is not considered above carrying capacity (S. Williamson, New Hampshire Fish and Game, Deer Project Leader, pers. comm.), the estimated moose density is high (1.97 moose/km^2) in sections of northern New Hampshire (NHF and G, 1988). However, the availability of deer yards is declining due to spruce budworm infestations and continual harvest of mature softwood stands.

Potential competition and interaction between deer and moose may be significant where browse availability is limited, such as may occur in certain deer yards in northern New Hampshire. Because moose likely forage in deer yards prior to winter, it is possible, given high moose densities, that moose consume browse critical to the survival of wintering deer in northern New Hampshire. Thus, overlap in food habits of the two species may result in competitive interaction between deer and moose with regard to browse use and availability in and around deer wintering areas.

The objective of this study was to investigate moose impacts on forage availability in wintering areas critical to deer survival in northern New Hampshire.

STUDY AREA

Fifteen deer yards, ranging in size from 39 to 1282 ha, were studied in primary moose habitat in central and northern New Hampshire (between 43° 45' and 45° 10' N latitude, and between 71° 00' and 72° 15' W longitude), inclusive of the White Mountain National Forest (WMNF) (Fig. 1). Prominent soil types in this region are well drained stony or sandy of glacial till origin (Pilgrim and Peterson 1979). The dominant forest cover types are northern hardwood forest (sugar maple (*Acer saccharum*), beech (*Fagus grandifolia*), yellow birch (*Betula alleghaniensis*), and red maple (*A. rubrum*)), and spruce-fir, 48 and 26%, respectively. White pine(*Pinus strobus*)-red pine(*P. resinosa*) (14%) and aspen(*Populus* spp.)-birch(*B.* spp.) (6%) types are less pronounced (Frieswyk and Malley 1985).

Mean January (the coldest month) temperatures range from -2.56 to -19.67 C. Snowfall ranges from 169cm (66.7in) in Benton, to 359cm (141.4in) in Pittsburg (NOAA 1971-91), townships located in the southwestern and extreme northern regions of the study area, respectively.

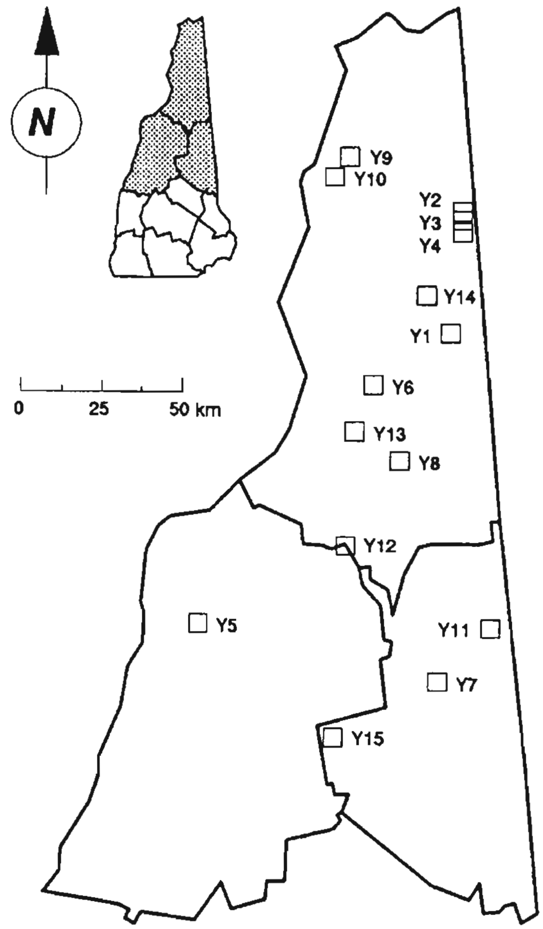

Fig. 1 Sample area locations in northern New Hampshire.

METHODS

The deer yards were chosen during winter based on current use by deer and location within primary moose range. Two yards (Y14, Y15) were proximate to ongoing logging operations and were specifically studied during fall 1990 and spring 1991 to record browse use and availability in one-year-old clearcuts.

