FNR-641-W

Managing White-tailed Deer Impacts on Indiana Woodlands

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Introduction

White-tailed deer are an integral piece of Indiana's forest ecosystems. When in balance with the ecosystem, deer can enhance the health of the forest. But when deer are overabundant they can have a negative impact on the forest ecosystem, including reducing plant diversity and tree regeneration.

This publication highlights the various tools available to woodland owners for mitigating the impacts of deer on their regenerating trees and is based on a compilation of research on the relative effectiveness of various deer browse control methods [41]. While this publication focuses on managing deer impacts to hardwood trees, many of the same methods (e.g., deer population reduction) apply to reducing deer impacts to forest ecosystems overall.

For more detailed descriptions of what impacts deer can have on Indiana woodlands and how to monitor those impacts, visit the other publications in the *Deer Impact Toolbox*.

Deer Damage to Hardwood Seedlings

One of the major obstacles to tree regeneration success over the past several decades is the damage to young trees by consumption of twigs and terminal buds by deer (often called deer browse or deer herbivory). Deer browsing poses a major obstacle to forest regeneration in Indiana as the resulting damage may decrease the value of trees, stunt tree growth, and indirectly make seedlings lose out to competition, ultimately changing future forest composition.

Newly regenerating trees are susceptible to browsing until they grow out of reach from deer, usually between four and five feet. This can take several years, but will take much longer or may never occur if deer browse them repeatedly or if other plants outcompete them. Deer tend to favor some species over others [1, 2]; for example, oaks are often preferred [3]. Deer may even shift forests to ecosystems dominated by unpalatable, and often non-native, plants from which they cannot recover without intervention [3, 4].

There are many scientific studies available on the effectiveness of browse control methods. However, the relative effectiveness of the range of available methods has not previously been readily available, aside from experience and anecdotal evidence.

Browse by deer has reduced the size of the sprouts on this sugar maple stump

What Amount of Herbivory Warrants Protection?

The impact deer have on woodlands depends on a suite of factors such as landscape characteristics and available or alternative food. It also depends on your objectives. If you wanted the maximum diversity of spring ephemeral wildflowers on your property (often called the *diversity carrying capacity*), you would want fewer deer than if you were just interested in regenerating certain hardwood species (often called the *regeneration carrying capacity*; [5]). The density of deer needed to reach these carrying capacities will vary based on the amount of available food and the quality of the habitat. Forests that are attractive as shelter but which contain little alternative forage are prone to higher levels of damage with lower deer populations [6].

A better way to view the question of "how many deer is too many?" is to think about the impact of those deer on a woodland. Monitoring deer browsing impacts will help clarify if deer are having a negative impact (and how bad of an impact) on a woodland; regardless whether there are five or 50 deer per square mile. Land managers should consider evaluating deer impact on their property before choosing a damage control method. One can find a variety of ways to evaluate deer impact in a woodland by reading the Purdue Extension Publication, *Monitoring White-tailed Deer and Their Impact on Indiana Woodlands*.

What Control Methods are Available?

There are many different control methods for reducing deer and the incidence of deer browse. As one author wrote, "the number of repellent systems found is roughly equal to the number of people with browse problems" [7]. However, the most researched methods fall into the categories of population control, fences, shelters (both solid-walled and mesh sleeves), cages, companion plants for trees, timber harvests, fertilizers, and repellents. See pages 10-17 for a complete description and photos of each of these methods.

Population Control

Population control involves removal of deer through lethal means such as hunting or sharpshooting (often called culling). It often focuses on the female portion of the deer population because the number of female deer impacts population growth more than males. Non-lethal methods, including sterilization and translocation, also exist but are costlier, less common, and not a realistic (or legal!) option for most landowners. The population control methods in this review refer to recreational hunting and intensive culls done for the purpose of population reduction.

Fencing

Fences can be constructed around an entire planting area and protect associated vegetation in addition to the trees. This effect can be desirable in cases where managers wish to protect plants or communities from damage. Common options include woven wire fences (Figure 4a), plastic mesh fences (Figures 4b and 6), and electrified fences. Fences need to be tall enough (7.5 feet at least) to keep out deer, and their entire perimeter must be maintained.

Tree Shelters and Cages

Tree shelters are plastic or fabric tubes (solid-walled or mesh) that are placed around trees for protection (Figures 4c and 4d). Mesh "sleeves" were reviewed separately from solid-walled "shelters" because shelters also provide a greenhouse effect that encourages growth. Wire cages can also be used to prevent access, and may be more durable than tree shelters (Figure 5).

Slash

Slash (tree tops or other woody debris left from harvest) is used in various ways to inhibit browse. It can be left in place, or moved and piled around trees (Figure 7) to block access to the food source. Some managers even construct fences from slash.

Plant Protection: Companion Plants for Trees

"Companion plants" (usually called "facilitation" in scientific studies) is the planting or regeneration of other vegetation to reduce herbivory by blocking access or visibility of seedlings or deter deer through bad tasting chemicals or thorns (Figures 8 and 9b) [8]. Examples of this would be planting palatable hardwoods with relatively unpalatable pines or avoiding vegetation control (e.g., not mowing between rows within a tree planting) to allow herbaceous vegetations and shrubs to hide and protect seedlings (Figures 7 and 8b).

Timber Harvest

Timber harvests could provide mitigation against deer herbivory by increasing food and thus decreasing the pressure on tree seedlings, or by changing how deer use a forested area for cover [9]. For example, a large enough timber harvest could allow for regeneration of sufficient tree seedlings in an open area so that not all of them are consumed by a small herd of deer (Figure 10).

