Abiotic Factors Influencing Deer Browsing in West Virginia

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ABSTRACT: *We present a comparison of woody browse availability and white-tailed deer (*Odocoileus virginianus*) use among clearcut interiors, skidder trail edges, and mature forest and an evaluation of the relative importance of aboitic factors in predicting browsing pressure within regenerating clearcuts in the central Appalachians of West Virginia. We sampled 810 1-m^2 plots in or adjacent to nine regenerating clearcuts (8–19 ha) during the summer of 2001. Availability and use of woody browse did not differ between clearcut interior and skidder trail plots for any species observed. Plots in the adjacent mature forest had less woody browse availability and higher utilization. Overall use of available woody browse in clearcuts was >15%. Combining all woody species, elevation (w_I = 0.618) and distance to mature forest (w_I = 0.379) were more important than landform index, plot surface shape, aspect, and slope in predicting deer browsing pressure in regenerating clearcuts. We believe that without management activities aimed at reducing deer browsing, in many parts of this region the ability of forest managers to regenerate stands will be jeopardized and the forested ecosystem will be compromised. North. J. Appl. For. 23(1):20–26.*

Key Words: Landform index, plot surface shape, slope, aspect, skidder trail.

The impacts of white-tailed deer (*Odocoileus virginianus*) browsing on forest regeneration in northern hardwood forests in the northeast and mid-Atlantic portions of the United States are well documented (Marquis 1974, Tilghman 1989, Horsley et al. 2003). These include a reduction in seedling height (Marquis and Grisez 1978, Marquis 1981, Tilghman 1984), shifts in species composition (Marquis 1974, Tilghman 1984), a reduction in stump sprout survival (Jordan et al. 1965, Tilghman 1984), alterations in herbaceous ground cover (Marquis 1974, Marquis and Grisez 1978, Tilghman 1984), and a reduction in habitat for other wildlife species (McShea and Rappole 1992, deCalesta 1994). However, in a review of white-tailed deer effects on vegetation, Russell et al. (2001) challenge future investigations to address the relative importance of factors in determining where substantial deer effects will occur. Research in Pennsylvania has focused on important biotic factors, such as deer densities (Tilghman 1989, deCalesta 1994, Horsley et al. 2003). However, no studies have examined the influence of abiotic factors on deer browsing pressure in this region.

In the central Appalachians, clearcutting is a silviculturally appropriate method for regenerating forest stands with a good species mixture (Smith 1995). On industry lands in this region, felled logs often are skidded out on trails established during the harvest and/or existing from decades of previous diameter-limit harvests. The impact of skidding and trails on water quality (Rapp et al. 2001), soils (Aust et al. 1993, Startsev and McNabb 2001), and residual stand productivity (Egan 1999) has been studied. However, investigations about skidder trail relationships with wildlife species, such as white-tailed deer, are few. With forest management practices increasingly coming under public scrutiny, it is important to understand the impacts of silvicultural activities on wildlife species. It seems reasonable to expect that woody browse use would be greater on skidder trails than in clearcut interiors. However, this relationship has not been evaluated.

Herein, we present a comparison of woody browse availability and deer use among clearcut interiors, skidder trail edges, and mature forest. We also evaluate the relative

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importance of abiotic factors in predicting deer browsing pressure within regenerating clearcuts. Specific hypotheses we examine are that that slope, aspect, site index, elevation, distance to mature forest, landform index (LFI), and plot surface shape (PSS) are important predictors of browsing pressure.

Study Area and Methods

From late July to early August 2001, we sampled 810 1-m^2 vegetation plots on the MeadWestvaco Wildlife and Ecosystem Research Forest (MWWERF) in West Virginia. The 3,260-ha MWWERF occurs in the Unglaciated Allegheny Mountain and Plateau physiographic province of the central Appalachians (Fenneman 1938). The MWWERF is characterized by steep slopes with broad, plateau-like ridgetops and narrow valleys with small, high-gradient streams. Elevations range from 740 to 1,200 m and precipitation averages from 170 to 190 cm/year (Smith 1995). Established in 1994 to assess the impacts of industrial forestry on ecosystem processes, the MWWERF is comprised of second growth Allegheny hardwood-northern hardwood forests that were originally harvested in the early 1900s (Clarkston 1993). The dominant forest type is American beech (*Fagus grandifolia*)-black birch (*Betula lenta*)-maple (*Acer* spp.). Harvested stands naturally regenerate through even-aged techniques, such as clearcuts and 2-age leave-tree harvests. Clearcuts, 0–5 yr of age, comprise <7% of the MWWERF. White-tailed deer densities using automated cameras during summer were estimated as 14 deer/km^2 during our study (Langdon 2001).