Feeding areas associated with deer yards were identified through field observation, and included openings (clear-cuts, blow-downs, open wetlands) and hardwood overstory (selection cuts, uncut hardwoods) within 100m of the softwood cover (the assumed maximum distance deer browse from an edge). They were measured and mapped using May 1989 aerial photographs and ARC/INFO (Environmental Systems Research Institute). Softwood cover and hardwood browse cover type data were transferred from aerial photographs to topographic maps with a Bausch and Lomb Z.T.S. zoom transfer scope.

Water bodies and rock outcrops were delineated to exclude them from the aerial estimates of each cover type. Total area of softwood cover, deciduous browse, and sampling for each yard was digitized using ARC/INFO; sampling effort was expressed as a percentage of that available per cover type and total area.

Browse availability and utilization were measured in yards during spring (21 April - 18 May) and autumn (15 September - 20 November) 1990, and spring (5 April - 3 May) 1991.

Sampling Design

Baselines were flagged between the softwood and deciduous browse cover types. Six 100m transects were flagged on each side of the baseline, diagonal to the slope to minimize topography-related sampling error in pellet group plots. Parallel transects were flagged >50m apart.

Pellet Group Measures

Because high winter deer densities were expected, relatively small sampling plots (1x20m) were established (Smith 1964). Small, narrow, rectangular plots reduce sampling time and error associated with missed pellet groups (Smith 1964, Neff 1968). Sampling intensity of most areas ranged from 0.5%-1.4% of the total area.

Plots were sampled during spring 1990 and 1991 between snow-melt and green-up to determine relative indices of winter moose and deer densities. Pellet group plots were sampled during autumn before leaf-fall, and again between leaf-fall and the first substantial snowfall to determine autumn moose and deer density indices. All pellet groups (30 pellets or more; Neff 1968), that lay within a plot were counted and removed. Groups that lay on a plot boundary were counted if the midpoint fell within the plot (Robinette *et al.* 1958).

To estimate deer and moose per hectare during each season, the respective pellet group densities (groups/1200m^2) were extrapolated to groups per hectare, and divided by the daily deposition rate of each species and the estimated number of days each species was in an area (Eberhardt and VanEtten 1956). Deer and moose populations were estimated by multiplying animal density by the number of hectares in each area. Confidence intervals (CI) for pellet group density were estimated using a standard formula for cluster sampling sample variance (Henry 1990). Upper and lower limits of population density estimates (animals/km^2) were calculated from the 95% confidence intervals.

Browse Availability and Utilization

Rectangular 1x2m vegetation plots (Renecker and Hudson 1986) were located at 20m intervals along all transects to measure remaining and utilized browse. All browsed and browsable hardwood stems between 0.3 and 2.1m were counted within each vegetation plot, and stratified at three height levels (0.3-0.6m, 0.6-1.8m, and 1.8-2.1m) to account for possible differences in utilization due to variable snow depth.

The twig count method was used to measure browse production (availability) and utilization on permanent sample plots (Shafer 1963). Available browse was defined as the portion of annual growth longer than 25.4mm (Telfer and Cairns 1978), and smaller than or equal to the largest diameter at point browsed (DPB) of a particular species.

In each deer yard, 100 non-browsed twigs of each deciduous species were collected randomly outside the sampling plots during autumn and winter. After air drying, twigs were dried in a convection oven at 100°C for 24 hours. Each twig was weighed to the nearest 0.01g using a Mettler balance, and the diameter at point clipped was measured to the nearest 0.25mm using vernier calipers. Regression analysis was used to determine relationships between diameter (x) and weight (y) for each species for the autumn and spring seasons. Polynomial equations of the form:

$$\text{browsed twig biomass (g)} = K - a(DPB(mm)) + b(DPB(mm))^2$$

were used because their R-values were largest of all equations tested; T-ratios were >1.96 ($p<0.05$) for all species' regressions.

Fifty browsed twig samples of each browsed species were collected at each study area. The DPB was measured for each browsed twig with vernier calipers, and the mean DPB was calculated for each species. The biomass removed for each species was estimated by using the plant species' mean DPB value and the species-specific diameter-weight relationship. Unbrowsed and utilized biomass was calculated by species for each plot by multiplying the mean biomass/twig for each species in the plot by the number of unbrowsed and browsed twigs of that species present in the plot. Unbrowsed and browsed twig biomasses were totaled for all species in the plot for non-parametric statistical analysis. Plot biomass totals ($g/120m^2$) were extrapolated for each yard (kg/ha).

