Monitoring White-tailed Deer and Their Impact on Indiana Woodlands

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Introduction

Deer are an important part of Indiana's forested ecosystems. So much so that they are considered a keystone species, meaning they can significantly influence the plant composition and look of our woodlands. When the number of deer is balanced with the available habitat their influence can be positive and enhance the health and diversity of a woodland. But when deer populations near or exceed carrying capacity, their impact can become harmful and cause lasting changes to forest ecosystems.

We know that overabundant deer can cause long-term damage to forest ecosystems, but how do we know *when* deer are overabundant and damaging a woodland? This is where monitoring deer and their impact comes into play and is an important consideration for biologists and woodland owners alike. This publication is written to help woodland owners better understand how to monitor deer and their impact.

As a first step, you should familiarize yourself with how deer impact Indiana forests by reading the *Understanding White-tailed Deer and their Impact on Indiana Woodlands* publication as part of the *Deer Impact Toolbox*, which is available through the Purdue Extension Education Store website. In that publication, you will find more information about how deer can impact woodlands. You will also find an initial questionnaire to help you assess if deer may be having an impact on your woodland.

How Do You Define Impact?

Wherever deer exist, they will be impacting the ecosystem through browsing. But at what level is that impact considered harmful? Many ecologists consider deer impact harmful when deer begin to reduce plant diversity in a woodland through browsing. This level of impact could occur at a relatively low deer density. Others may not be concerned about deer browsing until it begins to reduce the regeneration of shrubs and trees, which often occurs after a reduction in plant diversity. Review the *Understanding White-tailed Deer and their Impact on Indiana Woodlands* publication for more information on how deer impact woodlands.

How you define impact may depend on your values and objectives for your woodland. Do you want to maximize plant diversity in the forest? Are you interested in the regeneration of certain tree species? Are there certain species of wildlife beyond deer that you would like to encourage on a property? Are you trying to enhance habitat for deer? Answers to these questions will shape your perspective on what level of deer impact is tolerable.

For example, consider two landowners with relatively similar woodlands but different objectives for their woodlands. The first landowner is interested in maximizing the diversity of spring ephemeral wildflowers on their property. The second landowner is interested in enhancing oak regeneration to create the next oak-hickory forest. The first landowner would need to keep the deer population relatively low because wildflowers like trillium are often impacted, even at low deer population sizes. Keeping deer populations at this low level would also benefit oak regeneration. However, the landowner focusing on oak regeneration may be able to tolerate a higher population before deer would impact oak seedlings. But maintaining deer at a higher density would come at a cost to spring wildflowers, so there is a tradeoff.

FIGURE 2. Deer browse, such as the browse pictured above on this red oak, can impact woody regeneration.

Deer Numbers or Impact: Which to Measure?

Understanding deer populations on a property can be helpful when determining deer impact on a woodland. **But knowing the exact number of deer on a property is difficult to measure and unnecessary.** There are relatively easy ways to estimate the number of deer on a property or track trends in population sizes over time, such as through trail camera surveys or pellet count surveys.

No foolproof rules exist on how many deer are appropriate for an area. For example, 10 deer inhabiting a property in one part of the state may be causing more damage to the woodland than 20 deer on a property in another region. This is because the carrying capacity of a property (how many deer a woodland can support without damage) can vary greatly. Things like woodland age, size, plant composition, food available to deer, and the make-up of the surrounding landscape all play into how many deer an area can support.

For example, a recent research project by Purdue University measured deer densities and browse intensity (the proportion of twigs browsed from woody plants deer commonly eat) in three different regions of Indiana. One might expect that where deer densities were the highest, browse intensity was also the highest. But this wasn't the case. It was the opposite. Browse intensity was the highest in the region where deer densities were the lowest, and browsing was the lowest in the region with the highest deer densities. Researchers found the discrepancy in deer density and browse intensity was likely caused by differences in the amount of food available to deer (less food = lower carrying capacity = higher browse intensity) and the make-up of the landscape.

A more reliable and easier option for landowners is to monitor deer impact rather than the number of deer. Monitoring deer impacts helps you understand whether the number of deer in a woodland is in balance with the habitat available. There are numerous ways a landowner can monitor deer impact. We describe several of these methods here after and indicate which ones have been tested in Indiana. We also provide how-to instructions for several techniques at the end of the publication.

FIGURE 3. Monitoring deer browse, rather than just monitoring the number of deer on a property is important to help understand overall deer impact.

Monitoring Deer Populations

Monitoring deer populations over time can be helpful when considering deer impact on a woodland. This information will allow you to understand how deer populations respond to management (e.g., hunting) and if a change in the population over time results in a change in deer impact. This will allow you to tweak your management to achieve your property objectives (e.g., tree regeneration, plant diversity, etc.).

It's important to note that deer population monitoring should occur over three years or more to provide a good indication of population trends. Also, these methods will estimate density (deer per square mile or pellet groups per acre), but this number isn't exact. Though not exact, it helps compare the density over time to understand the population trend (i.e., is the population going up, down, or remaining stable).

Fortunately, landowners can use a few simple methods to track deer populations over time. Whichever method you choose, you should conduct the method the same way each year.

Deer Pellet Surveys

Deer pellet surveys are a reliable way to track deer populations over time. They are also easy to implement, as all you need to do is walk through the woods and count the number of pellet groups (deer droppings) within a given area (plot) along a set path (transect). Pellet surveys can also be done simultaneously with deer impact monitoring methods such as browse surveys or twig-aging (described later) to give a clearer picture of how deer impact your woodland.

Deer pellet surveys are generally conducted each year in the late winter to early spring (February – early April) before spring green-up. After completing this survey, you can estimate the number of pellets found per acre, which will help track the trend in the deer population over time. If the number of pellets you find decreases over time, it likely indicates that your deer population is getting smaller. You can find detailed instructions for how to complete a deer pellet survey in Appendix 1.

FIGURE 4. Counting deer droppings (pictured above) through pellet surveys can be a reliable way to estimate deer populations trends

Trail Camera Surveys

Trail camera surveys can be another relatively simple method to estimate deer populations over time. Cameras can be placed in the woods with or without bait (should be done the same way each year) for a set amount of time, usually 2-3 weeks, in the late summer (August-September) or winter (January-February). After collecting the cameras, you can estimate the deer population density by examining the number of pictures of does and bucks and identifying individual bucks by their antlers. Another benefit of trail camera surveys is that you can estimate fawn recruitment (number of fawns per doe) by comparing the number of pictures of does to fawns.

There are several free publications on how to implement trail camera surveys for deer:

- Estimating Deer Populations on Your Property: Camera Survey, University of Missouri Extension, g9481
- Using Camera Surveys to Estimate White-tailed Deer Populations, University of Kentucky Extension, FOR-133
- Conducting Camera Surveys to Estimate Population Characteristics of White-Tailed Deer, Mississippi State University Extension, P2788
- How to Run a Trail-Camera Survey, National Deer Association

Monitoring Deer Impact

While monitoring deer population numbers can be helpful, monitoring how deer directly impact a woodland is more critical for assessing woodland health. Monitoring deer impact is done by surveying what deer eat in a forest and how intensively they browse those species.

Deer are browsers rather than grazers (like bison and cattle), preferring to eat forbs (broadleaf herbaceous plants), vines, shrubs, and trees rather than grasses. Deer also select specific parts of the plants (e.g., leaves, twigs, and young tender growth).

Deer are also very selective in which plant species they eat, browsing certain plant species and avoiding others. However, deer will eat plants they typically avoid if there is little else to eat, indicating that deer may exceed an area's carrying capacity. For a more in-depth look into which plant species deer select and avoid in Indiana, read the publication *Understanding White-tailed Deer and Their Impact on Indiana Woodlands*, available through the Purdue Extension Education Store website.

We can determine how deer impact a woodland by using our knowledge of which plants deer select, which ones they avoid, and how deer browse those plants. Several different methods are available to woodland owners to help them determine how deer are affecting their woodlands. Researchers at Purdue University recently tested some of these methods throughout Indiana. Others have been studied in Wisconsin, Pennsylvania, and New York. Below are short descriptions of several available methods. Some of the methods best suited for Indiana landowners are described in detail in the appendices of this publication.

Browse Surveys

Browse surveys are a common way to monitor woodlands for deer impacts. While there are several ways to conduct a browse survey, they are generally done by walking transects (which are predetermined paths or routes) through a woodland, identifying plants (both woody and herbaceous together or separately), and recording if plants are browsed or how severely those plants are browsed. Deer impact is inferred by determining which plant species are browsed and how intensively they are browsed.

FIGURE 5. Browse surveys are an excellent technique to monitor deer impact on woody plants such as the white ash pictured above.

Depending on how they are conducted, browse surveys can be one of the best methods to gauge deer impact. This is because you are directly measuring the browse rate, or what proportion of available twigs or plants have been browsed. Woody browse surveys can also be done simultaneously with pellet counts to give you information on deer populations and their impact. However, deer browse surveys are not always easy to conduct as they can require considerable time and knowledge of plant identification.

Browse surveys for woody species have been used in Indiana. These surveys involve counting the number of browsed and available twigs of all encountered species along transects. From these counts, you can calculate a percentage of available twigs browsed, which measures browsing intensity. This method is also favorable because it encompasses all woody stems, does not require specialized identification knowledge, and can be conducted regardless of woody species. However, if you know what species deer avoid in your woodland (see *Understanding White-tailed Deer and their Impact on Indiana Woodlands*) and can identify these species, you can save time and effort by not including these species in the survey.