We quantified the availability of woody browse and use by deer in 9 regenerating clearcuts (0–5 yr of age) and adjacent mature forests. Selected clearcuts ranged in size from 8 to 19 ha and had a mean skidder trail density of 0.3 km/ha. We sampled 90 1-m^2 plots per clearcut. Within each clearcut, 30 plots were assigned systematically along skidder trail edges, with randomization applied to the first plot. Mean distance between plots was 121 m. For each plot on the skidder trail edge, a matched plot was established into the clearcut interior at 5 m in the cardinal direction most perpendicular to the skidder trail (Figure 1). Additionally, we established 30 plots ≥50 m into the adjacent mature forest. We randomly assigned the first plot in the mature forest and systematically established the remaining plots on transects parallel to clearcut edges. Within the mature forest plots, mean distance between plots was 19 m. Our sampling protocol was designed to maximize coverage within clearcuts and variability in elevation, slope, and aspect.

We semi-permanently marked plots with rebar stakes. We surveyed plots with a submeter global positioning systems (GPS) (Geoexplorer 3, Trimble Navigation Limited, Sunnyvale, California). At each plot, percent slope was determined with a clinometer and aspect was determined by sighting downhill in the direction of the fall line of the terrain with a compass. For plots occurring within clearcuts (540 plots) we measured the distance to nearest mature forest using ARCVIEW (Environmental Systems Research Institute 1999). Additionally, we computed from digital

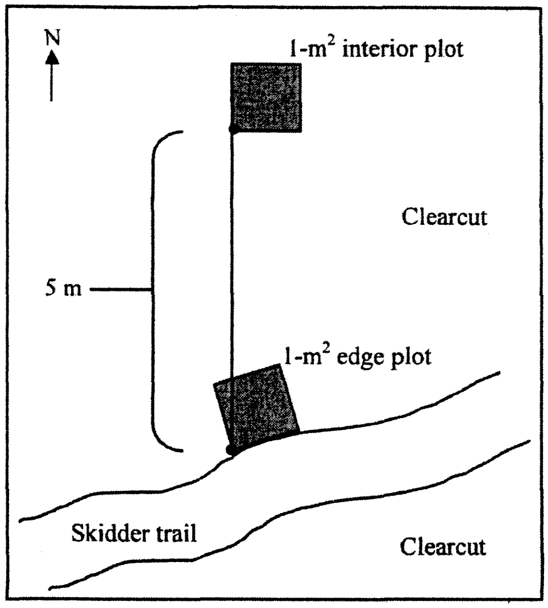

Figure 1. Layout for one set of skidder trail edge and clearcut interior plots on the MeadWestvaco Wildlife and Ecosystem Research Forest, West Virginia during summer 2001.

terrain models of the MWWERF, the LFI, and the PSS of each plot. Landform index is a measure of the degree to which a site is sheltered by surrounding landforms, with lower values indicating a less-sheltered position (McNab 1993, Ford et al. 2000). Plot surface shape is a measure of the degree of convexity or concavity of a site, with negative values indicating a concave position and positive values indicating a convex position (Ford et al. 2000).

Within each plot we identified all woody species. We quantified the total number of twig tips ≤1.5 m from the ground (i.e., available) by species and the number of those that were browsed following Ford et al. (1993). For each woody species we expressed deer use as the percent available that was browsed (i.e., % browsed). To compare availability and use of woody browse species among clearcut interior, skidder trail, and mature forest plots we used a randomized complete block analysis of variance (ANOVA) (SAS Institute 1989). For these analyses, clearcut area (n = 9) was the blocking factor and plot type (n = 3) was the main effect. Availability and use values were square-root transformed prior to analysis (Steel and Torrie 1980). We only included species with >50 available twigs/ha in analyses. Statistical significance was accepted at $\alpha = 0.05$. When statistical differences were determined, we used Tukey's honestly significant difference as a multiple range test. Unless otherwise noted, we reported means with standard errors in parentheses.