The percent of biomass browsed by either moose or deer was estimated from total browsed biomass, pellet group counts, species defecation rates, and the estimated number of days moose and deer occupied a yard.

Statistics

To test the null hypotheses that moose and/or deer presence in deer yards in different seasons had no effect on availability of browse biomass, unbrowsed twig biomass was compared between spring and autumn sampling seasons for each deer yard. Mann-Whitney tests were run to determine if there were significant differences between seasonal browse availability within yards from spring 1989 to autumn 1990, or fall 1990 to spring 1991.

Bonferroni Z-statistic confidence intervals were applied to six browse species common to yards heavily browsed by moose during fall to determine browse species preference (Neu et al. 1974, Byers *et al.* 1984).

Browsing Dynamics

To further evaluate the potential effect of moose browsing relative to deer, we estimated the number of deer present in deer yards based on the measured consumed browse biomass, the number of deer that a yard could support during winter based on the measured available browse biomass, and the percentage of deer theoretically displaced by browse reductions due to moose. The number of days deer occupied a deer yard was calculated based on the biomass of browse consumed. The number of deer days of use (DD) in a yard equalled the total consumed biomass (CB) (dry weight) in a deer yard divided by the estimated daily browse consumption of an average deer during winter, 0.842kgDM/deer/day (Mautz *et al.* 1976):

$$\text{DD deer/day} = \text{CB kg} / 0.842 \text{ kgDW/deer/day}.$$

The potential number of deer occupying each yard during winter (WD) was estimated by dividing DD by the estimated confinement interval. For a 70 day confinement period:

$$\text{WD deer} = \text{DD deer/day} / 70 \text{ days}.$$

The above values do not account for moose presence, which did occur in most yards during certain seasons. To correct for moose use, and to estimate how many moose and deer were in a yard, the percent contribution of each species based on pellet group deposition rates and animal specific browse consumption rates was calculated. Daily dry matter intake (DMI) of moose during January is 38g/

kgBW$^{0.75}$ (Renecker and Hudson 1986). The average weight of New Hampshire moose was estimated from weights of harvested animals (NHF&G 1988) corrected to live weight (LW):

LW = harvest weight + (0.20 * harvest weight).

Moose DMI was calculated:

Moose DMI kgDM = 38g * LW$^{0.75}$ / 1000 g/kg.

The average estimated live weight of New Hampshire moose was 312kg, and the calculated DMI for moose was 2.824 kg/moose/day. The ratio of moose browse consumption (MCR) to deer browse consumption was calculated by:

MCR = 2.824 kg/moose/day / 0.842 kg/deer/day,

= 3.35 deer/moose

The number of moose pellet groups counted in each yard was multiplied by a deer-moose pellet group deposition rate factor of 2, and the consumption rate factor (3.35), to get the moose browse index (MI) value.

The deer browse index (DI) value was simply the number of deer pellet groups counted in a yard. The index to total biomass browsed (BI) was DI + MI. The contribution of moose to browsing (MC) was:

MC(%) = MI / BI.

The associated potential reduction in deer numbers (DR) due to moose browsing was:

DR = WD deer * MC(%).

Theoretically, moose browsing during winter effectively reduces browse biomass that would be able to support DR deer for a specific confinement period.

Simulated Normal Winter

The effect a normal year's snow depth (102cm in hardwoods and openings, and 71cm under softwood cover, J. Lanier, USFS Wildlife Biologist, pers. comm.) has on available browse biomass was simulated for a one-year-old clearcut (Y14), and compared to the estimated available browse biomass during the mild winter of 1991. The 0.3-0.6m height class of unbrowsed biomass was removed during data analysis to estimate the browse that would normally be covered by snow.