Indicator Plants

We can also gauge deer impact in a woodlot by monitoring certain indicator plant species. These indicator plants could be highly preferred by deer, such as trillium, or commonly avoided by deer, such as American beech seedlings. Monitoring indicator species that are highly preferred can be useful in detecting if deer impact is low, whereas monitoring commonly avoided plants can be helpful when detecting if deer impact is high

Indicator plants are usually monitored over several years to give a clear picture of how deer impact a woodland. The loss of a species or increased presence of a species may suggest a change in plant diversity and excessive deer impacts. To see how deer impact changes over time, you can compare browse rates (the percentage of individuals browsed), heights of individual plants, and percent of individuals flowering (for trilliums). Several methods of monitoring deer impact using indicator plants have been developed and are freely available.

FIGURE 6. Browse rates on highly preferred species such as trillium (pictured above), can be used to identify when deer impact is low and before it becomes more problematic.

AVID – Assessing Vegetation Impacts from Deer

The Assessing Vegetation Impacts from Deer project was started in New York to determine how deer impact forest vegetation (Curtis et al. 2021). AVID provides a protocol for monitoring woody or herbaceous indicator species over time. This project involves identifying, tagging, and measuring the height of certain indicator species within a plot. The plants in these plots are remeasured yearly to provide a gauge of deer impact. AVID also allows you to compare the height between protected and unprotected plants (e.g., plants in or outside a deer exclosure). AVID provides an easy-to-use website (www.aviddeer.com) where data can be entered, viewed, and interpreted. AVID was developed by researchers at Cornell University in New York but has also been used by the University of Minnesota Extension.

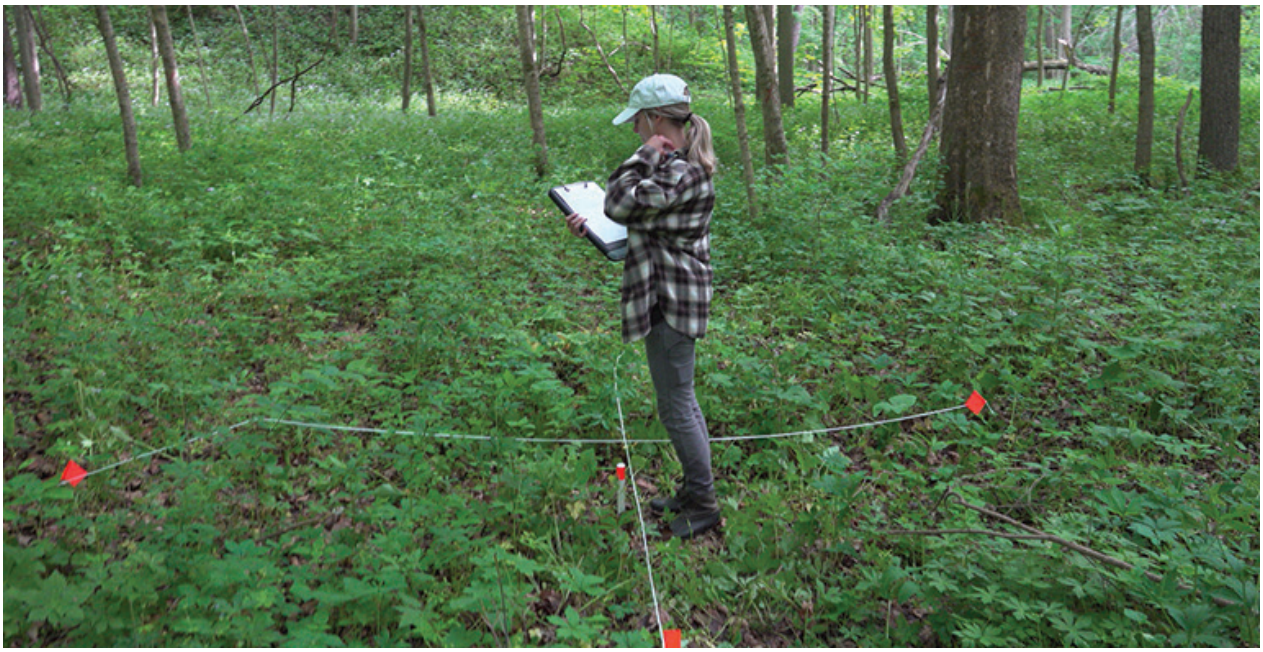

FIGURE 7. AVID plots like the one pictured can be used to monitor deer impact on several different indicator species.

Ten-Tallest Method

Another deer impact monitoring method using indicator species is the "ten-tallest method" developed by researchers with the USDA Forest Service. This method works for woody and herbaceous species. In this method, the ten tallest individuals of 1-3 indicator species are identified within a circular plot, and the height of these individuals is measured. In subsequent years, the ten tallest individuals are remeasured. You can gauge deer impact by examining how plant heights change over several years.

Twig-Aging

Twig-aging is a monitoring method that combines indicators plants with browse transects. This method was developed by researchers in Wisconsin (Waller et al. 2017) but has also been tested in Indiana. In this method, you walk transects through the woods and determine how intensively deer have been browsing certain woody indicator plants. This is done by counting the number of terminal bud scale scars on a twig until you reach a connected browsed twig. You can gauge deer impact by determining how many years it has been since the twig was browsed (1 bud scar = 1 year of growth without browse). This method requires some practice to identify bud scale scars, but otherwise is relatively simple and easy to conduct. This method works best for species with easily identifiable scars, like maples, ashes, and elms. In Indiana, this method has been proven effective for monitoring deer impacts and is quick and easy to implement.

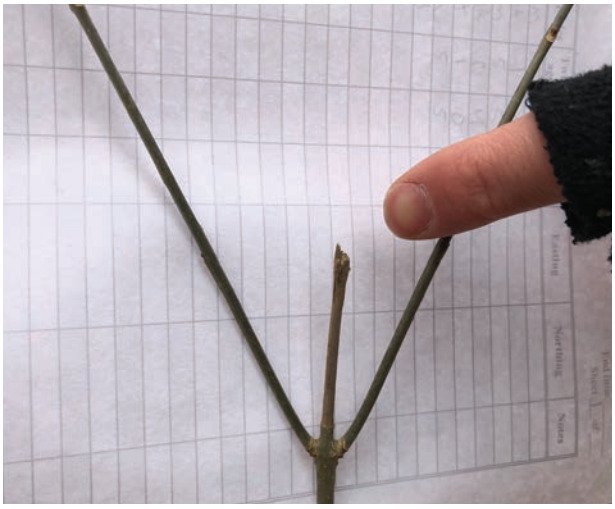

FIGURE 8. Twig aging using seedlings from trees such as white ash (pictured) is a reliable way to estimate deer impact to a woodland.

Oak Sentinel

Researchers at Cornell University developed the oak sentinel method (Blossey et al. 2019), and it has also been studied in Indiana. In this method, red oak seedlings are planted within a woodland and half are protected from deer with fencing, either a deer exclosure or metal wire cages. The height of all the oak seedlings and the browse rate (percent of seedlings browsed) of unprotected seedlings are measured yearly. Deer impact is gauged by looking at the difference in height between the protected and unprotected seedlings and determining the browse rate and growth rate of unprotected seedlings. This method requires a fair amount of initial work to plant the seedlings and build the exclosures. However, the level of impact can be seen very clearly by observing the difference in height or browse rate between the protected and unprotected seedlings.

When tested on Indiana woodlands, the browse rate of unprotected seedlings was the best metric for monitoring deer impacts. This monitoring method could be applied in Indiana by planting unprotected seedlings and comparing browse rates over time, eliminating the need to create expensive and time-consuming exclosures.

Stump Sprouts

The stump sprout method of determining deer impact is similar to the oak sentinel method but uses new growth from cut stumps rather than planting oak seedlings. This method was developed by researchers with the USDA Forest Service in Pennsylvania (Royo et al. 2016), but has also been tested in Indiana. In this method, small trees of certain woody indicator species are cut down and left to develop stump sprouts. Half of the stumps are protected from deer browse with metal wire cages, and half are left unprotected. As new growth emerges from the stumps (i.e., stump sprouts), the height of the tallest sprout is measured. The impact of deer can be gauged by comparing the height of protected and unprotected stump sprouts. Similar to the oak sentinel method, this method requires considerable up-front work. Still, the level of impact can be clearly seen by viewing the protected and unprotected stump sprouts. Stump sprouts of hackberry and sugar maple were tested in Indiana and were effective for monitoring deer impact.

FIGURE 9. Comparing the heights of sprouts from both protected (pictured) and unprotected hackberry stumps can be effective at monitoring deer impact.

How to Choose the Right Monitoring Method for You

There are a variety of monitoring methods to help you determine the level of deer impact in your woodland. The right method is the one that fits your goals, skills, and resources the best. For example, if you were interested in knowing more about deer's impact on wildflowers like trillium, you would choose a method like AVID that allows you to monitor certain herbaceous indicator plants. But, to use this method, you need to be able to identify species such as trillium. If you wanted a broader look at deer impact in your woodland and don't have the skills to identify individual wildflowers, you could choose a method such as Twig-aging. Twig-aging gives you a good indication of deer impacts and only requires you to be able to identify a few woody species and spend some time learning how to age twigs. Table 2 at the end of the publication provides more information about the time, cost, equipment, and expertise required for various monitoring methods.

OUR RECOMMENDED MONITORING METHOD: TWIG-AGING

While many monitoring methods exist, and the most appropriate method for a woodlot may vary, Twig-aging is an effective, efficient, and appropriate method for most Indiana woodland owners. When tested against other methods, twig-aging proved one of the most effective methods to monitor deer browse intensity. It was also less expensive, easier to implement, and more flexible than other methods. We suggest woodland landowners utilize twig-aging as a monitoring method unless their objectives call for another method (e.g., monitoring wildflowers). A "how-to" guide for twig-aging is provided in Appendix 3 of this publication.

