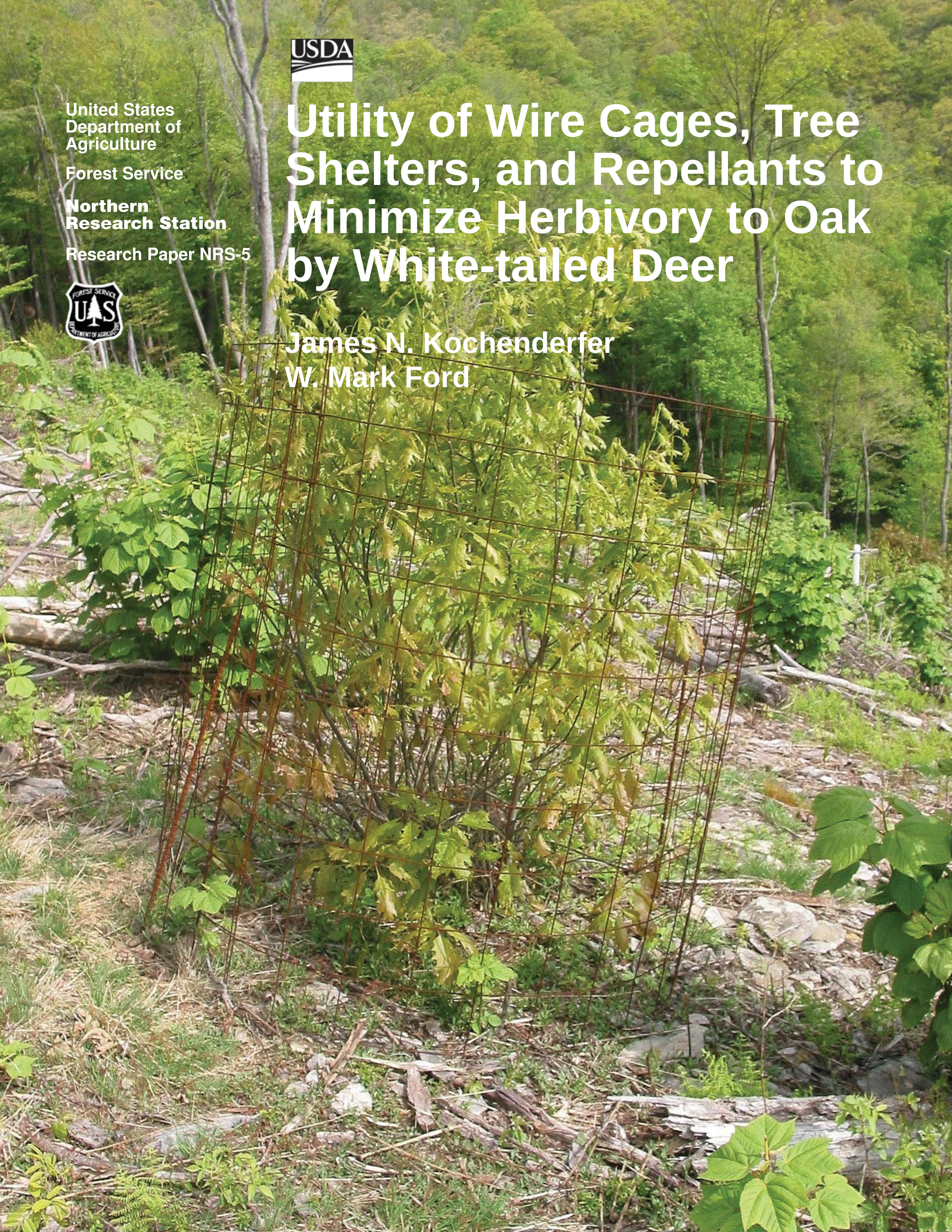

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Utility of Wire Cages, Tree Shelters, and Repellants to Minimize Herbivory to Oak by White-tailed Deer