RESULTS

Snowfall totals during winter 1990 ranged from 169cm (66.7in) in Benton, to 276cm (108.5in) in Pittsburg, and ranged from 117cm (46.3in) in Benton, to 227cm (89.2in) in Pittsburg during winter 1991. Snow depths averaged 33.2cm (SE=3.3) among yards during late winter, and did not limit browse availability within the three browse height classes. During the simulated normal winter, the unbrowsed biomass covered by snow (0.3-0.6m height class) in a one-year-old clearcut (Y14) accounted for 58.8% of the total unbrowsed biomass. The estimated maximum deer density Y14 could sustain decreased from 19.8 deer/km^2 to 8.2 deer/km^2 during winter 1991. The effect of normal snow depths on browse availability was greater in Y14 than that in yards adjacent to older cuts with more browse stems in the middle and upper height classes.

Size of deer yards averaged 218ha (SE=86.1), and ranged from 39ha (Y9) to 1282ha (Y5). The DPB of 23 hardwood browse species was measured during spring 1990 ($\bar{x}$=2.57mm), autumn 1990 ($\bar{x}$=2.27mm), and spring 1991 ($\bar{x}$=2.49mm). A significant relationship ($p<0.01$) was found between twig diameter and dry twig mass for 22 hardwood browse species collected during spring, and 19 species collected during autumn. The mean biomass (g) removed per browsed twig across all species was similar ($\bar{x}$=0.52, SE=0.14) among seasons.

Browse use was spatially related to browse availability. The proportion of browse consumed outside softwood cover (72.5 $\pm$ 4.6%), versus within softwood cover, was similar to its availability (70.7 $\pm$ 4.2%). The estimated biomass consumed within 60m of softwood cover (59.7 $\pm$ 9.2%) was close to expected

(60%), and was not significantly different ($p>0.05$) from that consumed within 100m of softwood cover.

Unbrowsed biomass decreased ($\bar{x}$=3.6kg/ha, SE=7.7) from spring 1990 ($\bar{x}$=59.8kg/ha, SE=29.7) to autumn 1990 ($\bar{x}$=56.2kg/ha, SE=23.7) (Table 1), however, unbrowsed biomass increased 48.5 $\pm$ 20.4% in 5 yards and only decreased 22.7 $\pm$ 6.0% in 6 yards, for a 9.7 $\pm$ 14.5% increase across the 11 yards sampled (Table 2).

Unbrowsed biomass decreased ($\bar{x}$=23.8kg/ha, SE=10.5) in all 15 yards from autumn 1990 ($\bar{x}$=49.3kg/ha, SE=17.5) to spring 1991 ($\bar{x}$=25.5kg/ha, SE=7.6) (Table 1). The decrease (39.0 $\pm$ 6.4%) ranged from 1% (Y10) to 88% (Y4) (Table 2).

Subjective measures of browse utilization generally classify heavy (50-100%), medium (10-50%), and light (<10%) browse levels (Aldous 1944). Browse utilization, primarily by moose, was measured as medium (10-50%) in four yards during autumn and six yards during spring 1990, and heavy in two yards during springs 1990 and 1991 (Table 1). In particular, moose were the primary contributors to autumn ($\bar{x}$=91.5%, SE=1.9) and winter ($\bar{x}$=70.8%, SE=25.0) browse reduction in the young clearcuts (Y11, Y14, Y15) (Table 3).

Winter logging supplied daily supplemental forage in the form of cut tree tops in Y14, possibly sustaining artificially high deer and moose densities during winter. Winter blow-downs also resulted in increased forage availability. Forage of this type reduces browsing pressure in traditional foraging areas, resulting in an underestimate of browse consumption. However, significant browsing pressure occurred in Y14 despite the availability of tree tops. Significant ($p<0.05$) decreases in available browse from spring 1990 to spring 1991 in 2 yards (Y7 and Y10), and a similar trend across most deer yards ($p<0.40$), indicated that browse availability may be declining in some yards.

Table 1. Unbrowsed and browsed biomass (kg/ha) in deer yards measured during spring 1990, autumn 1990, and spring 1991.