Important Skills to Monitor Deer Impact in Your Woodland

If you are interested in monitoring deer impacts in your woodlands, there are a few skills and key pieces of information that can be helpful. These will help you better understand how deer are impacting your woods.

Plant Identification

Identifying plants is one of the most important skills when monitoring your woods for deer impact. You do not need to be a botanist, but you should know some common species in your woodland – especially those used as indicator plants, such as wildflowers like trillium, sweet cicely, Canada mayflower, and others. Identifying woody indicator species like white ash, oaks, sugar maple, and others is also important. Even identifying invasive species like bush honeysuckle, garlic mustard, and Japanese stiltgrass can be important when monitoring deer impact.

There are several field guides to help you learn the native and invasive plants of Indiana, including:

- Native Trees of the Midwest, Purdue University Press
- Native Shrubs and Vines of the Midwest, Purdue University Press
- Wildflowers and Ferns of Indiana's Forests, Indiana University Press

You can also download one of several plant identification applications for your smartphone, such as:

- Seek
- iNaturalist
- Google Lens
- PlantSnap
- PlantNet

Tree and shrub identification videos are also available on the Purdue Extension – Forestry and Natural Resources YouTube page.

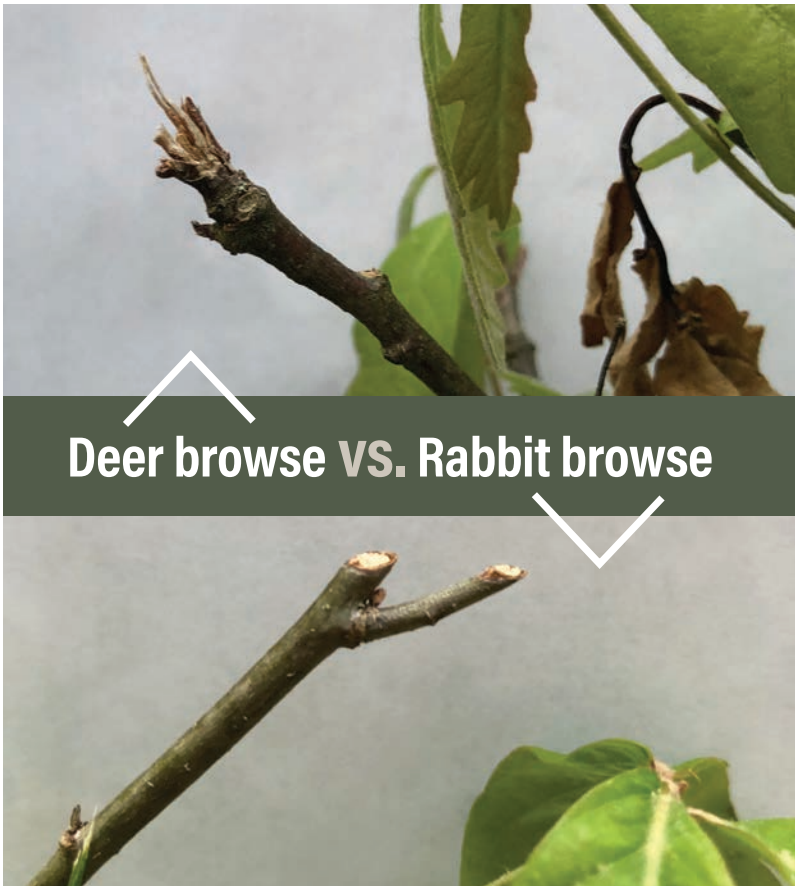

FIGURE 11. These pictures show the difference in deer (top) and rabbit (bottom) browse. Deer lack upper incisors, so their bite marks look ragged or torn. Rabbits do have upper incisors and they make a clean almost 45 degree angle bite mark.

Identifying Deer Browse

The signs of deer browse on plants can be obvious but can be confused with rabbit browse. The end of a plant or twig browsed by deer will appear jagged or messy. This is because deer only have incisors on their lower jaw, which causes their browse to look shredded. Rabbit browse appears clean with a cut at an almost perfect 45-degree angle because they have lower and upper incisors. You can also differentiate deer and rabbit browse by height. Deer can browse up to about 6 feet, whereas rabbits browse less than 3 feet.

Understanding a Deer's Diet

By understanding which plant species deer prefer to eat and which species they do not, you will be better suited to monitor the impact in your woodland. Coupling your plant identification skills, ability to identify deer browse, and knowledge of deer diets will tell you if deer in your woodland are eating species they prefer or if they are relegated to eating species they dislike because of a lack of food or overabundance of deer. See the *Understanding White-tailed Deer and Their Impact on Indiana Woodlands* publication for detailed information about deer diets and selection.

Identifying Terminal Bud Scale Scars

Twig aging relies on identifying terminal bud scale scars. These scars can be easily identified on a twig by looking for a scar that wraps around the twig. You can age the twig once you identify the terminal bud scale scars. Instructions for twig aging can be found in Appendix 3.

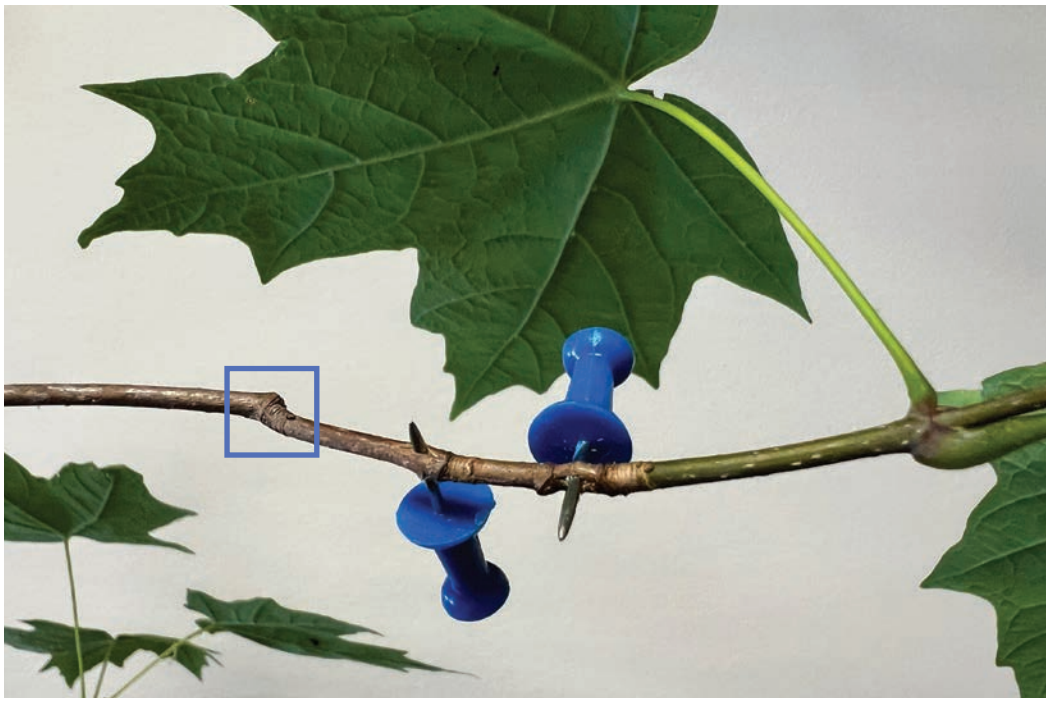

FIGURE 12. The light-colored tissue just to the right of the blue push pins and within the blue box that wraps around this sugar maple twig are the terminal bud scale scars. These scars separate the twigs growth between years. You can also see where this year's new growth (green twig) meets last year's growth (brown twig).

How to Interpret and Use Monitoring Data

Collecting data about deer and their impact is certainly a worthwhile endeavor in and of itself. Still, you also need to be able to interpret the data to truly evaluate how deer are impacting your woodland. How you interpret the data will depend on which monitoring method you choose. Techniques such as AVID make data interpretation easy because all you have to do is enter the data on their website, and it will create charts and graphs for you. For some methods, like twig-aging, you can summarize the data with just a calculator, whereas with others, you will likely have to enter the data into a spreadsheet program like Microsoft Excel or Google Sheets. Once entered, you can create tables, charts, and graphs to interpret the data.

Generally, you will want to compare trends in the data over multiple years, between woodlands, or before and after management changes (e.g., deer harvest or habitat management). If you are looking to change the management on your property, you should monitor the site for 1 to 2 years before you make the change and 1 to 2 years after. This will allow you to determine the effects of your management on deer impact.

Here are some examples of interpreting data from the browse survey, twig-aging, and oak sentinel methods.