Fertilizer

Fertilizer could help accelerate the growth of seedlings above the browse line, especially on sites such as reclaimed mine land where nutrients may be limiting [10]. But planted seedlings that have been fertilized may also be more attractive to deer, resulting in them receiving more browse pressure.

Repellents

Repellents are a common alternative to physical barriers. Repellents can be systemic or topical. Systemic repellents are taken up by the plant through the root system. Most available repellents are topical. Ammonium soaps of higher fatty acids (Hinder®), bone tar oil (Magic Circle®), topical capsaicin (Hot Sauce®), denatonium saccharides (Ro-pel®), putrescent egg solids (Deer Away®), and thiram have all been sold as repellents [11].

Combining Control Methods

These methods are often combined to increase effectiveness. For example, multiple repellents can be used in sequence or simultaneously to avoid deer becoming accustomed to them [12]. Fertilizer can be used inside fences to reduce the amount of time needed for trees to reach free-to-grow status [13]. Timber harvests can be combined with population control to simultaneously reduce the number of deer while increasing the food available

INTERPRETING THE EFFECTIVENESS OF CONTROL METHODS

"Effectiveness" is measured by the amount of herbivory or death of seedlings prevented, or tree growth protected, by the method in question averaged across studies, resulting in a measure called the effect size. The effect size is a (unitless) comparison of how much the treatment (browse reduction method) deviates from the control (no browse reduction method). In short, the larger the bar in the following graphs the more effective the method. Commonly accepted thresholds between sizes (e.g. large, medium, and small effects) are presented in the table. The following comparison is an attempt to combine the results of multiple studies. It is possible for a method to be successful or effective in one or two studies but rated ineffective in the following analysis if the combined literature shows no consistent effect. For example, out of five separate studies that examined the effect of slash on browse incidence, one study found a small desirable effect, one found a large desirable effect, and three found no effect. When the effect sizes for these studies are combined, the overall effect size is negligible, and the variability between studies is large (the studies are inconsistent).

Effect Size	Relative Effectiveness	Explanation
Large (with little variation): >0.8	Very Effective	In most of the research projects studied these methods had a very large effect on deer browse, tree seedling growth, or survival
Medium (with little variation): Between 0.5 and 0.8	Effective	In most of the research projects studied these methods had a large effect on deer browse, tree seedling growth, or survival
Small (with little variation): Between 0.2 and 0.5	Somewhat Effective	In most of the research projects studied these methods had a small effect on deer browse, tree seedling growth, or survival
Very small (with little variation): <0.2. Also any effect size with large variation, or any effect opposite of the desired effect	Ineffective	In most of the research projects studied these methods had a negligible effect on deer browse, tree seedling growth, or survival OR the results of the research projects studied were so variable that no reliable conclusion could be made OR the method in question increased browse, or decreased growth or survival.

to remaining individuals [14]. Careful thought must be given to choosing complementary methods as some methods may be redundant or even harmful in combination. For example, other trees or plants may outcompete, rather than protect, seedlings inside a fence where they are not exposed to browsing.

Which Control Methods Work?

There have been a variety of research projects looking at ways to reduce deer browse and impacts. We synthesized information from 99 of these studies below. Studies were from natural and planted regeneration in both existing forested areas and new tree plantings. See a full description of each of these control methods on pages 10-17.

Below is a comparison of various methods of control along with their effectiveness on deer browse, tree height growth, and survival (Figures 1-3).

Deer Browse

Figure 1 shows that the methods in dark blue have the largest reduction in deer browse of regenerating trees. Those methods include fencing, shelters, cages, and population control. Companion plants and repellents both have moderate effects. Slash had inconsistent results; it led to successful reduction in browse in some studies, producing the positive effect seen in the graph, but slash was not effective in other studies. Similarly, timber harvests sometimes increased browse, but not in enough studies to be conclusive. These methods are variable, and their success or failure depends on how they are implemented. Thus, when combining the studies we reviewed, they were found to be "ineffective" in general, though they may be effective in certain scenarios. Fertilizer consistently increased browse incidence (a small effect).