	Unbrowsed biomass			Browsed biomass		
Yard	Spring 1990	Autumn 1990	Spring 1991	Spring 1990	Autumn 1990	Spring 1991
Y1	33.2	31.2	15.1	18.2	2.0	4.1
Y2	350.1	284.3	121.6	68.3	6.0	3.0
Y3	27.8	25.7	21.5	1.0	0.9	3.4
Y4	84.1	62.9	7.6	15.9	0.5	0.1
Y5	11.5	11.9	6.4	3.5	0.1	1.6
Y6	7.4	9.8	6.4	14.5	0.8	10.5
Y7	19.0	12.5	10.3	14.0	5.6	9.0
Y8	26.9	56.4	37.7	4.8	16.2	1.9
Y9	41.6	47.6	34.5	9.0	8.9	0.6
Y10	21.7	12.3	12.2	19.6	2.0	6.9
Y11	35.0	63.8	45.9	3.5	7.1	0.2
Y12		27.8	18.1		2.1	1.4
Y13		42.1	25.0		0.8	3.9
Y14		10.0	1.7		1.8	10.7
Y15		41.3	18.3		0.9	1.4

Table 2. Percent biomass decreases from spring 1990 to autumn 1990 and autumn 1990 to spring 1991 and associated p-values* for unbrowsed biomass in New Hampshire deer yards.

	Spring 90 - Autumn 90		Autumn 90 - Spring 91	
Yard	% Decrease	P-value	% Decrease	P-value
Y1	6.0	0.2420	51.6	0.5654
Y2	18.8	0.2031	57.2	0.6310
Y3	8.3	0.1640	16.3	0.0656
Y4	25.2	0.8831	87.9	0.8622
Y5	-3.5	0.2218	46.2	0.2859
Y6	-32.4	0.0000	34.7	0.0000
Y7	34.2	0.0001	17.6	0.0002
Y8	-109.7	0.2715	33.2	0.1756
Y9	-14.4	0.6803	27.5	0.6069
Y10	43.3	0.0114	0.8	0.9539
Y11	-82.3	0.0594	28.1	0.7488
Y12			34.9	0.7768
Y13			10.1	0.1740
Y14			83.0	0.0203
Y15			55.7	0.4068

* Paired T-test between seasons for each yard's biomass by plot.

Spring 1990

The estimate of browsed biomass, relative to availability, was 26.5 ± 5.6% across all yards, ranging from 3.5% (Y3) to 66.5% (Y6) (Table 3). Estimates of moose density, extrapolated from pellet group counts and an 80 day use period (1 January - 20 March), averaged 4.5 moose/km^2 (SE=1.4), and ranged from 0 (4 yards) - 12.5 moose/km^2 (Y2). Deer density estimates averaged 28.4 deer/km^2 (SE=8.3), ranging from 0.7 (Y2, Y4) - 67.3 deer/km^2 (Y6, Y7).

We estimated that moose and deer browsed 7.2 ± 2.0% (26.3% of the total consumption) and 19.5 ± 6.6% of the available browse, respectively. Use by moose and deer ranged from 0-16% and 0.3-66.5%, respectively (Table 3).

Autumn 1990

Browsed biomass during late summer and autumn 1990 was 9.4 ± 2.3% of that available, ranging from 0.8% (Y5) - 22.3% (Y8) (Table 1). The estimated moose density was 1.2 moose/km^2 (SE=0.2) (assuming a 120 day use period from 18 August - 15 December) ranging from 0 (Y12) - 2.3 moose/km^2 (3 yards). The estimated deer density was 0.5 ± 0.1 deer/km^2, ranging from 0 (5 yards) - 1.6 deer/km^2 (Y7). We estimated that moose and deer browsed 7.7 ± 1.9% (81.1% of the total consumption) and 1.8 ± 0.7% of the available browse, respectively (Table 3). Use per species ranged from 0-23.5% and 0-8.3%, respectively (Table 3).

The 6 yards most heavily browsed by moose ($\bar{x}$=15.2 ± 2.1% of the available hardwood browse, Table 3) had 6 browse species in common. Red maple was the most available ($\bar{x}$=25.6 ± 3.8%), and constituted the largest proportion of total consumed biomass, but was removed below (17.4 ± 4.1%) its availability. Quaking aspen ($\bar{x}$=7.7 ± 3.2%) and mountain maple ($\bar{x}$=5.5 ± 2.7%) were

Table 3. Percent biomass browsed by moose and deer prior to each of the three sampling seasons.