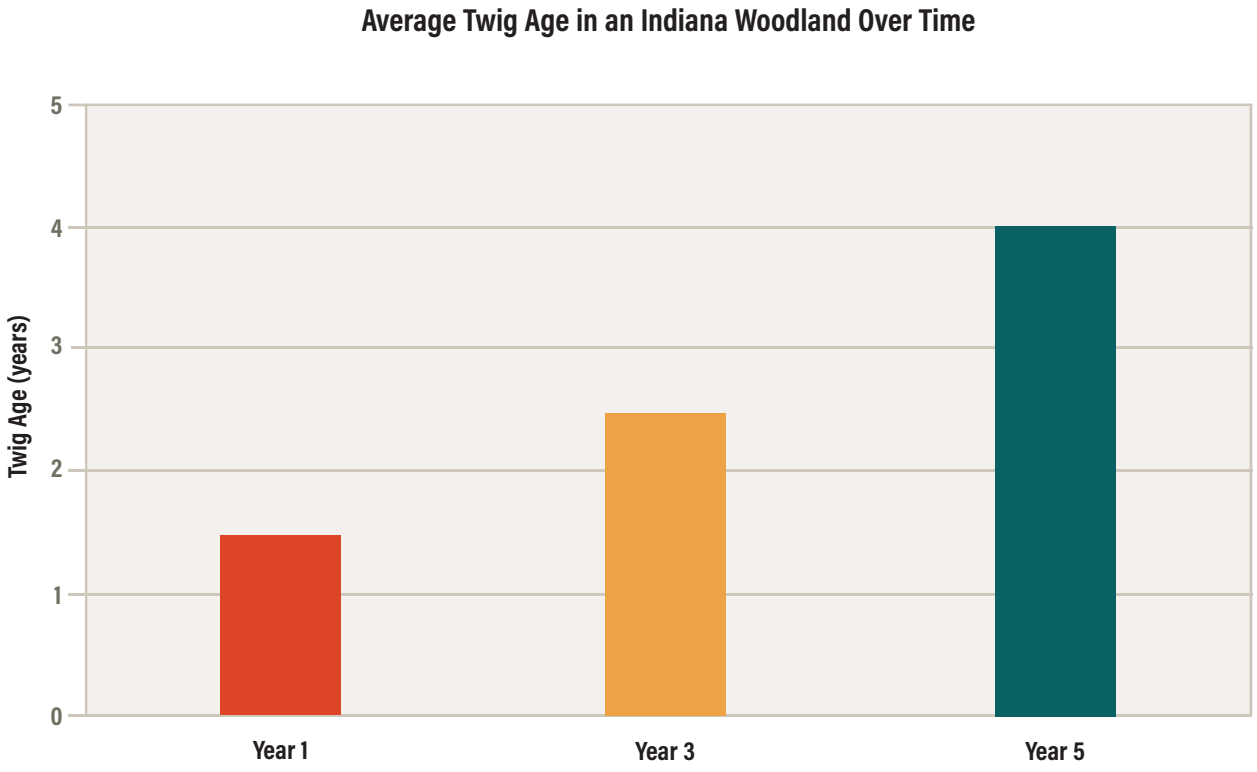

FIGURE 13. This graph shows the difference in twig age in an Indiana Woodland over time. In year 1, the twig age is 1.5 years, which indicates a high browse intensity and impact. In year 5, the twig age increased to 4 years, which indicates a low browse intensity and low deer impact.

Browse Surveys

Browse surveys will yield a measurement of browse rate or intensity, which is the proportion of twigs browsed. This value can be compared between years or woodlots. If you have two woodlots in the same general area, deer impact would be greater in a woodlot where 40% of twigs were browsed compared to a woodlot where 10% of the twigs were browsed.

Twig Aging

If you decide to use the twig aging method, you will want to compare the average age of twigs over several years or between woodlots. If the average age of a twig in a woodland is 1.5 in year one, 2.5 in year three, and 4 in year five, then deer impact is likely decreasing and relatively low in year five (Figure 13).

Oak Sentinel

Using the oak sentinel method, you can gauge deer impact by comparing the percentage of stems browsed across years or woodlots. For example, if 75% of planted red oak seedlings were browsed in woodlot A, but only 10% of red oak seedlings were browsed in woodlot B, this would indicate that deer are having a much greater impact on woodlot A.

What Do My Browse Monitoring Values Mean?

If you are just starting to monitor your woodland for impacts and want to get an idea of what your value of browsing intensity suggests, we provide some guidelines based on research in Indiana. These suggestions come from a statewide deer project at Purdue University in partnership with the Indiana Department of Natural Resources, and have been developed from private, state, federal, and other publicly-owned woodlands found within the southern, central, and northern regions of Indiana.

This research study compared several monitoring methods, including woody browse surveys, twig-age, oak sentinel, and stump sprout. You can compare your values to Table 1.

Table 1. **Potential deer impact classes for Indiana.**

Deer Impact Monitoring Method	*High Browse Intensity*	*Medium Browsing Intensity*	*Low Browsing Intensity*
Browse Survey (% of woody twigs browsed)	>31%	10-31%	<10%
Twig Age (years)	0-1.9	2-3.9	4-5
Oak Sentinel (% of red oak seedlings browsed)	>57%	29-57%	0-28%
Stump Sprout (% difference in protected and unprotected stump sprout height)	>49%	22-49%	<22%

Conclusion

The information gained from monitoring deer and deer impact on a woodland will help landowners make informed decisions about their properties. Managing deer is an important consideration for any landowner interested in maintaining a high-quality woodlot with a diverse mix of plants and wildlife and good timber growth and quality.

Once you collect, summarize, and interpret monitoring data from your woodland, you can use it to inform the management on your property. For example, if your monitoring indicates the average twig age of sugar maples is 1.65 in your woodland, it suggests that deer impact is high. You can then decide the appropriate management actions, such as hunting, to decrease the deer population or deer impact on your property. Information about options for managing deer impact on woodlands can be found in the *Managing Deer Impact on Indiana Woodlands* publication available on the Purdue Extension Education Store website.

Acknowledgements

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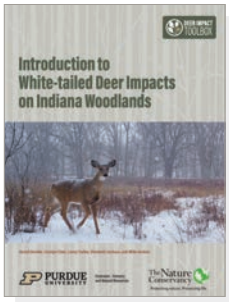
Additional Resources

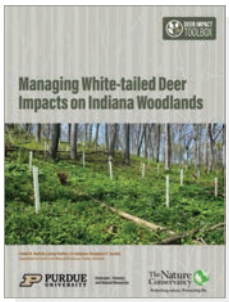
For more information about deer and their impact on forest ecosystems, view the publications below:

- Assessing Vegetation for Impacts from Deer – Cornell University - https://aviddeer.com/
- Blossey, B., P. Curtis, J. Boulanger, and A. Dávalos. 2019. Red oak seedlings as indicators of deer browse pressure: Gauging the outcome of different white-tailed deer management approaches. Ecology and Evolution 9:13085–13103.
- Curtis, P., K., Sullivan, P., Smallidge, and J. Hurst. 2021. AVID: A rapid method for assessing deer browsing of hardwood regeneration. Forest Ecology and Management 497:119534.
- Rawinkski, T.J. 2018. Monitoring White-tailed Deer Impacts: The ten-tallest method. U.S. Department of Agriculture, Forest Service.
- Royo, A., D. W. Kramer, K. V. Miller, N. P. Nibbelink, and S. L. Stout. 2016. The canary in the coal mine: Sprouts as a rapid indicator of browse impact in managed forests. Ecological Indicators. 69: 269-275. 69:269–275.
- Sample, R.D. 2022. Assessing White-tailed deer browsing in woodlands. Indiana Woodland Steward.



Introduction to White-tailed Deer Impacts on Indiana Woodlands

Understanding White-tailed Deer and Their Impact on Indiana Woodlands



Managing White-tailed Deer Impacts on Indiana Woodlands

Table 2. **Deer impact monitoring methods were ranked as LOW (L), MEDIUM (M), or HIGH (H) for different categories based on the authors' experience.** Methods with a LOW overall score are easily utilized with minimal time, equipment, or expertise requirements and offer flexibility. Methods with MEDIUM overall scores require some time or equipment investments or require some expertise. Methods with HIGH overall scores require considerable investment in time, cost, equipment, or expertise.

Method	Time[1]	Cost[2]	Equipment[3]	Expertise[4]	Inflexibility[5]	Data Entry and Interpretation[6]	Overall
AVID	H	M	M	M	M	L	M
	Considerations Time consuming, a decent amount of equipment, and knowledge of plant identification. It must occur at a specific time of the year (spring). You must also revisit the same plot and the same plants each year. Data interpretation is quick.						
Ten-Tallest	M	L	L	M	M	M	M
	Considerations It does not cover large areas of the property and may require multiple plots. You must find and revisit the same plot each year. Inexpensive and fast to measure and remeasure. Has not been tested in Indiana.						
Twig-Aging	L	L	L	M	M	L	L
	Considerations Fast and simple. However, it requires experience and has a limited species list.						
Stump Sprouts	H	H	H	M	M	L	H
	Considerations Considerable work to cut trees and install cages over stumps, but easy to measure and interpret results. It would be less effort if you were planning to cut some small trees in your woods.						
Oak Sentinel	M/H	M/H	M/H	M	M	L	M/H
	Considerations Considerable work to plant trees and build fencing, but easy to measure and interpret results. Requires less time and resources if you only planted unprotected species and do not build an exclosure.						
Browse Survey	L	L	L	M	M	M	L/M
	Considerations Negligible cost to implement, but it may require substantial knowledge of plant identification, depending on how it is implemented.						

[1] Time = the amount of time it takes to collect the data needed for the method (e.g., LOW = data can be collected in 1-2 hours per site and in 1 visit per year)

[2] Cost = the cost of using the method, including the cost of equipment and labor (e.g., HIGH = requires the purchase of fencing material, tools, and multiple people to implement)

[3] Equipment = the amount of equipment needed to complete the survey (e.g., LOW = requires only a tape measure and datasheet)

[4] Expertise = the level of skill or knowledge to implement the technique (e.g., HIGH = extensive plant identification knowledge required)

[5] Inflexibility = the ability to utilize this technique in a wide range of woodlands in Indiana (e.g., HIGH = inflexible; requires a narrow list of plant species to monitor that may not be present in many Indiana woodlands)

[6] Data Entry and Interpretation = the ease of entering and understanding the data collected (e.g., LOW = can be entered and understood without much effort or time)

Appendix 1. Deer Pellet Group Survey Protocol

Introduction

Pellet counts or pellet group surveys are a common technique to monitor deer populations. In these surveys, deer pellet groups (deer poop) are counted in small plots along a transect or while walking through the woods. Pellet group surveys are conducted in the late winter or early spring before spring green-up (February to early April). The number of pellet groups counted in the plots along the transects is used to determine the density (pellet groups per area) of pellet groups on your property. While pellet group density does not provide an exact density of deer, it is related to deer density and can be used to track changes in population. Pellet group surveys should be conducted similarly each year for the same property or similarly between properties so that you can compare results.