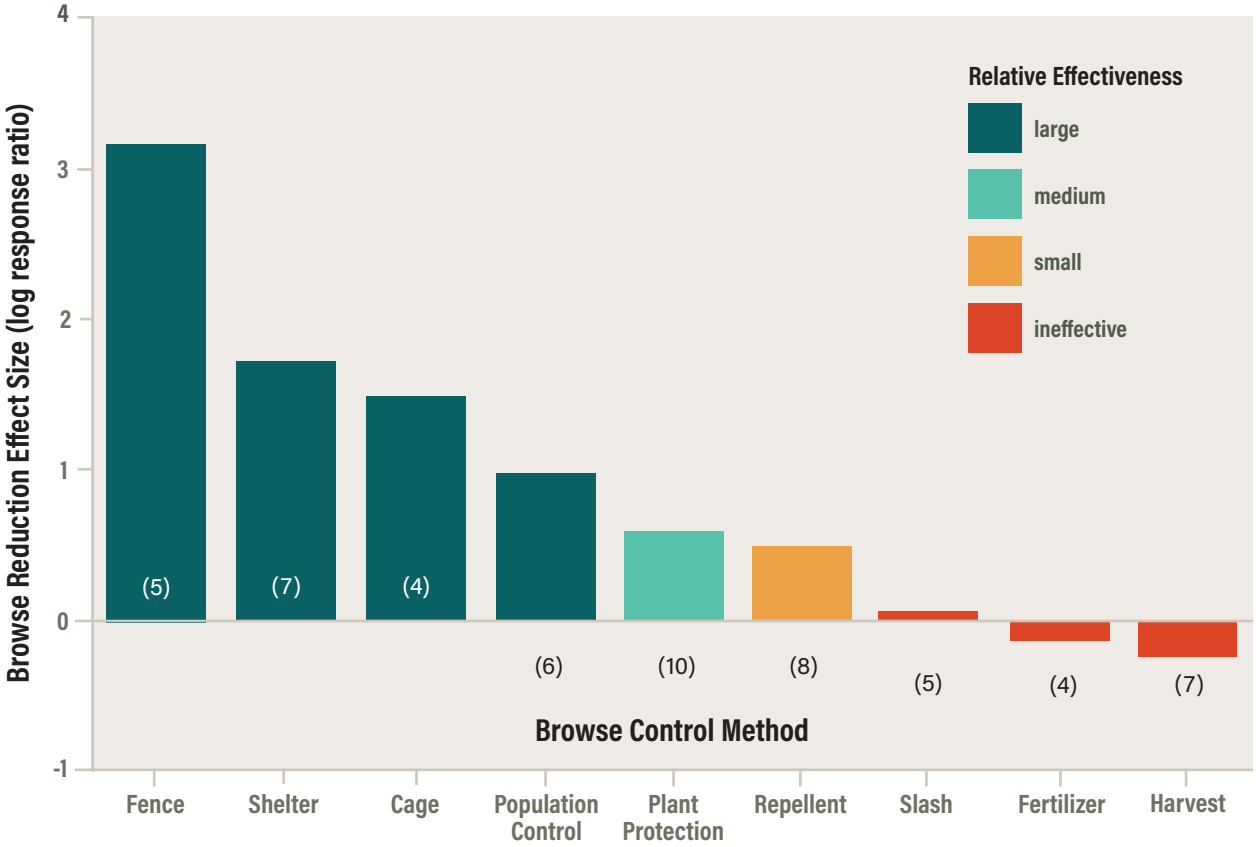

Figure 1. Reduction in browse incidence among nine methods of browse control. Numbers in parentheses represent the number of individual studies reviewed for each method. The size of the bar represents the relative degree of reduction in deer browse (<0.2 = ineffective, 0.2-0.8 = small, 0.5-0.8 = medium, and >0.8 = large). A negative effect size means that the method increased the incidence of browse.

Tree Growth

As Figure 2 shows, cages have a large positive effect on height growth of trees, while shelters, repellents, and fences have a moderate effect. Companion plants have a small positive effect on height growth, and fertilizer has no significant effect. Other methods like population control and timber harvest were not tested for their effectiveness on height growth.

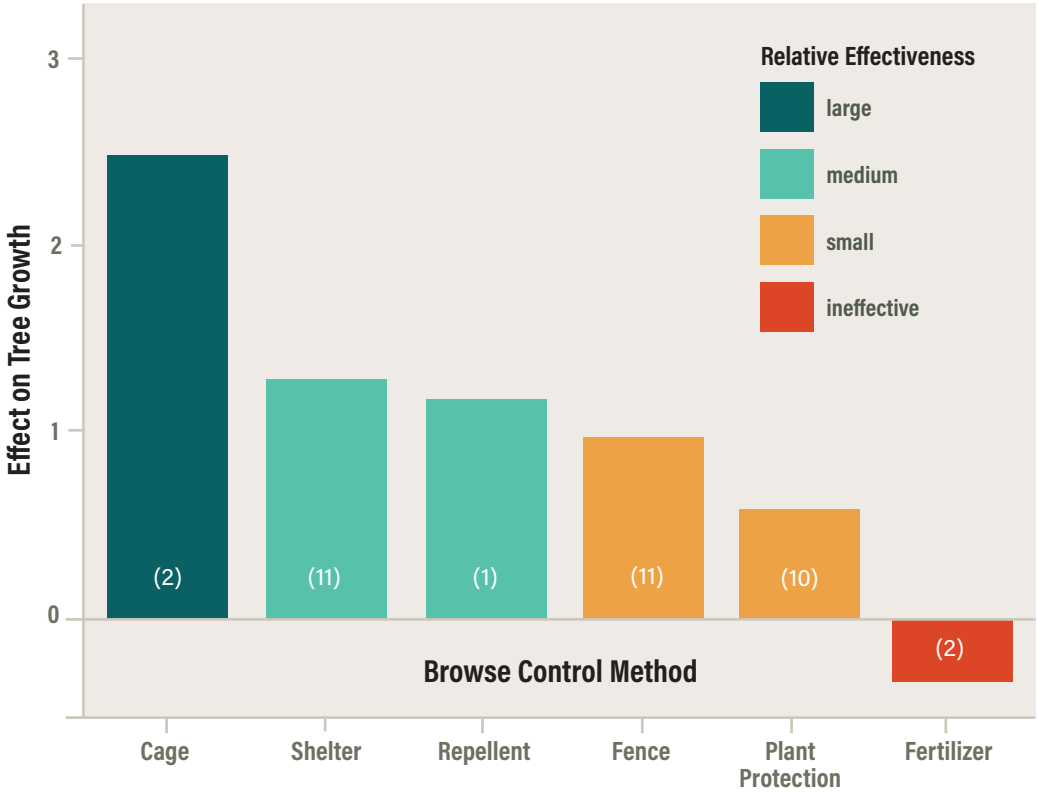

Figure 2. Mean height growth effect among six methods of browse control. The size of the bar represents the level of positive impact on seedling growth (<0.2 = ineffective, 0.2-0.8 = small, 0.5-0.8 = medium, and >0.8 = large). Numbers in parentheses represent the number of individual studies reviewed for each method.