	% Browse removed by moose			% Browse removed by deer		
Yard	Spring 1990	Autumn 1990	Spring 1991	Spring 1990	Autumn 1990	Spring 1991
Y1	0.0	6.0	6.3	35.4	0.0	14.8
Y2	16.0	2.1	2.1	0.3	0.0	0.3
Y3	0.0	3.1	4.3	3.5	0.2	9.5
Y4	15.5	0.8	1.2	0.3	0.0	0.0
Y5	13.6	0.8	0.0	9.4	0.0	19.3
Y6	0.0	7.5	0.0	66.5	0.0	62.0
Y7	0.0	23.5	2.8	42.3	8.3	44.2
Y8	6.9	18.4	2.3	8.1	3.8	2.5
Y9	5.2	13.8	0.5	13.4	2.1	1.2
Y10	14.5	11.8	2.5	33.7	2.4	33.7
Y11	6.9	8.9	0.4	2.1	1.1	0.0
Y12		0.0	0.0		6.7	6.9
Y13		1.7	10.0		0.1	3.7
Y14		14.8	18.0		1.6	67.6
Y15		2.0	6.5		0.1	0.6

preferred browse species. Pin cherry and nannyberry were browsed relative to their availability, and speckled alder was browsed below its availability (Table 4).

Spring 1991

The estimated biomass browsed during winter 1991 was 21.5 ± 6.6%, ranging from 0.4% (Y11) to 85.6% (Y14); four yards were browsed at levels >35%. Estimates of moose density ($\bar{x}$=2.3 moose/km^2, SE=0.5) assuming a 70 day use period [1 January - 5 March (10 days less than the 1990 winter use period because of less snow)], ranged from 0 (3 yards) - 4.8 moose/km^2 (3 yards). Mean deer density was 20.3 deer/km^2 (SE=5.0), ranging from 0 (Y4, Y11) - 69.8 deer/km^2 (Y10). We estimated that moose and deer browsed 3.8 ± 1.3% (17.6% of the total consumption) and 17.8 ± 6.0% of the available browse, respectively (Table 1). Use per species ranged from 0-18% and 0-67.6%, respectively (Table 3).

The combined contribution of moose to total browse consumption measured during autumn 1990 and spring 1991 was 25.3 ± 6.2%, and was similar to that measured during spring 1990 (26.3 ± 6.2%), a measure of both autumn 1989 and winter 1990 browse consumption (Table 3).

Moose potentially diminished the number of deer a yard could support by greater than 10% in 7 of 15 yards, and by more than 20% in 3 yards. Moose browsing in a one-year-old clearcut (Y14) during fall and winter combined, potentially decreased the number of deer the yard could support by 33% (44 deer).

DISCUSSION

Moose and deer concentrate feeding activity in clearcuts and along forest edges (Sweeney *et al.* 1984, Irwin 1985, Williamson and Hirth 1985) with high browse availability (Telfer 1978), especially during autumn and winter (Irwin 1975). Deer, however, are lim-

Table 4. Biomass usage for six common browse species in deer yards heavily browsed by moose during autumn, and Bonferroni confidence intervals (0.05 significance level) used to determine preference.

Species	Expected proportion of usage P_{io}	Actual proportion of usage P_i	Bonferroni intervals for P_i	Use relative to availability
Red maple	0.256	0.174	$0.123 \leq P_1 \leq 0.225$	*Below
Pin cherry	0.160	0.145	$0.098 \leq P_2 \leq 0.192$	At
Nannyberry	0.136	0.110	$0.068 \leq P_3 \leq 0.152$	At
Speckled alder	0.102	0.036	$0.011 \leq P_4 \leq 0.061$	Below
Quaking aspen	0.077	0.353	$0.289 \leq P_5 \leq 0.417$	Above
Mountain maple	0.055	0.107	$0.066 \leq P_6 \leq 0.148$	Above
Other	0.214	0.075	$0.040 \leq P_7 \leq 0.110$	Below

*Browsed above and at availability in some areas, but high availability across all areas makes it difficult to evaluate preference.