Equipment and Materials

You only need a few materials to conduct a pellet group survey, including:

- Clipboard, writing utensils, and datasheets
- Compass
- 4-ft or 8-ft survey pole (e.g., piece of PVC pipe cut to length)
- Transect tape (optional)
- Property map

Field Procedures

TRANSECTS

The first step is to determine the location of the transects on your property. Transects can start at the edge of your property or in random locations on your property. They should be oriented in similar cardinal directions to avoid intersecting or overlapping. For example, if your property is oriented north/south, transects starting at the south end of the property should be oriented north, and transects beginning at the north edge of the property should be oriented south (Figure 14). Transects should be spaced out every 100 to 350 yards throughout your property. Longer distances between transects can be used for larger properties. The number of transects per property will vary based on the size, but enough transects should be placed to cover most of your property.

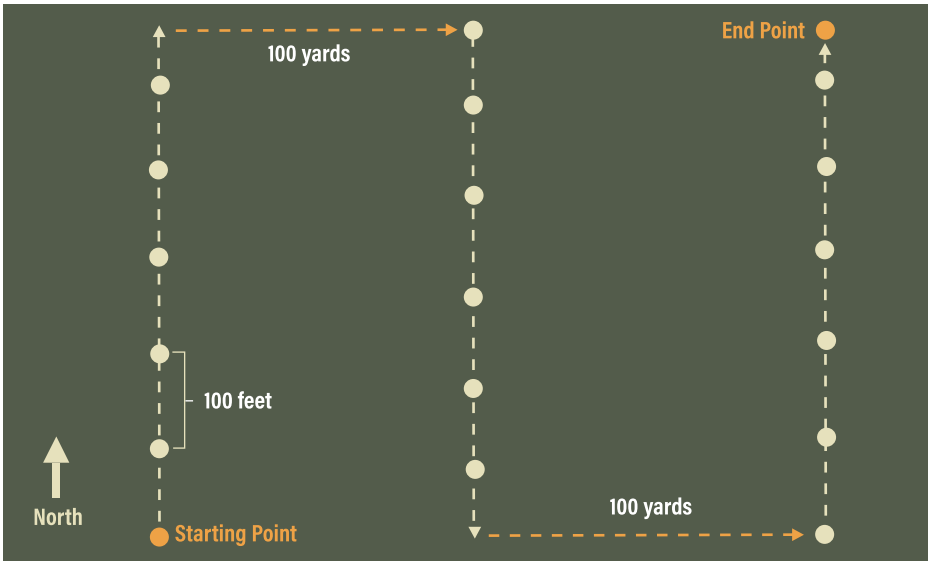


FIGURE 14. This diagram shows an example of how you would lay out transects on a property. The tan lines are the transects and the tan circles are the pellet survey plots.

PELLET SURVEY PLOTS

Deer pellet groups are counted in circular survey plots every 100 ft along a transect. For example, a 500-ft long transect would have five survey plots. You can use a transect tape to measure the length between plots or approximate 100 ft between plots using your pace. The radius of the plot is equal to 4 ft (length of the survey pole). *Note – an 8 ft pole is equal to the diameter of the plot and may be helpful when sampling.*

COUNTING PELLET GROUPS

At each plot, the survey pole is placed on the ground, and all deer pellet groups (not individual pellets) are counted within the 4-ft radius plot. A pellet group must have at least six pellets to be counted as a pellet group. Record the number of pellet groups counted and the number of plots sampled for each transect. Pellet groups are counted within plots along all the transects.

FIGURE 15. Pellet groups (deer droppings) are counted within a 4-ft radius (8-ft diameter) plot.

RESAMPLING

You can utilize the same transects and sampling locations yearly, but this is not required as long as you randomly sample your property. Resampling should be done at relatively the same time each year to ensure the data is comparable over time.

OPTIONAL – CONDUCT BROWSE SURVEYS OR TWIG-AGING DURING PELLET GROUP SURVEY

To provide you with more information about deer or deer impact on your property, you can couple a browse survey or twig-aging with a pellet group survey. This can be done by either surveying woody plants for browse or aging twigs at each pellet survey plot or walking between plots. For more information about these surveys, see *Appendix 2. Browse Survey* and *Appendix 3. Twig-Age Survey*.

Data Entry and Interpretation

Data collected in the field can be entered into a spreadsheet program such as Microsoft Excel or Google Sheets. These programs can help with summarizing and interpreting data.

DETERMINING PELLET GROUP DENSITY

The density of pellet groups for each site is calculated by dividing the number of pellet groups counted across all transects by the number of plots sampled and the area of the plot. If you use a 4-ft radius plot, the area of the plot is 50 ft^2 or 0.0012 acres.

$$\text{Deer Pellet Groups Per Acre} = \frac{\text{number of pellet groups counted}}{(\text{number of plots}) * (0.0012 \text{ ac})}$$

You can compare the pellet group densities for the same property over several years to determine trends in the population. You can also compare pellet group densities between properties to assess differences in deer populations between those properties.

Deer Pellet Group Survey Datasheet

Observers:	Date:	Property:
		Woodlot or Stand #:

Transect #	Number of Plots[2]	Number of Pellets Groups[3]

[1] Number transects sequentially
[2] Tally the sampling plots as you complete them.
[3] Tally the pellet groups as you encounter them.

Deer Pellet Survey Formula

$$\text{Deer Pellet Groups Per Acre} = \frac{\text{number of pellet groups counted}}{(\text{number of plots}) * (0.0012 \text{ ac})}$$

Deer Pellet Survey Calculation

Number of Pellet Groups Counted	
Number of Plots	
Number of Pellet Groups Per Acre	

Notes

Appendix 2. Woody Browse Survey Protocol

Introduction

Browse surveys are a common way to monitor woodlands for deer impacts. Browse surveys can be one of the best ways to gauge deer impact. This is because you are directly measuring the browse rate, or what proportion of available twigs or plants have been browsed, for each species.

The following protocol is based on a browse survey used during a statewide deer research project in Indiana. It is a simplified version of other browse surveys and does not require you to identify individual woody plants or judge the browse intensity of each plant. Instead, you count the browsed and available stems within a small plot and determine the percentage of twigs browsed. These browse surveys can be conducted at any time of year, but they should be conducted at the same time each year to compare the browse rates between years or woodlots.

FIGURE 16. Browse surveys involve counting the number of browsed and unbrowsed stems on a woody plant like this white ash seedling.

Equipment and Materials

This browse survey method does not require extensive materials and equipment. It can be conducted utilizing the following materials:

- Compass
- Transect tape (optional)
- 4 ft x 4 ft sampling frame (can be built with PVC pipes)
- Datasheet

Field Procedures

TRANSECTS & BROWSE PLOTS

Conduct browse surveys along 150-ft transects in your woodland. You should sample two transects for every 30 acres of property (e.g., four transects for a 60-acre woodland). Each transect should be walked in similar cardinal directions (e.g., north/south or east/west) so that transects do not intersect or overlap. Transects should be spaced out at least 500 feet apart.

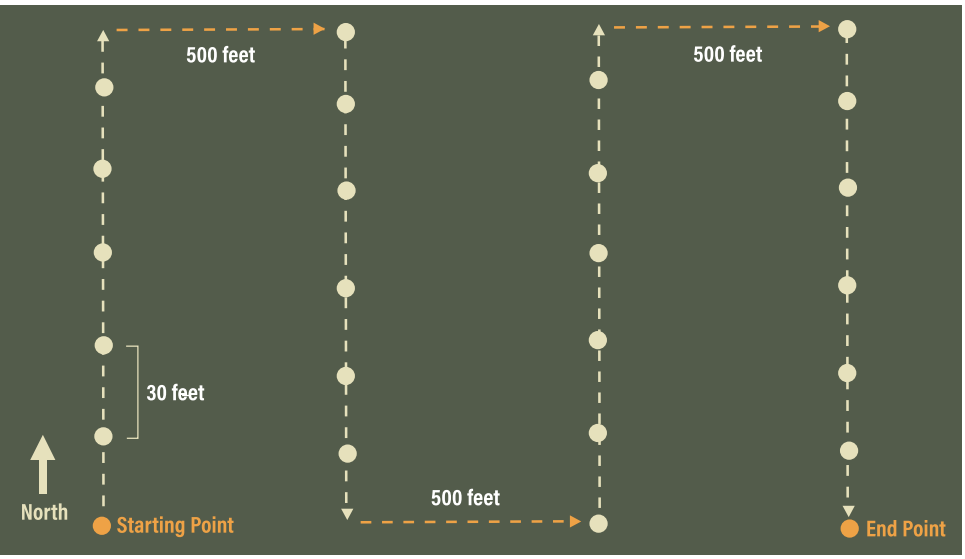


FIGURE 17. This graphic shows the layout for browse transects (tan lines) and browse plots (tan circles) for a 60-acre woodland (not to scale).

Place browse survey plots every 30 ft along each transect to estimate woody browse. There should be five browse plots per transect. Each plot is 4 ft x 4 ft. You can lay out a transect tape to measure each transect or use pacing to measure the approximate distance between transects and plots.

SAMPLING BROWSE PLOTS

Place the 4 ft x 4 ft sampling frame along the right side of the transect tape every 30 ft. Estimate the percent of twigs browsed in each plot by counting the number of browsed twigs and the total number of available twigs (browsed and unbrowsed twigs) within the plot. Treat the sampling frame as a cube and count the browsed and available twigs between 8 inches and 6 feet above the ground. Do not count twigs that appear to have been dead for more than a year.