Tree Survival

Figure 3 shows that mesh sleeves, fences and timber harvest have a small to moderate positive effect on tree survival, but this effect is variable across studies. Cages have a negligible positive effect, and shelters and protection by companion plants have no significant effect. The lack of great differences and the great variation in regards to survival may stem partly from the fact that deer browse does not usually directly kill seedlings, rather it causes stress, reduces their growth, and makes them less competitive. Some species can survive below the browse line for years before they finally die or grow out of reach of herbivores. Population control was not tested for its effectiveness on tree survival.

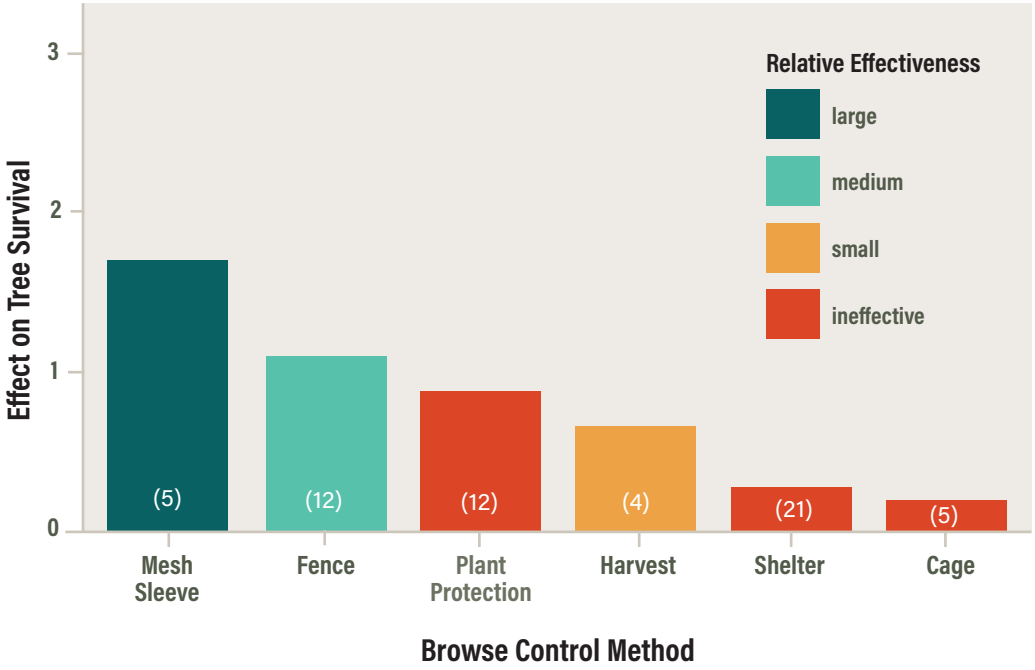

Figure 3. *Mean seedling survival effect among seven methods of browse control. Effect sizes represent the level of positive impact on seedling survival (<0.2 = ineffective, 0.2-0.8 = small, 0.5-0.8 = medium, and >0.8 = large). Numbers in parentheses represent the number of studies reviewed for each method. Companion plants had a small mean effect size, however, the effect between studies (not shown) was so variable the effect was nonsignificant (not consistently effective).*

What Does this Mean for Forest Landowners?

Population Control

Deer population control can be an effective method to reduce deer browse, and is more effective than methods like repellent, slash, and fertilizer. However, it is not as effective as fencing an area to exclude deer, but may be more cost-effective and accessible to woodland owners. Population control through hunting can also reduce deer impacts across your property, whereas fencing is used to limit deer impact in a more localized area within the property (e.g., tree plantation, regeneration opening).

To be most effective, hunting must be used at a high enough pressure for multiple years to stabilize or reduce the deer density. Population control of deer can be undertaken by individual landowners, their family members, or friends through recreational hunting. But forest landowners may also consider leasing their property to other hunters who would pay a fee for the hunting opportunities. It is important to ensure hunters are targeting does rather than bucks, as population growth is limited by the number of offspring does can produce each year. This could be accomplished by requiring hunters to harvest at least one or more does before they can harvest a buck. To help determine the proper numbers of deer to harvest from a property, consult with a professional wildlife biologist or forester. Local natural resources professionals can be found in your area by using the *Find Your County Contact* tool on the Purdue Extension Pond and Wildlife Management website (www.extension.purdue.edu/pondwildlife).

Even with adequate deer harvest, plant recovery can take long periods of time. Annual deer population control will have to be performed indefinitely. In the case of tree regeneration, population control must at least be performed until the regeneration is above the height a deer can browse, though the problem must also be addressed for the following generation of trees as well. And until deer populations are reduced on a larger scale, other indirect methods of browse control such as those listed in this document may be necessary. This is corroborated by research showing that a combination of appropriate silvicultural methods (i.e., timber harvest), control of competing vegetation, and deer population reduction is required for desirable regeneration [15].