ited by snow depth to browse within and adjacent to softwood cover (Verme 1965). Clearcuts adjacent to deer yards provide higher availability of preferred browse species than in uncut areas, and because moose are well adapted for rapid colonization of newly created, favorable habitats in boreal forests (Geist 1971, Irwin 1975), they concentrate in these clearcuts. Moose feed more selectively with the onset of plant senescence during autumn (Rénecker and Hudson 1989). The smaller average DPB measured during autumn 1990 versus spring 1990 and 1991 suggests a tendency toward selective browsing for smaller, more digestible stem tips by moose and deer during autumn. Available biomass estimates for northern New Hampshire deer yards during autumn ($\bar{x}$=49.3kg/ha, SE=17.5) and remaining biomass in spring ($\bar{x}$=40.0kg/ha, SE=13.4), were lower than biomass estimates for yards in Quebec ($\bar{x}$=73kg/ha) (Crete 1989) and Alberta ($\bar{x}$=536kg/ha) (Renecker and Hudson 1986), but higher than in other Quebec yards ($\bar{x}$=37kg/ha) (Potvin and Huot 1983).

Clearcuts adjacent to softwood cover were important for foraging. The highest moose and deer densities in yards were during autumn and winter, respectively, and were adjacent to those clearcuts with high browse availability. Use by moose in such areas during autumn resulted in the browse reductions attributed to moose in certain yards.

Similarly, substantial reductions in browse availability of quaking aspen and other important browse species has been attributed to moose during the late summer and autumn in Quebec and Alaska (Joyal and Scherrer 1978, Regelin 1987, VanBallenberghe *et al.* 1989). Quaking aspen stems browsed during late summer and autumn are not browsable during winter and are susceptible to winter desiccation (Prachar and Samuel 1988). Younger twigs in 1 and 2 year-old openings that are preferred by cervids are particularly susceptible to browse induced mortality (Prachar and Samuel 1988, Heinen and Sharik 1990). This type of browse reduction is of greatest concern in deer yards that border on recent clearcuts that are particularly susceptible to summer and autumn browsing by moose and deer.

The availability of tree tops from winter

Table 5. Browsed biomass measured during spring 1991 and the related deer yard occupancy rates and moose browse effects.

Yard	Browsed biomass (kg)	Total deer days	Number of deer if confined 70 days	Max.number of deer possible*	% of deer reduced by moose browsing
Y1	434.6	516.2	7.4	74	12.2
Y2	180.0	213.8	3.1	338	4.2
Y3	765.0	908.6	13.0	115	7.4
Y4	9.0	10.7	0.2	112	2.0
Y5	2051.2	2436.1	34.8	303	0.1
Y6	598.5	710.8	10.2	11	7.2
Y7	945.0	1122.3	16.0	26	26.2
Y8	121.6	144.4	2.1	72	20.7
Y9	23.4	27.8	0.4	37	14.4
Y10	759.0	901.4	12.9	27	14.6
Y11	9.8	11.6	0.2	62	9.2
Y12	364.0	432.3	6.2	143	0.0
Y13	464.1	551.2	7.9	99	11.7
Y14	7211.8	8565.1	122.4	133	32.8
Y15	63.0	74.8	1.1	37	6.8

* Calculated from confinement period, deer energy requirements, and available browse biomass prior to confinement.

logging may have attracted more deer and moose to at least one yard, and increased the browsing pressure in the immediate logging area. Conversely, browse regeneration may have improved in portions of the deer yard located away from immediate logging activity.

We assumed that moose were confined to the same area for an equal time as deer, which may not be true because moose are more mobile than deer and not as inhibited by snow depth. Regardless, if pellet groups represent the time spent in an area browsing, the estimate of moose browse should be reasonable, even if caused by different moose whose home ranges overlap within a deer yard.

The available browse biomass in deer wintering areas can be expressed in terms of the number of deer and moose the area can sustain for a specific number of days. The estimated number of deer that the 15 deer yards could support prior to winter 1991 (70 day confinement period) ranged from 19.4 - 563.9 deer/km^2 (Pruss 1991). Previous studies in Quebec and New York (Potvin and Huot (1983) (0-18 deer/km^2); Jackson (1974) (1.9-11.6 deer/km^2), respectively) estimated lower browse availability based on deer confinement to softwood cover, without including openings and cuts adjacent to softwood cover. However, these areas provided 71% of the available browse, and contributed 72% of the browsed biomass in our deer yards. The number of deer an area could support based only on browse availability under softwood cover would reduce the population estimates on average 71%, closer to those reported by Potvin and Huot (1983), and Jackson (1974).