For this method, you do not have to identify individual species; just count the total number of available twigs and the number of browsed twigs. However, if you can identify woody species, you can record the available and browsed twigs by species. Identifying the species will help you determine how browse selection varies between species.

Once the number of browsed twigs and the total number of twigs has been recorded, move another 30 ft along the transect and repeat the sampling process.

RESAMPLING

You can utilize the same transects and sampling locations from year to year, but this is not required as long as you randomly sample your property. Resampling should be done at relatively the same time each year to ensure the data is comparable over time.

Data Entry and Interpretation

Data can be entered into a spreadsheet program such as Microsoft Excel or Google Sheets, or a calculator can be used to calculate the browse rate immediately after data is collected. You can calculate browse rate or intensity by dividing the total number of browsed twigs by the number of available twigs in each woodlot. This will give you the percentage of twigs browsed. The percentage of twigs browsed correlates to the impact caused by deer. The table below summarizes data collected during a statewide research project and relates the percent browse to deer impact levels.

Deer Impact Monitoring Method	*High Browse Intensity*	*Medium Browsing Intensity*	*Low Browsing Intensity*
Browse Survey (% of woody stems browsed)	>31%	10-31%	<10%

Woody Browse Survey Datasheet

Observers:	Date:	Property:
		Woodlot or Stand #:

Transect #	Plot #	Number of Twigs Browsed[1]	Number of Twigs Available[2]

[1] Number of twigs browsed within the plot from 8 inches to 6 feet off the ground

[2] Total number of browsed and unbrowsed twigs within the plot from 8 inches to 6 feet off the ground

$$\text{Browse Rate} = \frac{\text{Browsed Twigs}}{\text{Available Twigs}}$$

Total Browsed Twigs	
Total Available Twigs	
Browse Rate	

Notes

Appendix 3. Twig-Aging Protocol

Introduction

Researchers at the University of Wisconsin created the Twig-aging method for monitoring deer impact (Waller et al. 2017). Researchers at Purdue have also studied this method to evaluate deer impact in Indiana. Twig-aging focuses on determining the number of years since a twig has been browsed (twig-age). Aging the twig is done by looking at the terminal bud scars on a twig. Twig-aging provides a quick and easy way to monitor deer impacts in a woodland. Unlike the AVID and Ten-Tallest methods, Twig-aging does not require setting up permanent plots or tagging individual plants. Twig-aging is only valid for woody species. The following protocol was adapted from the original Twig-aging protocol to fit Indiana forests.

Equipment and Materials

The following materials are needed to conduct this method:

- Clipboard, writing utensils, and datasheets
- Flagging
- Compass
- GPS (optional)

Field Procedures

SELECTING AN AREA

For this method, finding an area large enough to sample 50-60 individuals of your target species is important. The location you select should have seedlings between 6 inches and 5 feet tall (i.e., the height where deer commonly browse). You should not choose an area based on how much browse you see, but rather select a site based on the species present and their abundance.

You will not be setting up permanent plots like in the Ten-Tallest and AVID methods. Instead, the size of the area you need to survey will depend on how much space you need to find 50-60 individuals of the same species. Because this method does not require a permanent plot, you can walk around a site to find enough individuals to sample.

SELECTING SPECIES

Select one to three woody species in your woodland that are considered potential indicator species for deer browse. Maple and ash species are highly recommended for this method because they commonly occur throughout Indiana and are easy to sample. Other indicator species are listed in the table below.

Potential Indicator Species for Twig-Aging
Maple
Ash
Elm
Sassafras
Oak (only if other species listed are not present)

SAMPLING

You can sample a woodland using the Twig-aging method any time of year. But, identifying seedlings is easiest when they have leaves during the growing season. To begin sampling, select a starting point and direction of travel (Figure 18). Place your starting point toward the edge of your woodlot and move away from the edge. One way to complete this is to visualize a transect or straight line through the woods and pick an object in the distance to move towards it. As you walk along the transect, sample stems as you see them. Make sure to sample stems throughout your woodlot, not just in one small area. You can place a piece of flagging on each individual you sample so you do not recount it. As you move along the transect, look for seedlings with at least two twigs. If it only has one twig, skip it. For each seedling,

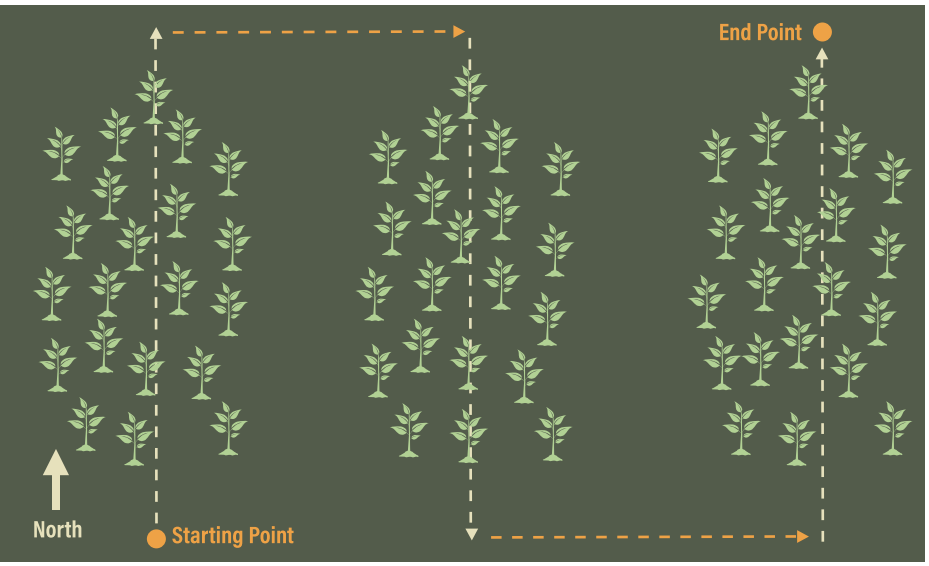


FIGURE 18. This graphic shows an example of twig age transects (tan lines) through a woodland. You would same the seedlings of your selected species (green plants) throughout the woodland.

age two random twigs and check it for fresh browse. Only twigs within reach of a deer (8 inches to 6 feet tall) should be used for twig-aging.

Determining twig-age

Twig aging relies on identifying terminal bud scale scars (Figures 19 and 20). These scars can be easily identified on a twig by looking for a scar that wraps around the twig. To age a twig, follow these steps:

- Start at the end of the twig where there is new growth, and move backward down the twig.
- While doing so, count one year for each terminal bud scale scar you pass.

  When counting terminal bud scale scars, you want to make sure it wraps entirely around the twig and is similar in appearance to a thin rubber band.
- Continue to count until you reach five years or come to a connected twig that is browsed. This may appear as an angled connection.

Repeat this process for preferably 50-60 twigs of each species, but at least 30 or more twigs are required to obtain enough data.

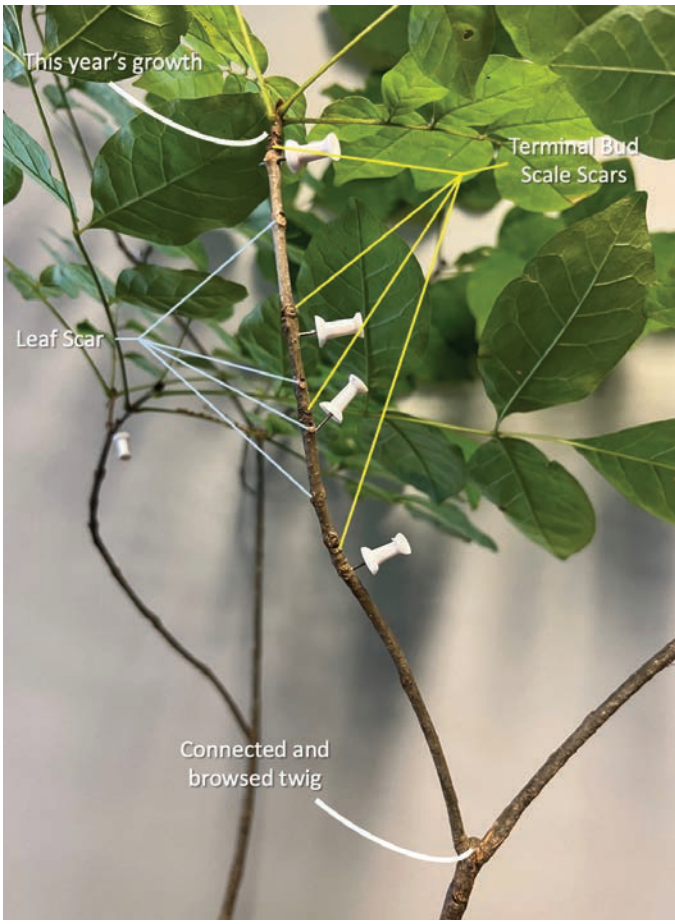


FIGURE 19. This white ash twig is five years old. The white push pins mark the approximate location of the terminal bud scale scars. The leaf scars are also labeled, but these scars do not wrap around the twig. The connected and browsed twig is where the parent twig was browsed and new twigs were formed.