Physical Barriers

TREE SHELTERS

Tree shelters have been shown by many studies in the eastern U.S. to be effective in increasing growth [16] [17] and survival [18] [19], and height above the browse line [20, 21]. Tree shelters had a large effect on reduction of browse incidence and a moderately positive effect on tree growth. Many of these studies have been done on northern red oak [17, 19] though a range of species have been studied in combination with different control methods (Figures 4c and 4d).

Shelter type and height can affect success. When used with tree seedlings of similar height, short shelters are not effective because deer can reach the terminal buds [22, 23]. In one study, two-foot shelters increased browsing damage possibly by increasing visibility of seedlings [22]. The correct shelter height to use depends on the height of the seedlings planted. Shelters should be at least 20 inches taller than planted seedlings, but the best performing shelters are 5-feet tall. Fabric and mesh sleeves do not create a greenhouse effect like solid-walled shelters; thus, they tend to have less of an effect on height growth (Figure 4c) [17, 16]. However, solid-walled shelters may decrease survival for some seedlings in very hot climates, and mesh sleeves could avoid such an effect.

Disadvantages of shelters and other mechanical barriers include impeded or distorted growth as well as reduced light [16], and solid-walled shelters may be attractive to voles, nesting birds, or wasps. Some of these disadvantages can be reduced by choosing a color that allows more light transmittance, by removing shelters at the right time (after trees emerge and can stand on their own, but before trees outgrow their

width), and by providing sufficient support. Other physical barriers, including cages, have fewer studies available to review, but some show that cages have a large effect on reduction of browse incidence as well as tree growth [20] (Figure 5).

Tree shelters or cages may be cost-prohibitive for larger tree plantings where hundreds or thousands of trees would need to be protected. Tree shelters are more cost-effective (cost per tree) than fencing for tree plantings less than one acre in size.

FENCING

Fencing is one of the most effective methods of controlling deer herbivory and eliminates browsing within the protected area if used properly (Figure 4a-b, Figure 6, and Figure 9c-d). Common options