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Abstract

We evaluated the efficacy of exclusion cages and commercially available repellants in deterring white-tailed deer (*Odocoileus virginianus*) herbivory on northern red oak (*Quercus rubra*) and chestnut oak (*Q. montana*) stump sprouts and planted red oak seedlings following a commercial clearcut harvest in West Virginia. Our treatments included application of two repellants (Deer Away® and Plantskydd®) for cut stumps and seedlings and wire cages for cut stumps or 1.5-m-tall tree shelters for seedlings. Numbers of chestnut oak stumps and northern red oak stumps with sprouts or northern red oak seedlings surviving over three growing seasons were relatively high and were equitably distributed among treatments. After three growing seasons, only 17 percent of the sheltered northern red oak seedlings reached 1.5 m in height and out of reach of deer whereas no seedlings in the other treatments reached that height. For northern red oak and chestnut oak, more caged stumps, 75 percent and 36 percent, respectively, produced sprouts reaching 1.5 m than did stumps treated with repellants or those left untreated. For northern red oak stumps, 65 percent sprayed with Plantskydd and 58 percent sprayed with Deer Away produced sprouts reaching 1.5 m whereas for chestnut oak stumps, only 25 percent sprayed with Deer Away and 15 percent sprayed with Plantskydd produced sprouts reaching 1.5 m. Regardless of treatment, the probability of a stump sprout reaching 1.5 m for both species declined as residual stump diameter increased. The continuous protection from browsing coupled with low material costs makes the use of wire cages around cut-stumps a potential alternative to the use of deer repellants or artificial seedling establishment to enhance and maintain oak following regeneration harvests.

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INTRODUCTION

Regenerating oak, especially northern red oak (*Quercus rubra*), on moderate to high quality sites in the central and southern Appalachians has been recognized as a problem for many years (Carvell and Tryon 1961, Loftis 2004, Schuler 2004, Schuler and Miller 1995). Successful natural regeneration of oak is a difficult process that is linked to the availability of competitive sources of reproduction that will respond to release at the time of a major disturbance event such as harvest. Often, this can require pre-harvest cultural activities, such as removal of competing advance regeneration with herbicides or prescribed burning (Brose and Van Lear 1998, Kochenderfer et al. 2004). Post-harvest activities such as crop-tree release or fencing can be used to retain or enhance the residual or regenerated oak component (Miller et al. 2004, Sander and Graney 1993). Artificial regeneration of northern red oak also has been successfully used in the Appalachians to hasten the development of competitive oak (Schuler et al. 2005, Schuler and Miller 1999, Wendel 1980).

Regardless of the method used, browsing by white-tailed deer (*Odocoileus virginianus*) is a problem in much of the East. Herbivory impacts long noted in the northern portion of the central Appalachians in Pennsylvania (Horsley et al. 2003, Marquis and Brenneman 1981) now occur farther south in Virginia (McShea and Rappole 2000) and West Virginia (Campbell et al. 2006). Although the browse preference for northern red oak or other oak species varies (Ford et al. 1993, Kittredge and Ashton 1995), even low herbivory pressure on advance regeneration or seedlings can reduce competitiveness or even wholly eliminate northern red oak in newly harvested stands (Campbell et al. 2006). In addition to fencing (Miller et al. 2004, Nicholas et al. 2004), other control measures such as deer repellants (Trent et al. 2001) and tree shelters (Smith 1993a) have been used to control herbivory damage to natural and artificial regeneration following timber harvest.

Both northern red oak stump sprouts and planted northern red oak seedlings are vulnerable to deer herbivory (Collins and Carson 2003, Oswalt et al. 2006). Moreover, most oak species, including northern red oak, have seedlings with very slow juvenile growth rates (Lorimer 1993, Smith 1993b), thereby increasing the susceptibility to browsing damage over several growing seasons. In contrast, stump sprouts can exhibit much faster initial growth rates than seedlings, thus limiting the time sprouts are vulnerable to browsing. Stump sprouts can overtop and suppress most seedling-origin reproduction (Wendel 1975). Many stump sprouts have good potential to develop into canopy trees (Lamson 1988, Wendel 1975) and stump sprouts can account for half the reproduction in young hardwood stands growing on good sites in the central Appalachians (Wendel and Trimble 1968). Unfortunately, the ability to sprout and the vigor of sprouts varies by oak species and residual stump size and age (Weigel et al. 2006).

The objective of our study was to compare the efficiency of wire cages (stumps only), deer repellants, and tree shelters (seedlings only) in protecting northern red oak and chestnut oak (*Quercus montana*) stump sprouts, and planted northern red oak seedlings from deer herbivory that would inhibit survival and attainment of sufficient height growth (Marquis 1977). Concomitantly, we also examined the probabilistic relationship of cut stump size and treatment of measured stump sprouts reaching 1.5 m within three complete growing seasons.