Moose increase browsing of hardwood stems during autumn as green leaves become less available (Wolff and Cowling 1981, Renecker and Hudson 1989). Any pre-winter hardwood browse removal of this type could be critical in Y14, because deer browsed more biomass there during winter 1991 than was estimated available during autumn 1990.

Foraging conditions progressively deteriorate when moose density exceeds 1 moose/km^2 (Messier 1991). Carrying capacity for moose in the eastern boreal forest in Quebec was estimated at 1.8-2.0 moose/km^2 (Crete 1989). Thus, the moose population density (1.97 moose/km^2) in portions of northern New Hampshire (NHF and G 1988) may be nearing carrying capacity, and the moose may be reducing forage availability.

Effects of moose on browse are of particular importance in areas where deer and moose populations are both increasing, as in many areas of northern New Hampshire (S. Williamson, NHF and G Deer Project Leader, K. Bontaites, NHF and G Moose Project Leader, pers. comm.). Increased moose browsing in deer yards during autumn could further reduce the available winter browse and the number of animals a yard could support. Winter mortality of moose has not been documented in New Hampshire, and is not considered an important factor in their population dynamics. However, increased reports of moose winter tick infestation (Bontaites, pers. comm.) indicate a potential population control mechanism. Although obvious signs of *P. tenuis* infection in moose were not observed, and the organism does not appear to be highly prevalent in New Hampshire, higher moose and deer densities may increase its prevalence in the future. In the absence of natural or man induced moose and/or deer population control mechanisms, browse carrying capacity for cervids will be reached, as indicated by certain of our data, and increased mortality of wintering deer will probably be the competitive result.

MANAGEMENT IMPLICATIONS

Habitat Management

Within the study areas, 2-10 year-old clearcuts supplied the greatest twig density, whereas older cuts showed less browse availability and winter use. Moose had an especially large impact on the browse available in the yard adjacent to a large one year old clearcut (Y14), probably because of the high browse productivity in the area. Conversion of coniferous forest to shrub stands by commercial logging has a high potential for increasing moose populations (Telfer 1978), thus, high browse productivity in an area may also have a positive effect on the moose population.

Rapid height growth of early successional species in clearcuts limits full browse utilization by deer to 3 years in Vermont (Williamson 1983). Decreased light intensities in shelterwoods with higher residual basal areas would slow height growth, keeping browse accessible to deer longer, however, browse quality may be lower in these cuts (Williamson 1983). Additional crop-tree release cuts in shelterwoods would provide high production of browse for at least another 3 years (Williamson 1983). Group selection harvests on the WMNF (New Hampshire and Maine) removes trees in small groups, usually from 0.1 to 0.25 acres in softwoods, and 0.25 to 2.0 acres in hardwoods, resulting in small even-aged blocks within a stand representing different age classes. This method sustains a moderately dense, continuous forest canopy important for wintering deer (WMNF 1986). Forest harvesting practices, such as shelterwood cutting, that provide adequate browse adjacent to and within deer yards in small and scattered quantities may reduce the logged area's attraction to moose and minimize the potential competition for browse with deer.

Deer and Moose Management

Although present conditions may not

warrant widespread changes in management of moose and deer populations, management in some areas will be necessary if current population trends continue. Deer and moose foraged near or above browse availability in 20% of the deer yards. These yards need special attention when setting permit levels and hunting seasons. Implementing doe seasons and/or increasing season length in critical deer management units should increase the deer harvest and decrease the potential for substantial winter deer mortality. Current increases in moose permits allocated throughout northern New Hampshire should help decrease potential forage competition. Areas of high potential browse resource competition should be considered for permit increases when future moose hunt permits are allocated.

Although moose are not presently competing with deer for total browse biomass in most northern New Hampshire deer yards, they may be competing with deer for preferred browse species (e.g., quaking aspen, maples). Both species prefer larger, more nutritious stump sprouts to seedlings. Because moose browse substantially in deer yards during the fall prior to deer occupation, they potentially remove a large portion of the more nutritious preferred browse in clearcuts. Remaining stems are probably nutritionally poorer and less palatable, thereby negatively affecting the food supply and potential winter survival of deer. Competition for browse at this level may be an important factor in future browse studies and for the future of moose and deer in northern New Hampshire.

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