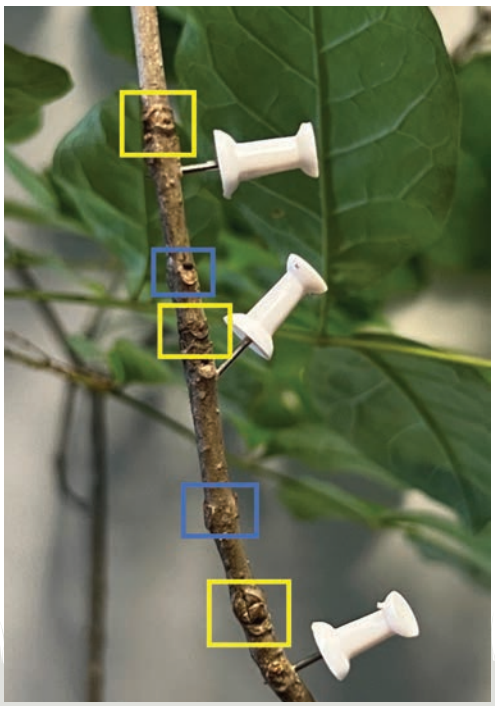


FIGURE 20. This is a close up view of the terminal bud scale scars (yellow boxes) and leaf scars (blue boxes).

RESAMPLING

As with any deer impact monitoring method, resampling over several years is important to determine how deer impact changes over time. You should resample each area at the same time each year.

Data Entry and Interpretation

Data can be entered into a spreadsheet program (e.g., Google Sheets) or summarized using a calculator. Calculate the mean twig age for the target species on your property to summarize the data. This is done by adding all the twig ages for each species, then dividing by the number of twigs sampled for each species.

Data can be immediately interpreted since you will not return to tagged plants in future years. Using a spreadsheet program, you can use the data to compare species, treatments, sites, and years. Woodland owners can use the data to monitor deer habitat conditions and impacts. The table below is based on research conducted in Indiana and will help you interpret how the average twig age in your woodland relates to potential deer impact levels.

Deer Impact Monitoring Method	*High Browse Intensity*	*Medium Browsing Intensity*	*Low Browsing Intensity*
Twig Age (years)	>31%	10-31%	<10%

Additional Resources

- The Twig-Age Method – University of Wisconsin – https://wiunderstory.wisc.edu/the-twig-age-method
- Waller, D.M., S.E. Johnson, and J.C. Witt. 2017. A new rapid and efficient method to estimate browse impacts from twig age. Forest Ecology and Management. 404:361–369.

Twig-Aging Datasheet

Observers:	Date:	Property:
		Woodlot or Stand #:

Stem #	Species	Twig 1 Age[1]	Twig 2 Age[1]	Fresh Browse? (Y/N)[2]
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
11				
12				
13				
14				
15				
16				
17				
18				
19				
20				
21				
22				
23				
24				
25				
26				
27				
28				
29				
30				
31				
32				
33				

continued from page 27

Stem #	Species	Twig 1 Age[1]	Twig 2 Age[1]	Fresh Browse? (Y/N)[2]
34				
35				
36				
37				
38				
39				
40				
41				
42				
43				
44				
45				
46				
47				
48				
49				
50				
51				
52				
53				
54				
55				
56				
57				
58				
59				
60				

[1] Age the twig to 0-5 years 0 = a freshly browsed twig
[2] Record if there is fresh browse on any twigs on the stem

Average Twig Age Calculation	Twig 1	Twig 2
Sum of All Twig Ages		
Number of Stems Aged		
Average Twig Age		

Notes

Appendix 4. Assessing Vegetation Impacts of Deer (AVID) Protocol

Introduction

AVID stands for Assessing the Vegetation Impacts of Deer and was initially developed by Cornell University (www.aviddeer.com). It can be used for both woody plants and spring wildflowers. This method would be most beneficial for a landowner who would like to understand deer impacts over a large area of their woodland for multiple species over several years. The free online portal makes data entry and interpretation a simple task.

The following protocol was adapted from the original AVID protocol to fit Indiana forests. You can visit the original protocol by visiting the AVID website.

Equipment and Materials

- Clipboard, writing utensils, and datasheets
- Flags
- 6 ft string or rope
- Two 12 ft strings or ropes
- Permanent marker
- PVC pipes
- Stakes
- Metal Tags
- Tape measure or yardstick
- Camera (optional)
- GPS (optional)

Field Procedures

The AVID method can be used with both woody seedlings and spring wildflowers. The procedures for each technique are similar, with a few minor differences. You can implement AVID with woody seedlings at most times of the year as long as you sample at the same time each year. However, spring ephemerals can only be sampled during a small window in the spring, usually late April through early June in Indiana.

SELECTING AN AREA

Before starting AVID sampling, it is important to familiarize yourself with the property and its plant composition. This is important to ensure that your target indicator species are present. When selecting plot locations, choose an area at least 50 feet away from the forest edge or human disturbance. Also, avoid areas with permanent standing water, more than 65% cover of exposed rock, slopes greater than 70%, high densities of interfering plant species, and extremely dense canopy.

Record all the pertinent information about the site on the *Site Description* datasheet. This information only needs to be collected during the first year of sampling. Collect the following information: county, owner, and address of the property, the basal area of the site (if known), average overstory tree diameter (if known), and most common plants (both overstory and understory) on the site. It can also be helpful to draw a map of the area and locations of the plots to help you find them each year.

SELECTING SPECIES

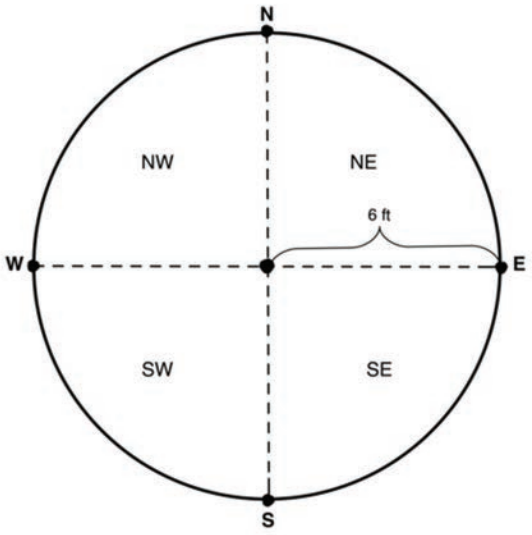
After you have found an appropriate area, select 1-3 species to sample. Choose species that are numerous, as you will need at least 30 individuals of each species in the area. Select species that are either highly preferred by deer or of low preference to deer, or choose a mix of preferences to allow you to gain more insight into overall deer impact.

Below are potential indicator plants to use when monitoring deer impact in Indiana. Ideally, you should sample at least one species from each preference group. You can find more information about deer food habits in Indiana by reading the *Understanding White-tailed Deer and Their Impacts on Indiana Forests* publication from Purdue Extension.

Preferred Woody Plants	Low Preference or Avoided Woody Plants
Sugar maple	American beech
White ash	Pawpaw
Oak	Spicebush
Hackberry	Coralberry

Preferred Wildflowers	Low Preference or Avoided Wildflowers
Sweet cicely	Jack-in-the-pulpit
Trillium	Garlic mustard
Canada mayflower	Wild ginger
Solomon's seal	Mayapple

PLOT AND QUADRANT SETUP



For the AVID method set up at least 4-6 plots. A plot is a circular area with a 6-foot radius (12-foot diameter), where you should be able to find at least five individuals of the plant species you are monitoring. Select a center for each plot which should be at least 25 feet from the center of other plots. Write the plot number on your PVC pipe with a permanent marker and put it into the ground. It is easier to set up the plots if you have a partner helping.

Tie a 6-ft string to the plot center and place a flag at the end of the string in each cardinal direction. Then stretch the two 12-ft strings across the plot, one reaching from North to South and one from East to West using the flags placed. This will create four quadrants in the plot and complete the plot setup. You should use a compass or the compass on your smartphone to determine the cardinal directions.

Record the GPS coordinates of each plot center on the datasheet using a handheld GPS or your smartphone. You should record important information about the plot using the *Woody Seedling* or *Spring Wildflower* datasheet. This includes plot number, date, recorders' names, GPS location, description of the vegetation, if the plants are protected from deer, and any important things to note about the plot location.

FIGURE 21. Here is an example of an AVID plot set-up. The PVC-pipe with orange tape represents the plot center. Each orange pin flag is 6 feet from the center. Two 12-ft pieces of string divide the plot into 4 quadrants for sampling.

TAGGING PLANTS AND COLLECTING DATA

Whether you are tagging wildflowers or seedlings, try and tag at least one to two individual per quadrant, at least five to ten individuals per plot, and 25-30 individuals of the same species per site. When tagging woody seedlings place the tag directly on the stem. When tagging wildflowers, place the tag on a stake next to the plant. Write the species and tag number on each tag with a permanent marker to identify it when you return the following year.

After you have tagged each plant, measure and record the height (inches) of the plant. For woody plants, measure the tallest height of the woody growth, NOT the height of the tallest leaf. For wildflowers measure the tallest stem of each plant. For certain species like trillium, you should measure the height from the ground to the leaf whorl, NOT the height from the ground to the flower. Also record the quadrant the plant is in, if it has been browsed, and, if you are sampling wildflowers, whether the individual is flowering or yet to flower this year.

FIGURE 22. A metal stake with a metal tag is used to "tag" or mark each plant for resampling. The plant number is written on the tag.

FIGURE 23. When sampling plants, measure to the tallest stem, not the tallest leaf. Be sure to measure the height of the plant as it actuals grows and without moving the plant.

When selecting woody seedlings to monitor, you should ideally tag individuals taller than 6 inches and shorter than 3 feet, but seedlings less than 6 inches or shorter than 5 feet can be used if needed. Wildflowers should be at least 4 inches tall.

RESAMPLING

Each plot should be resampled once a year to track trends in deer impact. Sample the plots at about the same time each year. If you cannot find a tagged individual when resampling, you should mark it "NF" (for not found) on the datasheet. If needed, you can re-flag plots and re-tag plants each year to ensure you can find them the following year.

Data Entry and Interpretation

Data can be entered through the online data entry portal at www.aviddeer.com. Before entering the data you will need to register for an account, allowing you to enter, store, and analyze your data.