To evaluate factors important in predicting browsing pressure within regenerating clearcuts we used information-theoretic approaches and multimodel inference (Burnham and Anderson 2002), methods that rank models according to their relative importance. A priori, we formulated seven hypotheses (or models) based on the literature and knowledge of the system. Hypotheses 1 and 2: percent slope and aspect (linearized using [1-cosine (aspect in degrees)]+[1-sine (aspect in degrees)]) are important in predicting deer browsing pressure. We expected deer browsing pressure to be negatively related to percent slope (via deer conserving energy) and positively related to aspect (from northeast to southwest; via vegetative responses from varying solar radiation). Hypothesis 3: site index is important in predicting deer browsing pressure. We expected deer browsing pressure to be positively related to site quality (Ford et al. 1994, Gribko et al. 1999). Hypothesis 4: elevation is important in predicting deer browsing pressure. We expected deer browsing pressure to be positively related to elevation (via high elevations occurring in or near flat plateaus with comparatively easy access). Hypothesis 5: distance to mature forest is important in predicting deer browsing pressure. We expected deer browsing pressure to be negatively related to distance from mature forest (Wentworth et al. 1990). Hypotheses 6 and 7: LFI and PSS are important in predicting deer browsing pressure. As with site index, we expected deer browsing pressure to be positively related to both LFI and PSS because they are indicators of site quality (McNab 1993), which is positively related to browsing pressure (Ford et al. 1994, Gribko et al. 1999). Our hypotheses assumed a similar deer density at all plots.

To rank models according to their relative importance, we used second-order Akaike information criterion (AIC_c) to estimate relative Kullback-Leibler (K-L) information (Kullback and Leibler 1951). We used these analyses on 3 groups of species. Group 1 included all woody species. Group 2 contained commercially valuable species, including northern red oak (*Quercus rubra*), black cherry (*Prunus serotina*), yellow-poplar (*Liriodendron tulipifera*), and sugar maple (*A. saccharum*). Group 3 contained species of preferred deer browse as reported from the Appalachian Mountains (Ford et al. 1993, Healy 1971, Horsley et al. 2003), including blackberry (*Rubus* spp.), greenbrier (*Smilax* spp.), oaks (*Quercus* spp.), red maple (*A. rubrum*), sugar maple, striped maple (*A. pennsylvanica*), pin cherry (*P. pensylvanica*), American beech, sassafras (*Sassafras albidum*), and yellow-poplar. For all models within each group, the dependent variable was the percent available woody twigs that were browsed at each plot. Browsing pressure data were square-root transformed before analysis (Steel and Torrie 1980). Plots were only included if they occurred within clearcuts (i.e., only clearcut interior and skidder trail plots) and had values for available and browsed >0.

To determine whether model parameters were independent, we used PROC CORR (SAS Institute 1989) to generate correlation coefficients among parameters. Because site index values were negatively correlated with percent slope, aspect, and LFI, positively correlated with elevation, and determined at the stand-level, we omitted this parameter from analyses. We used PROC GENMOD (SAS Institute 1989) to produce log likelihood estimates ($\log(L)$) for each model. We calculated the number of parameters (K), AIC_c, AIC differences (Δ_i), and Akaike weights (w_i) for each model following Burnham and Anderson (2002). We determined our confidence set for the K-L best model based on Akaike weights ($w_i \geq 10\%$ of w_{max}). We quantified the relative importance of each parameter in the confidence set

Table 1. Mean (SE) browse species availability (twigs/0.0001 ha) and use (% browsed) in clearcut (≤5 yr old) interiors, on clearcut skidder trails, and in adjacent mature forests on the MeadWestvaco Wildlife and Ecosystem Research Forest, West Virginia during summer 2001.