STUDY AREA

We installed our study on a 7-ha regeneration area in Grant County, West Virginia, on the Monongahela National Forest in the Allegheny Front Foothills (Fore Knobs) that constitute the border of the Allegheny Mountains and the Northern Ridge and Valley sections of the Central Appalachian Broadleaf Forest ecological land type (McNab and Avers 1994). Elevation is approximately 800 m and the site is characterized by a steep sideslope (50%) with an east to southeast aspect. Pre-harvest, the site was dominated by northern red oak, chestnut oak, and red maple (*Acer rubrum*) with an abundant striped maple (*Acer pensylvanicum*) understory. A more xeric mixed oak-pitch pine (*Pinus rigida*) community with a dense mountain laurel (*Kalmia latifolia*)-*Vaccinium* sp. understory occurs on the ridge above the regeneration unit. The coves and riparian zones on the lower slopes below contain stands dominated

Table 1.—Number of stumps and planted seedlings tracked, percent of tracked with surviving sprouts or seedlings, percent of tracked with surviving sprout or seedling reaching 1.5 m in height, and overall mean height of survivors after three growing seasons of chestnut oak stumps, northern red oak stumps, and planted northern red oak seedlings subjected to wire cage (stump sprouts only), tree shelter (seedlings only), deer repellant, or control treatments in Grant County, West Virginia, 2005

	n	Survived	To 1.5 m	Survivor Mean Ht. (cm)	Survivor SE (cm)
Chestnut oak stumps					
Control	14	8 (57%)	2 (14%)	116	17
Deer Away	12	8 (67%)	3 (25%)	136	26
Plantskydd	13	7 (54%)	2 (15%)	140	31
Wire Cage	14	7 (50%)	5 (36%)	214	36
Northern red oak stumps					
Control	16	12 (75%)	5 (31%)	137	22
Deer Away	17	14 (82%)	10 (59%)	184	13
Plantskydd	17	16 (94%)	11 (65%)	188	15
Wire Cage	16	12 (75%)	12 (75%)		2457
Northern red oak seedlings					
Control	29	22 (76%)	0	335	
Deer Away	30	25 (83%)	0	41	4
Plantskydd	30	21 (70%)	0	53	5
Shelter	30	26 (86%)	5 (17%)	99	11

by mixed mesophytic hardwood species and eastern hemlock (*Tsuga canadensis*). The soils are predominately Dekalb-Hazelton and Lehew associations of loamy colluvium characterized by acid shale-chips and thinly bedded sandstones (Estepp 1989). Emergent rock occurs throughout. The estimated northern red oak site index (base age 50) is 20 m. The average annual precipitation is approximately 80 cm, and the growing season varies from 120 to 180 days (DeMeo 2002). The area was clearcut harvested down to 2.54 cm d.b.h., using cable-logging in the fall of 2002. At study onset following harvesting, the deer impact score was considered "high" (Marquis et al. 1992). Actual deer density in the surrounding area was estimated at 20/km^2 in 2001. However, herd density did fall to 11/km^2 by 2003 following two successive poor mast crops and severe winters with deep snow (West Virginia Division of Natural Resources 2004).

METHODS

In March 2003 before sprout emergence, we established two parallel transects 25 to 30 m apart along the contour near the center of the clearcut equidistant from the upper and lower slope edges of the cut unit where we then selected 53 chestnut oak stumps and 66 northern red oak stumps as encountered. Both transects began and ended at distances greater than 50 m from forested edge to avoid edge effects. We measured each stump with a diameter tape flush with the cut surface and randomly assigned each to four treatments (Table 1). Residual stump heights for both species were 38 cm or less. We applied one of four treatments to stumps: (1) Wire cages, (2) Deer Away Big Game repellent (capsaicin as active ingredient), (3) Plantskydd repellant (animal protein as active ingredient), and (4) untreated. We also planted 119 northern red oak 1-0 seedlings approximately 2.5 m from the selected stumps along transects. These seedlings received the same two repellant treatments, but we substituted 1.5-m-tall tree shelters using 1.6-cm fiberglass "T" posts for support as a treatment rather than wire cages to prevent browsing. We constructed wire cages for the stumps using 10 gauge, 15.25-cm mesh concrete reinforcing wire 1.5 m wide cut in 5.8-m lengths. We overlapped wire ends to form a circular cage 1.85 m in diameter. Although the cages were rigid enough to stand without any support, we anchored each to the ground using two pieces of 1.3 cm x 0.9 m construction rebar.