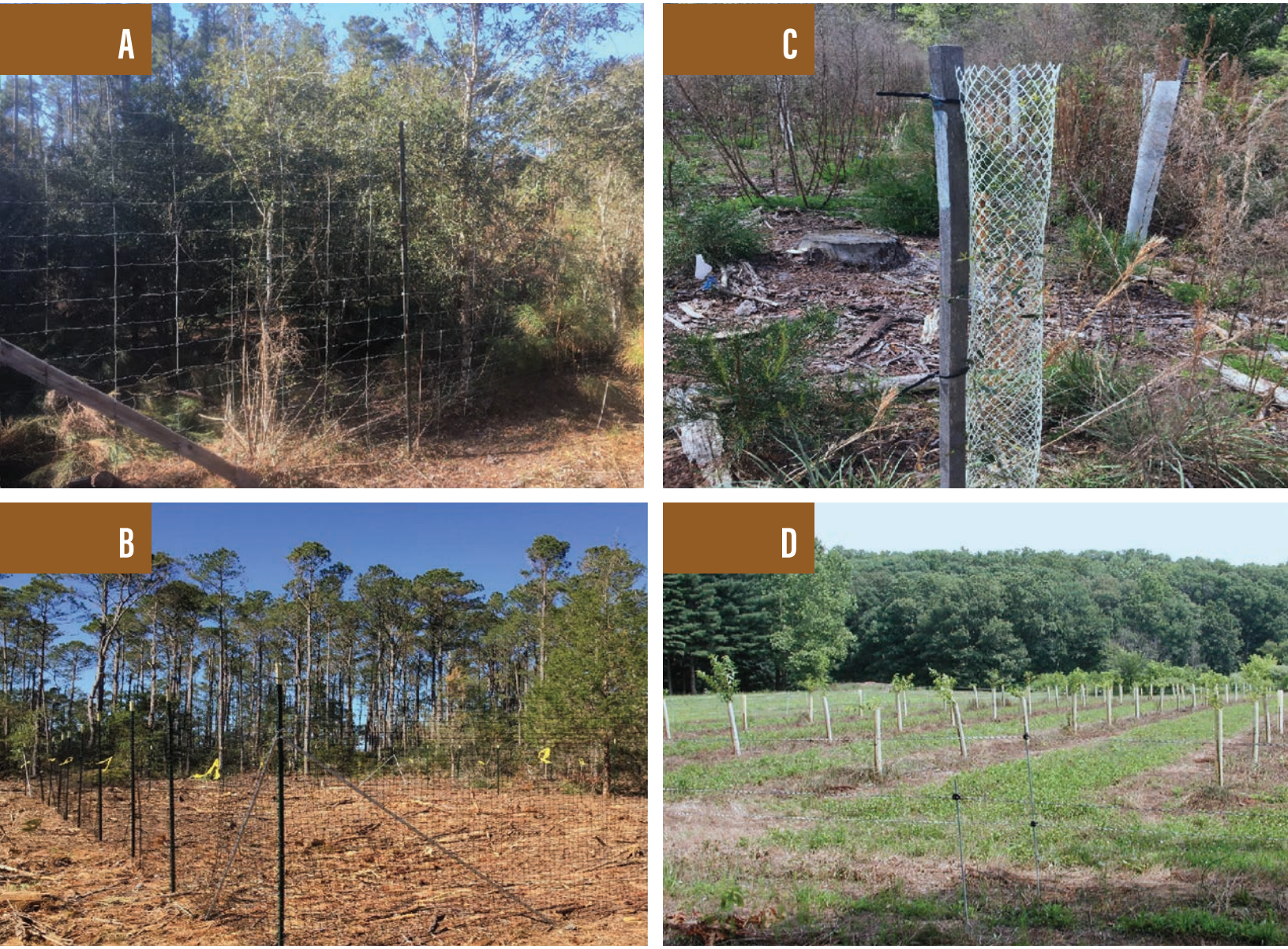

Figure 4. *Illustrations of some browse control methods: Wire fencing with southern live oak (*Quercus virginiana*) in coastal Georgia, USA (A), plastic mesh fencing around an area just cleared of loblolly pine (*Pinus taeda*) and slated to be planted in coastal Georgia, USA (B), mesh sleeve (foreground) and a solid-walled shelter (background) on southern live oak in coastal Georgia, USA (C), and solid-walled tree shelters on planted black cherry (*Prunus serotina*) combined with electric fencing (foreground) in Indiana, USA (D).* Photo credits: C.H. Redick (A,C), Emily Thyroff (B) and Brian Beheler (D).

include woven wire fences (Figures 4a and 9c-d), plastic mesh fences (Figures 4b and 6), and electrified fences (Figure 4d). Livestock fences are not very effective as deer can leap over them. Studies have found that fences had a very large effect on reduction of browse incidence, a moderate effect on tree growth, and a small effect on survival (Figures 1-3). The main problem with fencing is its high cost. For tree plantings larger than 1 acre in size, plastic mesh fencing is more cost effective (cost per tree) than plastic tree tubes. However, because deer no longer keep vegetation inside the fences in check, it can complicate regeneration efforts if unmanaged vegetation is allowed to compete with seedlings. This method, as well as other physical barriers, will not solve the root of the problem (high deer populations), and could concentrate deer impacts on unfenced areas if applied on a large scale.

Figure 5. *Cages at Purdue University in West Lafayette, Indiana, USA.*
Photo credit: Brian Beheler

SLASH

Across the literature we reviewed, slash was found to have no consistent effect on deer browsing damage. However, this method is quite variable in its implementation. Slash piles have been used successfully in some instances as physical barriers around patches of regeneration [24] (Figure 7), but one study found that slash actually increased browse incidence, possibly by increasing visibility to deer [25]. Some researchers have found that "hinge barriers," in which trees are partially cut down, but left connected to the stump to form a barrier around patches of regeneration, are effective against deer and elk, though not as effective as woven wire fencing [26]. In the end, slash is less costly than other physical barriers, but must be implemented in a specific manner and may not succeed.

In one study where slash was effective at increasing tree seedling height, researchers constructed "slash walls" that were 10 feet tall by 10 feet wide around the perimeter of forest regeneration openings [27]. These slash walls cost on average $1.47 per linear foot to create and in total an average of $219 to protect 1 acre of harvest area. They determined this was 3-4 times cheaper than the cost of fencing.

Figure 6. *Illustration of a hardwood plantation at Purdue University in West Lafayette, Indiana, USA after three growing seasons. The left half of the plantation was protected with a plastic mesh fence while the right was left unfenced. Note there are no visible seedlings on the right.* Photo credit: Lenny Farlee.

Figure 7. *Illustration of a slash wall at Arnot Forest at Cornell University in New York, USA. The wall is about 10 feet high and 20 feet wide and was formed by pushing slash into a perimeter around the regenerating harvest area.* Photo credit: www.slashwall.info. Used with permission by Cornell University.

Plant Protection: Companion Plants for Trees

Adding other plants to a tree planting to reduce seedling herbivory had a moderate effect on reduction of browse incidence, a small positive effect on tree growth, and no effect on survival (Figures 1-3). The effects of adding other plants are dependent on their relative palatability compared to the target seedling, as well as the amount of herbivore pressure on-site (Figure 8). For example, unpalatable or thorny shrubs or plants, such as hawthorn or brambles (e.g., blackberry or black raspberry) may protect palatable seedlings when deer populations are low or alternative forage is high, but not when pressure from herbivores is greater [28]. Companion plants will often regenerate naturally from the seed bank on site, but in some cases companion plants can be added through planting. In cases where planting is necessary, native plants should be used and never plant invasive species, (many of which are illegal to sell or distribute [42]).

While weed control is often beneficial to tree growth in areas where deer herbivory is reduced (Figure 9c-d), removing all competing vegetation can exacerbate the problem where deer herbivory is an issue (Figure 9a-b). Leaving some shrubs or other plants to grow along with seedlings can protect them from herbivory. Another method commonly used by landowners is to plant seedlings at a higher density than normal, so that some escape deer herbivory. No studies of this method were covered in the review. However, similarly, timber harvest (discussed below) can be used to encourage dense natural regeneration.

Species selection is also important in the presence of deer. Deer find some species, such as oaks, to be more palatable than others. In addition, some species, though somewhat palatable, may be able to tolerate browse better. Information on deer diets can be found in the Purdue Extension publication, *Understanding White-tailed Deer and Their Impacts on Indiana Woodlands*.
The palatability of some species depends on context such as microenvironment, alternative forage, and nutrient status. For example, black cherry is targeted by deer more frequently when fertilized [29].

Figure 8. *Illustration of a northern red oak* (Quercus rubra) *regenerating in the midst of natural woody vegetation for protection in Indiana, USA.*
Photo credit: Lenny Farlee

Figure 9. *Illustrations of the effects of wire fencing and vegetation control on southern live oak* (Quercus virginiana) *seedlings in coastal Georgia, USA five growing seasons after planting: Two years of weed removal with no fence (A), no weed removal with no fence (B), two years of weed removal inside a wire fence (C), and no weed removal inside a wire fence (D). Planted oaks are circled in red. As illustrated, oaks were most successful inside the fence with weed removal. Outside the fence, weeds (holly shrubs) protected some of the trees from browse.* Photo credits: Caleb Redick and Steve Kipp.