	Clearcut interior[a]		Skidder trail[a]		Mature forest[a]	
Species	Available (twigs/0.0001 ha)	Use (%)	Available (twigs/0.0001 ha)	Use (%)	Available (twigs/0.0001 ha)	Use (%)
Blackberry (*Rubus* spp.)	31.50 (2.80)A[b]	19.5 (2.1)a[c]	37.50 (3.18)A	18.7 (1.8)a	1.08 (0.29)B	1.8 (1.2)b
Black birch (*Betula lenta*)	10.49 (2.05)A	11.7 (2.7)a	10.19 (1.69)A	11.6 (2.3)a	4.26 (0.97)B	12.5 (3.1)a
Greenbrier (*Smilax* spp.)	9.96 (1.45)A	24.2 (2.8)a	10.30 (1.66)A	23.5 (2.7)a	4.82 (0.88)B	63.4 (3.9)b
American beech (*Fagus grandifolia*)	5.23 (1.13)A	3.3 (1.1)a	4.31 (1.01)A	4.1 (2.5)a	1.40 (0.41)B	12.5 (4.4)b
Yellow-poplar (*Liriodendron tulipifera*)	4.60 (0.57)A	4.4 (1.4)a	5.09 (0.86)A	3.6 (0.9)a	0.22 (0.08)B	0.0 (0.0)a
Black cherry (*Prunus serotina*)	4.10 (0.66)A	11.8 (2.8)a	3.06 (0.65)A	13.7 (3.1)a	0.88 (0.23)B	8.2 (2.7)a
Pin cherry (*Prunus pensylvanica*)	3.54 (0.81)A	20.0 (3.6)a	2.52 (0.50)A	19.8 (3.5)a	0.26 (0.08)B	5.1 (3.9)b
Striped maple (*Acer pennsylvanica*)	3.41 (0.72)A	4.3 (1.5)a	2.64 (0.58)AB	2.4 (0.7)a	1.10 (0.26)B	7.7 (2.3)a
Sugar maple (*Acer saccharum*)	3.36 (0.77)A	5.3 (2.1)a	3.63 (0.70)A	9.4 (2.4)a	1.95 (0.32)A	2.4 (1.2)a
Red maple (*Acer rubrum*)	2.53 (0.53)A	2.9 (1.1)a	2.44 (0.51)A	6.7 (2.0)a	2.74 (0.43)A	2.1 (0.8)a
Northern red oak (*Quercus rubra*)	1.54 (0.53)A	7.4 (3.2)a	0.73 (0.29)A	6.8 (2.9)a	0.05 (0.04)B	20.5 (20.5)a
Mountain magnolia (*Magnolia fraseri*)	1.51 (0.54)A	9.4 (3.7)a	0.54 (0.19)AB	4.8 (2.6)a	0.04 (0.02)B	0.0 (0.0)a
Cucumbertree (*Magnolia acuminata*)	1.35 (0.32)A	8.6 (3.5)a	0.82 (0.21)A	6.9 (3.3)a	0.03 (0.02)B	0.0 (0.0)a
Wild grape (*Vitis* spp.)	0.94 (0.40)A	6.7 (5.6)a	0.55 (0.19)A	2.1 (1.5)a	0.00 (0.00)B	
Witch−hazel (*Hamamelis virginiana*)	0.92 (0.44)A	7.1 (6.2)a	0.78 (0.36)A	11.3 (5.2)a	0.01 (0.01)B	0.0 (0.0)a
Black locust (*Robinia psuedoacacia*)	0.73 (0.33)AB	5.9 (4.2)a	1.94 (0.72)A	14.1 (5.5)a	0.01 (0.01)B	0.0 (0.0)a
Yellow birch (*Betula allegheniensis*)	0.38 (0.11)A	12.9 (6.3)a	1.11 (0.65)A	15.3 (6.9)a	0.21 (0.16)A	9.5 (6.3)a
Sassafras (*Sassafras albidum*)	0.36 (0.12)A	24.9 (8.8)a	0.15 (0.08)AB	28.8 (17.7)a	0.00 (0.00)B	
American basswood (*Tilia americana*)	0.15 (0.14)A	27.6 (27.6)a	0.18 (0.15)A	50.0 (50.0)a	0.05 (0.04)A	45.8 (20.8)a
Eastern hemlock (*Tsuga canadensis*)	0.14 (0.11)A	0.0 (0.0)a	0.01 (0.01)A	0.0 (0.0)a	0.05 (0.03)A	9.4 (9.4)a
Chestnut oak (*Quercus prinus*)	0.06 (0.03)A	15.8 (7.5)a	0.14 (0.12)A	4.0 (4.0)a	0.06 (0.03)A	7.1 (7.1)a
All species	88.55 (5.12)A	15.5 (1.2)a	92.25 (4.98)A	19.5 (1.3)ab	20.3 (1.80)B	20.5 (1.9)b