We sprayed stumps and seedlings designated for the repellant treatments in mid-July 2003 using backpack sprayers, following label directions for both mixtures. By that time, sprouting had occurred. Some sprouts of both oak species had green leaves present, but most stumps still exhibited white and reddish sprouts without leaves before the time of any appreciable herbivory. A second application was made in mid-August 2003. During the 2004 and 2005 growing seasons, we applied repellant in mid-May and late-June to maximize protection during the periods of most active height growth when succulent shoots are most likely to be browsed (Ford et al. 1994). We measured the dominant sprout and seedling heights to the nearest 0.5 cm in October 2005 for final survival and height tallies.

To assess the efficacy of wire cages, tree shelters, and repellant application to enhance stump sprout or seedling survival and growth, we tested to see if the numbers of stumps with at least one surviving stem over three growing seasons were equitably distributed among treatments using Fisher's exact tests because some treatment/surviving stem cell sizes were less than 5 (SAS 1995). We also tested the distribution among northern red oak seedlings reaching 1.5 m in height among treatments using a Fisher's exact test. We used generalized linear models with binomial probability distributions and logit link functions along with pre-planned contrasts (PROC GENMOD; SAS Institute 1995) to assess how the probability of a surviving chestnut oak or northern red oak stump sprout reaching 1.5 m in height differed among treatments and by varying stump diameter.

RESULTS

After three growing seasons, overall rates of survival of at least one sprout per stump and the planted seedlings were high regardless of treatment. There were no differences among the treatments for the numbers of chestnut oak stumps with a surviving sprout (Fisher's exact test, P = 1.0) and northern red oak stumps with a surviving sprout (Fisher's exact test, P = 0.98) or surviving northern red oak seedlings (Fisher's exact test, P = 0.98). Final mean heights for the dominant surviving northern red oak and chestnut oak stump sprouts and northern red oak seedlings were quite variable. Still, values for wire cage treatments for stump sprouts or shelters for seedlings tended to be the greatest followed by repellants and lastly controls (Table 1). The percentage of chestnut oak stumps with a surviving sprout reaching 1.5 m in height was less than 40 percent among all treatments; the percentage of surviving northern red oak stump sprouts reaching 1.5 m in height was greater than 50 percent for all treatments other than controls (Table 1). Numbers of surviving northern red oak seedlings that reached 1.5 m in height did differ among treatments (P = 0.007): 20 percent of the sheltered seedlings reached 1.5 m in height but no repellant-applied or control seedlings reached that height (Table 1).

Table 2.—Generalized linear models showing the effect of wire cage, repellant, or control treatments and residual stump diameter for chestnut oak and northern red oak stump sprouts on reaching 1.5 m in height in Grant County, West Virginia, 2005

Source	df	χ^2	$P > \chi^2$
Chestnut oak			
Treatment	3	3.62	0.30
Diameter	1	7.34	0.01
Northern red oak			
Treatment[1, 2]	3	11.87	0.01
Diameter	1	12.25	0.001

[1]Reaching 1.5 m greater for all treatments than control (P = 0.003), greater for all repellants than control (P = 0.01), and greater for wire cages than control (P = 0.004).

[2]Reaching 1.5 m not different between repellants and wire cages (P = 0.24)

Results from generalized linear model tests showed no difference among treatments for chestnut oak stump sprouts reaching 1.5 m in height, but treatments did differ significantly for northern red oak stumps (Table 2). For northern red oak, repellants and wire cages were more effective at allowing stump sprouts to reach 1.5 m in height than untreated controls (Table 2). Residual stump diameters ranged from 18.5 cm to 101.5 cm for chestnut oak and 15.5 cm to 92.5 cm for northern red oak. Stump diameter was a significant negative covariate (Table 2) for both chestnut oak (parameter estimate = -0.047, [$P > \chi^2$] = 0.02) and northern red oak stump sprouts (parameter estimate = -0.052, [$P > \chi^2$] = 0.003). For chestnut oak, the probability greater than chance that a stump sprout would reach 1.5 m in height increased at approximately 20 cm d.b.h or less when sprayed with Deer Away and at approximately 50 cm d.b.h. or less for those protected by wire cages (Fig. 1). For northern red oak, the probability that a stump sprout would reach 1.5 m in height increased for stumps approximately 65 cm d.b.h. or less when sprayed with Deer Away, for stumps approximately 55 cm d.b.h. or less sprayed with Plantskydd, and across all stump diameters protected by wire cages (Fig. 1).