Timber Harvest

Timber harvest can be performed in a manner that allows shrubs or herbaceous vegetation to grow alongside a high density of regenerating trees. This can provide enough forage to reduce deer impacts to desired seedlings. The use of timber harvests to reduce impacts by deer has been tested with positive results in several experiments [14, 30, 31]. Timber harvests had no consistent effect on reduction of browse incidence, but had a small effect on survival. One study, which found that some timber harvests were effective in reducing deer impact, examined a range of opening sizes and suggest that regeneration openings be made no smaller than two acres [30], because deer had less of an impact on regeneration success above this size. A study in southern Indiana also indicated deer impacts to the forest were lower in larger forest openings (~10 acres) compared to smaller openings (~3 acres) [32].

If a landowner is interested in using timber harvest as a way to mitigate deer impacts, they should consider even-aged forest management (e.g., clearcut or shelterwood), or larger regeneration openings (>2 acres), rather than single-tree selection. Gaps created by single-tree selection will not be large enough or produce enough food to reduce deer impacts. Regeneration openings not only decrease browse within the opening, but also within adjacent mature forests [31] as they draw deer to areas with higher forage and dilute the pressure from herbivores on individual seedlings.

Harvest openings or other areas with high forage availability (e.g., old fields) must be distributed so that they are available to deer in the entire area of interest. See the Purdue Extension Publication, *Managing Your Woods for White-Tailed Deer* for more information about different forest management techniques for deer.

While providing more food for deer can deter deer damage in the short term, without control of deer populations in the long term increases in available forage will increase carrying capacity and the deer population, worsening the problem [33]. The combination of timber harvests and lethal population control was tested in West Virginia [14] and was effective.

Fertilizers

Across studies, our analysis showed that field fertilization increased browse by a negligible amount and had no effect on growth (Figures 1-3). While controlled release fertilizers do benefit the growth of seedlings in many instances in areas with low impact from deer, they may also have no effect, or a negative effect on growth by attracting deer in some instances [13]. Fertilizers have been shown to increase the attractiveness of the seedlings or the site to deer by increasing palatability of the affected plants, so browsing by deer may reduce the advantages of applying fertilizer [34]. This effect is not universal, but depends on the species. Black cherry and sugar maple take up extra nitrogen and store it until it is needed, making them more susceptible to browse, while others, such as white oak, do not [29].

All of these studies were done in the presence of significant deer pressure, so effects are unclear when deer damage is low or when other control methods are implemented. For example, some studies found that controlled release fertilizers only increased height and diameter of seedlings inside fenced treatments [10, 13]. Fertilization may be useful in combination with physical barriers by increasing the growth rate and shortening the time that maintenance of these barriers is necessary (a large part of their cost) [13].

Repellents

Repellents had a small effect on reduction of browse incidence and no effect on tree growth (Figures 2-3). This is probably because they are short-lived (the most effective ones last about 3 months) and their effectiveness is dependent on time of year, deer density, availability of alternative food sources, and weather [35, 36]. Some repellents are systemic (taken up into the plant tissues), but not all are concentrated in the plant in appreciable amounts (for example, capsaicin tablets) [37]. Most commercially available repellents are topical (applied to the surfaces of the plant). Repellents made from putrescent egg solids, such as Deer Away®, have been shown to be effective in several studies [38, 39, 40]. Such repellents can be reapplied periodically to maintain their effectiveness; however, deer may become accustomed to them especially if there is little alternative food around. This problem was overcome in one experiment by using multiple repellents [12]. Some experiments only measured browse in one season, and though a repellent may work when pressure from herbivores is low in the summer, it may fail in the winter when food is scarcer.

In this woodland, deer impact control methods have been combined. A shelterwood timber harvest was completed and planted seedlings of certain species favored by deer, like oak, were protected with tree tubes.

A Review of Browse Control Methods for Forest Regeneration and Their Effectiveness

Table 1. Summary of Browse Control Methods and their Effectiveness

Control Method	*Examples*	*Effectiveness*	*When to use*	*Considerations*
Fencing	**Plastic mesh fence, wire fence, electrified fence**	Highly effective for reducing deer browse, increasing tree growth and survival.	Use when population control is not an option, on new tree plantings, or in newly created forest openings where browse pressure is expected to be high or they are of small size (< two acres)	Most effective option especially on small scale plantings or openings (< two acres). Can be cost prohibitive and requires maintenance. Can reduce access to site by other important wildlife. Does not limit impact to other areas of the woodland outside the fence.
Population Control	**Recreational Hunting, Culls**	Highly effective for reducing browse.	Use when one has determined that deer populations are at undesirable levels. Often the first option available to landowners. "Culls" outside of the legal hunting season are not a legal option for most landowners, though deer control permits are available in certain circumstances.	May be difficult to have an effect if property is small and surrounded by non-hunted properties where populations cannot be controlled on a larger scale. Recreational harvest can be done by landowners, friends, family, or a lessee. Harvest should focus on female (doe) deer.
Tree Shelters	**Solid-walled, Mesh, Various heights and materials**	Highly effective for reducing browse and increasing tree survival. Moderately effective for increasing tree growth.	Use when the number of trees being planted is small or stock is especially valuable.	Must be removed after several years or damage may occur. Reduces impact to singular plants (mostly tree seedlings) or small area, but not to the broader forest plant community.