[a] $n = 270$ in each plot type.
[b] Available means in the same row not followed by the same upper case letter are different ($P < 0.05$) in the transformed data.
[c] Percent browsed means in the same row not followed by the same lower case letter are different ($P < 0.05$) in the transformed data.

Table 2. Summary of model selection statistics for six models of white-tailed deer browsing pressure (square root of % woody species browsed) for all species at 1-m² plots (n = 335) within clearcut regeneration areas on the MeadWestvaco Wildlife and Ecosystem Research Forest, West Virginia in 2001. Statistics include the total number of estimable parameters (K), log likelihood (log(L)), AIC$_c$ values, AIC differences (Δ_i), and Akaike weights (w_i). Models are in descending order of w_i.

Model	K	log(L)	AIC$_c$	Δ_i	w_i
Elevation (m)	3	−722.361	1450.795	0.00	0.618*
Distance to forest (m)	3	−722.850	1451.773	0.98	0.379*
Landform index	3	−727.773	1461.618	10.82	0.003
Plot surface shape	3	−734.589	1475.251	24.46	<0.001
Linear aspect	3	−734.988	1476.049	25.25	<0.001
Slope	3	−735.206	1476.485	25.69	<0.001

*Included in candidate set of models.

Table 3. Model averaged parameter estimates (for all, commercially valuable, and preferred species) of parameters within the confidence set of models with unconditional standard errors (SE) and resulting confidence intervals on the MeadWestvaco Wildlife and Ecosystem Research Forest, West Virginia in 2001. Dependent variable is the square root of percent woody species browsed.

				95% CI	
Species	Parameter	Estimate	SE	Upper	Lower
All					
	Intercept	−1.016	4.961	8.658	−10.69
	Elevation (m)	0.01	0.002	0.014	0.006
	Distance to forest (m)	−0.016	0.003	−0.01	−0.022
Commercially valuable					
	Intercept	−3.718	4.093	4.264	−11.7
	Elevation (m)	0.011	0.003	0.017	0.005
	Landform index	−12.995	4.679	−3.87	−22.12
Preferred					
	Intercept	−6.628	1.74	−3.235	−10.021
	Elevation (m)	0.012	0.002	0.016	0.008

of models (Burnham and Anderson 2002). We generated model averaged parameter estimates and associated confidence intervals produced from unconditional standard errors for parameters in our confidence set of models following Burnham and Anderson (2002).

Results

For all species combined, both clearcut interior and skidder trail plots produced abundant woody browse (Table 1). As expected the availability of woody species in mature forest plots was less than ($F_{2,799}$ = 216.72, P < 0.001) clearcut interior and skidder trail plots. This was a common observation within most species except sugar maple, red maple, yellow birch (*B. allegheniensis*), American basswood (*Tilia americana*), eastern hemlock (*Tsuga canadensis*), and chestnut oak (*Q. prinus*). For all species combined, the percent use of woody species in mature forest plots was greater than ($F_{2,744}$ = 3.02, P = 0.05) clearcut interior plots (Table 1). Blackberry and pin cherry use was less in mature forest plots than the other plots. Greenbrier and American beech use was greater in mature forest plots than other plots (Table 1). Availability and use did not differ between clearcut interiors and skidder trails for any species (Table 1).