DISCUSSION

Stump sprouts of both species in wire cages grew best and those sprouts that survived showed higher likelihood of growing beyond the reach of deer herbivory within three growing seasons. The same was true for northern red oak seedlings protected in tree shelters, although to a lesser extent than northern red oak stump sprouts. Mean heights of caged stump sprouts of both species and sheltered northern red oak seedlings were approximately 1.8 and 3 times taller, respectively, than the untreated sprouts or seedlings. The repellants Deer Away and Plantskydd also were more effective than the untreated controls at deterring browsing and allowing some stump sprouts of both oak species to reach 1.5 m in height. Kimball and Nolte (2006) similarly observed a high degree of protection from black-tailed deer (*O. hemionus*) for western redcedar (*Thuja plicata*) from a single application of Deer Away and Plantskydd over a 25-day period. However, repellant applications did not sufficiently deter browsing to allow any planted northern red oak seedlings to reach that height; all showed evidence of herbivory. Nonetheless, because we examined stump sprout and seedling response in one regeneration unit only, our zone of inference to other forest types or other physiographic provinces is limited.

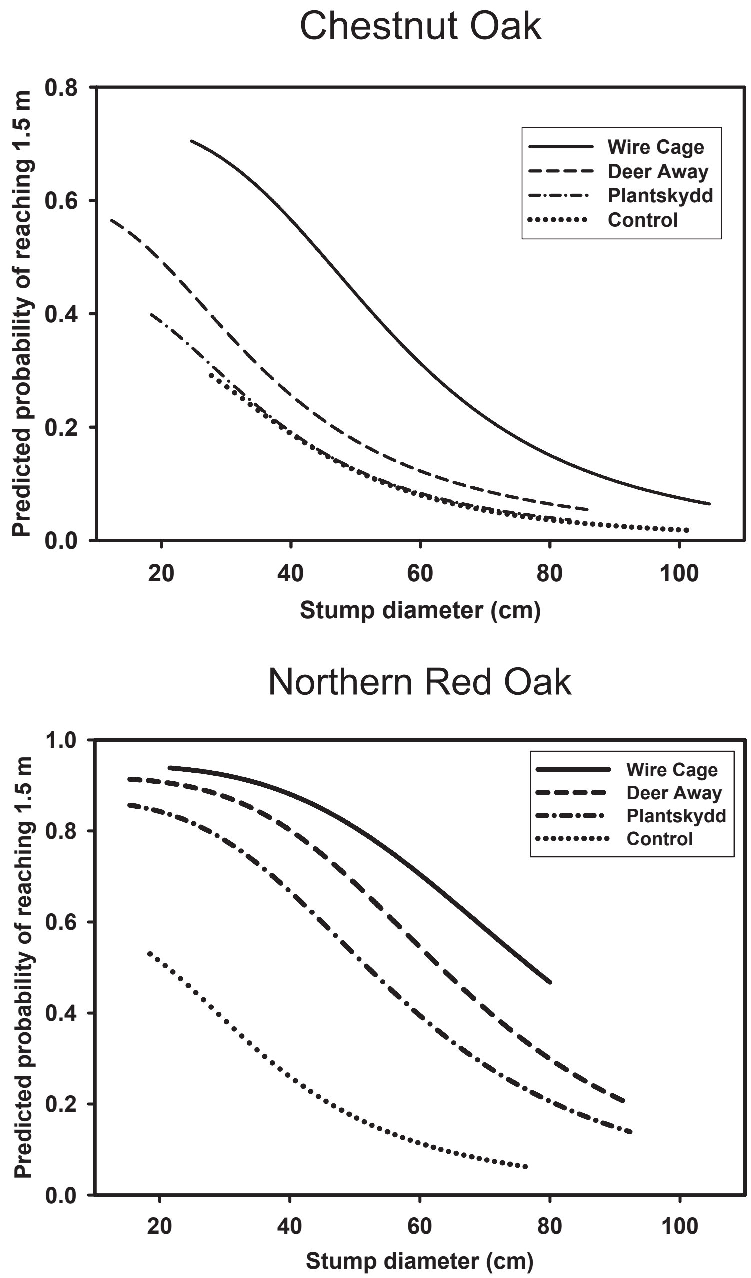

Figure 1.—Predicted probability of a stump sprout reaching 1.5 m in height after three growing seasons for chestnut oak and northern red oak stump sprouts left untreated, those sprayed with deer repellants, and those protected by wire cages across residual stump diameters, Grant County, West Virginia, 2005.

Initial sprouting from cut stumps generally increases with site index but also declines as stump size and tree age increase (Lamson 1988, Weigel and Peng 2002). In general, the chestnut oak stump sprouts we tracked appeared to be less vigorous than northern red oak sprouts as is typically observed regionally (Wendel 1975). On similar site indices in southern Indiana, Weigel and Peng (2002) reported declining probabilities of both northern red oak and chestnut oak sprouts remaining competitive after 5 years with increased residual stump size and age. However, the northern red oak in our study appeared to show a higher probability of producing competitive sprouts across a larger range of residual stump sizes.