Continued on next page

Table 1. *Continued*

Control Method	*Examples*	*Effectiveness*	*When to use*	*Considerations*
Cages	**Wire mesh fencing**	Highly effective for reducing browse and increasing tree growth.	Same as shelters, but are even more expensive.	Do not have a greenhouse effect like solid shelters. Metal cages are more expensive, but more durable than plastic tree shelters. Reduces impact to singular plants (mostly tree seedlings) or small area, but not to the broader forest plant community.
Companion Plants	**Natural vegetation, planted shrubs or trees**	Moderately effective for reducing browse.	Use when more effective methods cannot be used.	Do not use in combination with fences. May need to release target trees after a certain age.
Repellents	**Many commercial options are available**	Slightly effective for reducing browse.	Use on a small scale for valuable trees and in combination with more effective methods.	Many topical repellents will have to be reapplied frequently. Deer may also become accustom to various repellents reducing their effectiveness.
Timber Harvests	**Clearcuts, Shelterwoods, large group selection openings**	Ineffective on browse. Slightly effective on increasing survival.	Use other methods in combination, such as recreational hunting.	Should be combined with other methods like population control. Smaller harvest areas will be more prone to damage from deer browse.
Slash	**Leaving behind slash from a harvest, piling around trees, creating slash fences**	Ineffective.	Use after harvest and in combination with more effective methods.	Slash is readily available after a harvest and free, but may take considerable effort or planning to create slash barriers. May require the construction of a "slash wall."
Fertilizer	**Controlled-Release, Broadcast, Many Formulations**	Ineffective.	Do not use as a browse control method.	Fertilizers can be useful to increase growth when browse is controlled with other methods (e.g., fencing).

Conclusion

Based on a worldwide review of experiments, fencing is the most consistently effective method for reducing deer browse of regenerating hardwoods. Solid-walled tree shelters are also effective, provided that they are the appropriate height. Adding or retaining companion plants is also effective, but did not perform as well as fences. While low cost, companion plants are highly dependent on the species used. Methods such as timber harvest to increase forage may also be effective in certain situations or in combination with other methods.

Population control is also an important method for controlling deer browsing damage and may be more accessible and cost-effective than many other methods. Because of this, as well as the benefits on the understory from population reduction, it is recommended that a landowner use hunting when possible.

Repellents can be effective control methods, but repellents are less effective than fencing, population control, or companion plants. Fertilizer had the opposite of the intended effect, and ended up increasing browse in most cases. While fertilizers are a useful silvicultural tool, they are not useful in reducing browse damage, and other methods should be considered.

In the end, landowners must decide what tools are best for their region and budget. Often the best tool may be a combination of several of these methods. For example, planting trees among shrubs could be combined with repellents, making the difference in palatability between the target tree species and surrounding vegetation starker; or several repellents could be used in series or together to avoid deer becoming accustomed to them. As previously mentioned, other combinations include fertilizers and fencing, or timber harvests and population control.

Figure 10. All the green forage in the understory created after the first stage of a shelterwood harvest can help dilute the impacts of the deer on this forest.
Photo credit: Jarred Brooke

Additional Resources

- Diagnosing and Controlling Wildlife Damage in Hardwood Plantations (FNR-216), Woodland Stewardship for Landowners: Managing Deer Damage to Young Trees (FNR-611-WV), and How to Build a Plastic Mesh Deer Exclusion Fence (FNR-486-W) demonstrate the use of some of the methods described here.
- Managing Your Woods for White-Tailed Deer (FNR-596-W) describes use of various timber harvest methods and their effect on deer.
- Electric Fences for Preventing Browse Damage by White-Tailed Deer (FNR-136) and Electric Fence Designs for Deterring White-tailed Deer (FSA-9111) provide guidance on electrified fencing.

Local professional foresters should be familiar with these issues and many of the methods described here, including technical and financial assistance. Cost sharing for deer fences is available from the USDA Natural Resources Conservation Service (NRCS) for the protection of forest regeneration in Indiana and other states.

Acknowledgements

Many thanks to Jarred Brooke (Purdue Extension), Allen Pursell (The Nature Conservancy), and Scott Haulton (Indiana Department of Natural Resources Division of Forestry) for editing this publication and providing valuable feedback, and to everyone who provided pictures.

DEER IMPACT TOOLBOX

This publication is part of the Deer Impact Toolbox, a series of resources for landowners who want to learn more about deer and their impact on our woodlands. This toolbox provides the resources needed to understand, identify, monitor, and manage deer impacts to your woodland. Resources within the Deer Impact Toolbox can be found on the Purdue Extension Education Store website (www.mdc.itap.purdue.edu).

Understand the Problem

1

Understanding White-tailed Deer and Their Impact on Indiana Woodlands provides the necessary information to help you understand the problem with deer impacts.

Identify the Problem

2

Understanding White-tailed Deer and Their Impact on Indiana Woodlands publication and looking at the signs and symptoms of deer impact described in this publication.

Monitor

3

Monitoring White-tailed Deer and Their Impacts on Indiana Woodlands publication.

Manage

4

Managing White-tailed Deer Impacts on Indiana Woodlands.

Evaluate

5

The last step in the process of addressing deer impacts is evaluating what you did. To evaluate the impact of your actions you should monitor your property following the action. This should be done by conducting the same methods you used during the monitoring step.

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