For group 1 (all species), given the data and set of models, the evidence weights suggest that the elevation model (hypothesis 4) was the best approximating model for predicting browsing pressure (Table 2). The elevation model was 1.6 times more likely to be the best model of browsing pressure than the distance to mature forest model (hypothesis 5). There was very little evidence supporting the other hypotheses. Our confidence set of models included those with a w_i > 0.062 and was comprised of the elevation and distance to mature forest models. The relative importance of each parameter in the confidence set of models were, elevation = 0.618 and distance to mature forest = 0.379. The model averaged parameter estimates and associated confidence intervals for parameters in the confidence set of models are provided in Table 3. For all species, browsing pressure was positively related to elevation and negatively related to the distance to mature forest.

For group 2 (commercially valuable species), given the data and set of models, the evidence weights suggest that the elevation model (hypothesis 4) was the best approximating model for predicting browsing pressure (Table 4). The elevation model was 6.9 times more likely to be the best model of browsing pressure than the LFI model (hypothesis 6) and 24.9 times more likely to be the best model of browsing pressure than the slope model (hypothesis 1). There was very little evidence supporting the other hypotheses. Our confidence set of models included those with a w_i > 0.083 and was comprised of the elevation and LFI models. The relative importance of each parameter in the confidence set of models were, elevation = 0.832 and LFI = 0.120. The model averaged parameter estimates and associated confidence intervals for parameters in the confidence set of models are provided in Table 3. For commercially valuable

Table 4. **Summary of model selection statistics for 6 models of white-tailed deer browsing pressure (square root of % woody species browsed) for commercially valuable species at 1-m^2 plots (n = 104) within clearcut regeneration areas on the MeadWestvaco Wildlife and Ecosystem Research Forest, West Virginia in 2001. Statistics include the total number of estimable parameters (K), log likelihood (log(L)), AIC$_c$ values, AIC differences (Δ_i), and Akaike weights (w_i). Models are in descending order of w_i.**

Model	K	log(L)	AIC$_c$	Δ_i	w_i
Elevation (m)	3	−221.360	448.959	0.00	0.832*
Landform index	3	−223.295	452.830	3.87	0.120*
Slope	3	−224.577	455.393	6.43	0.033
Distance to forest (m)	3	−226.199	458.638	9.68	0.007
Linear aspect	3	−226.576	459.391	10.43	0.005
Plot surface shape	3	−227.011	460.263	11.30	0.003

*Included in candidate set of models.

Table 5. **Summary of model selection statistics for 6 models of white-tailed deer browsing pressure (square root of % woody species browsed) for preferred species at 1−m^2 plots (n = 310) within clearcut regeneration areas on the MeadWestvaco Wildlife and Ecosystem Research Forest, West Virginia in 2001. Statistics include the total number of estimable parameters (K), log likelihood (log(L)), AIC$_c$ values, AIC differences (Δ_i), and Akaike weights (w_i). Models are in descending order of w_i.**

Model	K	log(L)	AIC$_c$	Δ_i	w_i
Elevation (m)	3	−664.259	1334.596	0.00	0.985*
Distance to forest (m)	3	−668.605	1343.288	8.69	0.013
Landform index	3	−670.534	1347.147	12.55	0.002
Slope	3	−679.730	1365.539	30.94	<0.001
Plot surface shape	3	−680.436	1366.951	32.36	<0.001
Linear aspect	3	−681.261	1368.600	34.00	<0.001

*Included in candidate set of models.

species, browsing pressure was positively related to elevation and negatively related to LFI.

For group 3 (preferred species), given the data and set of models, the evidence weights suggest that the elevation model (hypothesis 4) was the best approximating model for predicting browsing pressure (Table 5). The elevation model was 77.0 times more likely to be the best model of browsing pressure than the distance to mature forest model (hypothesis 5). There was very little evidence supporting the other hypotheses. Our confidence set of models included those with a $w_i > 0.099$ and was comprised of only the elevation model. The relative importance of the elevation model was 0.985. The model averaged parameter estimates and associated confidence intervals for parameters in the confidence set of models are provided in Table 3. For preferred species, browsing pressure was positively related to elevation.