Use of root-pruned 2-0 northern red oak seedlings with a minimum root collar diameter of 1 cm is recommended by Smith (1993a). Larger seedlings would probably have grown faster and been more resistant to deer herbivory (Oswalt et al. 2006) than the smaller 1-0 seedlings, but planting in the rocky soil conditions we encountered would have been difficult. Based on data presented by Smith (1993a), caged northern red oak stump sprouts probably would have outperformed most root-pruned 2-0 sheltered seedlings after three growing seasons.

Deer browsing was evident in our study area during each growing season and to some degree in the dormant seasons on unprotected and treated stump sprouts and seedlings. It is highly possible that the lower deer density in the area and thereby lower deer impact score following harsh winters and poor mast crops may have positively biased our results with repellants. With higher deer densities, their performance might have been less. Regardless of deer density trends, our study site was among the few early-successional habitats in the local area and therefore experienced concentrated browsing. For example, we observed evidence of browse impacts even on striped maple, a woody species generally avoided by deer (Marquis and Brenneman 1981).

The treatments described in our study to control browsing impacts from deer could be used successfully to maintain or perhaps increase the presence of desirable species in hardwood regeneration areas in the central Appalachians and elsewhere. Providing early protection to fast growing stump sprouts of species such as northern red oak cannot be emphasized enough for managers seeking to develop high-value hardwood crop trees or to hasten hard-mast production capability in younger stands. As such, we believe that wire cages, and to a lesser extent, deer repellants are practical alternatives to complete fencing that would be logistically difficult and financially prohibitive in mountainous terrain. Unlike whole-stand fencing as is used in the Northeast, use of wire cages would still allow deer access to regeneration units to browse less desirable woody species such as red maple, black birch (*Betula lenta*), or blackgum (*Nyssa sylvatica*) that might compete with northern red oak and other desirable crop trees in the future stand. Emphasis should be placed on protecting smaller (less than 40 cm d.b.h.), generally younger residual stumps because they show higher sprout rates than do larger stumps. Also, low cut stumps that will develop well-anchored, decay-resistant sprouts should be selected by managers (Roth and Hepting 1943).

We found that individual stumps can be caged for approximately $13 of material, and each 1.85-m section of wire used can easily be carried and installed by an individual. With a cage's projected utility of 7 to 10 years, dominant sprouts would have ample time to exceed browse-susceptible heights. Moreover, the cost of one wire cage was equivalent to two tree shelters in our study and none suffered damage from black bears (*Ursus americanus*) as sometimes occurs with tree shelters (Kochenderfer et al. 2006). Because many of the caged chestnut oak and northern red oak stump sprouts reached 1.5 m in height at the end of two growing seasons, some cages probably could have been moved to other unprotected sprouting stumps within the regeneration unit. Such reuse of shelters would be impractical with seedlings that had reached 1.5 m in height. Although the repellants we tested were somewhat effective here and would be to the east in the more xeric conditions of the northern Ridge and Valley, full protection in the wetter Allegheny Plateau to the west probably would have required more frequent reapplications throughout the growing season (Nolte and Wagner 2000). Caging a modest number of stumps before sprouts emerge of targeted oak or other high-value species such as black cherry (*Prunus serotina*) at levels of even 15 to 30/ha would enhance the recruitment of desirable regeneration and hence timber and wildlife attributes in the future stands.

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We evaluated the efficacy of exclusion cages and commercially available repellants in deterring white-tailed deer (*Odocoileus virginianus*) herbivory on northern red oak (*Quercus rubra*) and chestnut oak (*Q. montana*) stump sprouts and planted red oak seedlings following a commercial clearcut harvest in West Virginia. Our treatments included application of two repellants (Deer Away® and Plantskydd®) for cut stumps and seedlings and wire cages for cut stumps or 1.5-m-tall tree shelters for seedlings. Regardless of treatment, the probability of a stump sprout reaching 1.5 m for both species declined as residual stump diameter increased. The continuous protection from browsing coupled with low material costs makes the use of wire cages around cut stumps a potential alternative to the use of deer repellants or artificial seedling establishment to enhance and maintain oak following regeneration harvests.

Capitalizing on the strengths of existing science capacity in the Northeast and Midwest to attain a more integrated, cohesive, landscape-scale research program

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