Discussion

Contrary to our predictions, plots occurring on skidder trail edges did not have greater deer browsing pressure than clearcut interiors. Although skidder trails likely facilitate travel by deer within regenerating clearcuts, our data do not support the notion that deer forage preferentially along these linear areas. The greatest impact of skidder trails on deer foraging behavior may be that they increase accessibility of areas not otherwise open (i.e., they may disperse browsing across clearcuts), resulting in more uniform browsing pressure within regenerating clearcuts. We believe the higher use of greenbrier (63% browsed) and American beech (13% browsed) in mature forest plots than in clearcut interior and skidder trail plots is a result of the overall lack of available woody browse in mature forests, which resulted in concentrated deer browsing.

Ford et al. (1993) from the southern Appalachians and Castleberry et al. (1999) from a bottomland hardwood forest in the Coastal Plain documented overall summer deer use (% available woody twigs that were browsed) as 2.5–3.0%. From these data, Ford et al. (1993) and Castleberry et al. (1999) conclude that deer do not interfere greatly with forest regeneration in those areas. In contrast, our data from West Virginia clearcuts suggest overall summer deer use of >15%. The apparent explanation for regional differences in browsing pressure is varying deer densities. For example, Ford et al. (1993) report deer densities of 6–8 deer/km^2, which is approximately 2 times less than ours. Clearly, deer maintained at densities of 14 deer/km^2 in the central Appalachians of West Virginia may alter the dynamics of clearcut regeneration. These findings are consistent with investigations from northwestern Pennsylvania (Tilghman 1989, Horsley et al. 2003).

Within clearcuts, heavy browsing of sassafras, American basswood, yellow birch, and chestnut oak, coupled with their low relative abundance suggest that future stands may contain fewer trees of these species. In contrast, we predict that future stands may include more American beech, yellow-poplar, and red maple because of their high relative abundance and light browsing pressure. If this comes to fruition then the commercial value of future stands may be diminished, particularly given the moderate to high relative browsing pressure on black cherry, which is traditionally considered a low preference deer forage.

Our analysis of the relative importance of factors in explaining deer browsing pressure suggests that elevation is more important than distance to mature forest, LFI, PSS, aspect, and slope in explaining deer browsing pressure for all, commercially valuable, and preferred woody species in regeneration areas on the MWWERF. Specifically, our data suggest that when considering all woody species, browsing pressure increases with elevation and decreases with distance from mature forest. The positive relationship between browsing pressure and elevation was expected and suggests preferential browsing at higher elevations. However, our original explanation for this, that plots at higher elevations are comparatively flat and accessible to deer, is not supported by our analyses because for all groups, slope was relatively unimportant in predicting browsing pressure. Other unexamined causative mechanisms must be present. The negative relationship between browsing pressure and distance to mature forest was also expected and suggests preferential browsing along a gradient of forest-clearcut edge. A similar relationship was documented in forest-field edges (Meiners 2002) and in relation to overstory disturbances (Gribko et al. 1999). We recommend future evaluations of independent data sets incorporate elevation, distance to mature forest, and LFI (particularly in areas with high variability in topographic sheltering) as predictors of browsing pressure in regenerating clearcuts of the Appalachians.

Our study transcends simple documentation of deer browsing impacts to assessing the relative importance of factors in determining where deleterious effects may occur (Russell et al. 2001). When considering all woody species, our data suggest that elevation and distance to mature forest are most important in predicting browsing pressure in regenerating clearcuts. We suggest that a reduction in browsing pressure may result from increasing clearcut size and reducing deer densities. Because public sentiment is generally against the clearcut regeneration technique, it is uncertain if increasing clearcut size is a viable option. Therefore, we recommend that forest managers reduce deer densities. In the southern Appalachians, Ford et al. (1993) observed adequate regeneration with deer densities of 6–8 deer/km^2. In northwestern Pennsylvania, Tilghman (1989) recommends deer densities of ≤ 7 deer/km^2 to ensure forest regeneration. We believe the above densities are reasonably accurate guidelines for timber industry land in the central Appalachians of West Virginia. However, given current deer densities, hunter participation, and harvest regulations, it is uncertain whether deer densities of 6–8 deer/km^2 are obtainable in the near future. We believe that without management activities aimed at reducing deer browsing, in many parts of this region the ability of forest managers to regenerate stands will be jeopardized and the forested ecosystem will be compromised.

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