Once you enter the data online, the website analyzes and graphs the average height of each species. These graphs and a statistics page that automatically generate results from your data are helpful in interpreting it. After sampling over several years, there is much more information that can be analyzed. You can determine trends in height that relate to deer impact in your woodland. Ultimately, you want to use your information to measure changes in vegetation as deer browsing pressure changes. For example, if you compare the unprotected and protected plant graphs, and the heights are similar, then deer are not having much of an impact on your property.

Additional Resources

- Assessing Vegetation Impact from Deer Website – www.aviddeer.com
- Curtis, P., K. Sullivan, P. Smallidge, and J. Hurst. 2021. AVID: A rapid method for assessing deer browsing of hardwood regeneration. Forest Ecology and Management.

Avid Site Description Datasheet

Recorders:	**Date:**
County:	**Town:**

Owner Name and Contact Information:

Approximate basal area, sq.ft./ acre (optional):

Plant Community Description

Four most common overstory tree species in stand:

1. _____
2. _____
3. _____
4. _____

Four most common seedling or shrub species in stand:

1. _____
2. _____
3. _____
4. _____

Map of stand features and plot locations:

AVID Wildflower Datasheet

Plot #:	Date:	Recorders:

Location (Latitude/Longitude)	Vegetation Description	Percent Cover Estimation
	Ground and shrub cover (0-8 ft)	_____ %
Basal Area (optional):	Subcanopy (8-29 ft):	_____ %
	Canopy (> 30 ft):	_____ %

Is the plot enclosed or protected from deer? ☐ YES ☐ NO

Initial Measurement					Remeasure Date:		Remeasure Date:		Remeasure Date:	
Species	Tag #	Quadrant	Height (inches)	Flower Evidence (Y/N)	Height	Flower Evidence (Y/N)	Height	Flower Evidence (Y/N)	Height	Flower Evidence (Y/N)

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Initial Measurement					Remeasure Date:		Remeasure Date:		Remeasure Date:	
Species	Tag #	Quadrant	Height (inches)	Flower Evidence (Y/N)	Height	Flower Evidence (Y/N)	Height	Flower Evidence (Y/N)	Height	Flower Evidence (Y/N)

* If a plant is no longer alive or available to measure, enter "D" under height

Notes

AVID Woody Seedling Datasheet

Plot #:	Date:	Recorders:

Location (Latitude/Longitude)	Vegetation Description	Percent Cover Estimation
	Ground and shrub cover (0-8 ft)	_____ %
Basal Area (optional):	Subcanopy (8-29 ft):	_____ %
	Canopy (> 30 ft):	_____ %

Is the plot enclosed or protected from deer? ☐ YES ☐ NO

Initial Measurement					Remeasure Date:		Remeasure Date:		Remeasure Date:	
Species	Tag #	Quadrant	Height (inches)	Flower Evidence (Y/N)	Height	Flower Evidence (Y/N)	Height	Flower Evidence (Y/N)	Height	Flower Evidence (Y/N)

continued from page 36

Initial Measurement					Remeasure Date:		Remeasure Date:		Remeasure Date:	
Species	Tag #	Quadrant	Height (inches)	Flower Evidence (Y/N)	Height	Flower Evidence (Y/N)	Height	Flower Evidence (Y/N)	Height	Flower Evidence (Y/N)

* If a plant is no longer alive or available to measure, enter "D" under height

Notes

Appendix 5. Ten-Tallest Method Protocol

Introduction

In the Ten-tallest method, you are selecting the ten tallest individuals of a species within a plot. Researchers with the USDA Forest Service developed the original protocol for this method. This method provides a simplistic way to monitor growth and browse damage of plant populations based on changing levels of deer impacts. This method is similar to the AVID method in that it can be used for woody seedlings or spring wildflowers, but it does not require you to tag individual plants.

Sampling woody species can occur at any time of the year, but the plot should be resampled at the same time each year. Spring wildflowers can only be sampled from mid-April to early June.

The following protocol was adapted from the original Ten-tallest protocol to fit Indiana forests. You can find the original protocol in the Additional Resources section.

Equipment and Materials

The following equipment is needed to conduct this method:

- Clipboard, writing utensils, and datasheets
- Permanent marker
- 18.5 ft string or rope
- Wire Pin Flags
- PVC pipe(s)
- Tape measure or yardstick
- Camera (optional)
- GPS (optional)

Field Procedures

SELECTING AN AREA

When selecting an area to conduct the Ten-tallest method, you should choose areas where the species you will monitor are abundant. Often, this can be in a canopy gap created by either natural tree mortality (windfall, disease, etc.), forest stand improvement, or timber harvest. You want to avoid the edges of forests or areas with heavy human traffic.

Be sure to sample different areas across your woodland as deer impacts and plant growth are not uniform across the entire woodland. Sampling multiple locations will ensure you account for the variations across your woodland.

SELECTING SPECIES

For this method, start by selecting 2-3 species. Tree seedlings are recommended; however, wildflowers will also work. The species must be abundant where you plan to sample as you will need to find at least 10 individuals of each species in a plot but you can monitor multiple species in each plot. Monitor both plant species that are preferred by deer and those that might commonly be avoided. This will give you a clearer picture of deer impact by helping you understand both what and how much deer are browsing. Below are a few examples of indicator species you can use in Indiana.

Preferred Woody Plants	Low Preference or Avoided Woody Plants
Sugar maple White ash Oak Hackberry	American beech Pawpaw Spicebush Coralberry

Preferred Wildflowers	Low Preference or Avoided Wildflowers
Sweet cicely Trillium Canada mayflower Solomon's seal	Jack-in-the-pulpit Garlic mustard Wild ginger Mayapple

PLOT SETUP

Plot setup and sampling are most efficient if it is completed with a partner. You will be sampling a 1,076 square foot (100 square meters) circular plot. Once you have found a location with a sufficient number of individuals of your target species, mark the center of the plot by placing your PVC pipe into the ground. Write the plot number and species monitored on the stake with a permanent marker.

FIGURE 24. A PVC pipe with tag and the number of the plot written on it can be used to mark the center of the plot.

Next, take your 18.5-foot string and tie it to your center stake. Then run the string out in each cardinal direction and place a flag at the end to denote the boundary of your plot. When you have finished setting up the plot, return to the center of the plot to record the date, observers, GPS coordinates, and the approximate number of individuals in the plot. If you select a species categorized as a forb or a shrub, you will also need to record the actual number of individuals in the plot. You can use a compass and handheld GPS or a smartphone to determine your plot's cardinal directions and GPS location.

PLOT SAMPLING

When you begin sampling the plot, look around to pick out the individuals of the target species you believe are the 10 tallest in the plot. Be sure you are not measuring plants taller than 6 feet because these are not reachable by deer. Start measuring the heights of the individuals you believe are the ten tallest in no particular order. Mark plants you have measured by laying flagging tape over them. This will help you remember which plants you have measured. You should also indicate whether or not deer have browsed each plant.

After you have measured the individuals of a species you think are the 10 tallest, you should look for individuals in the plot that may be taller than the shortest one you measured. If you find a taller individual, you can erase the data for the shortest individual on your datasheet and measure the taller individual. Continue this until you have identified the 10 tallest individuals in the plot.

After completing a plot for one species, repeat the process for the rest of the target species in the plot. When you complete each plot remove the flagging from the plants but leave the flags and center stake so you can find the plot the following year.

PLOT RESAMPLING

Resampling of your plots should be done every year at the same time of year as the first sampling. Resampling should be done in the same way as your initial measurements. Since the 10 tallest individuals in the plot were not tagged the first year, you may be measuring different individuals in each plot. This is okay as you are looking for changes in the average height of the 10 tallest individuals in each plot, not individual plants. Resampling should happen for at least 3 to 5 years to give you a trend in how deer are impacting your woodland.

Data Entry and Interpretation

Data collected can be entered into a spreadsheet, such as a Microsoft Excel workbook or Google Sheet. Woodland owners can use the data to monitor the growth, browse damage, and overall deer impact to their forests. Over several years, this information can be interpreted as an indication of changing levels of browse impact.

Once you have the data entered, you can visualize the data in tables or graphs. Looking at the average height of the 10 tallest individuals in the plot will allow you to compare how the average height changes over time. If the average height increases over time, it is an indication deer impact is decreasing. If the average height is decreasing, it is an indication deer impact is increasing.

You can also use this method to monitor deer impact before and after taking a management action such as increasing doe harvest or implementing habitat management. Comparing the results of this method before and after your management will allow you to better understand if the management is working.

Additional Resources

- Rawinski, 2018. Monitoring white-tailed deer impacts: the ten-tallest method. USDA For. Serv., Northeastern Area State and Private Forestry, Durham, NH. 13pp. https://flnps.org/sites/default/files/newsletters/Ten-tallest%20Method%20Instructions%202018.pdf

Ten-Tallest Datasheet

Site Name:

Site location	State:	County:	City:
Plot Location	Latitude:	Longitude:	

Plot Number:

Species Monitored:

Number of Individuals in plot: ☐ 10 - 20 ☐ 21-50 ☐ 51-100 ☐ 100+

Actual Count:

Observer(s):			**Observer(s):**			**Observer(s):**			**Observer(s):**		
Date:			**Date:**			**Date:**			**Date:**		
Plant ID	Height (in)	Browse (Y/N)	Plant ID	Height (in)	Browse (Y/N)	Plant ID	Height (in)	Browse (Y/N)	Plant ID	Height (in)	Browse (Y/N)
1			1			1			1		
2			2			2			2		
3			3			3			3		
4			4			4			4		
5			5			5			5		
6			6			6			6		
7			7			7			7		
8			8			8			8		
9			9			9			9		
10			10			10			10		

Notes

Appendix 6. Stump Sprout Protocol

Introduction

Stump sprouts offer an effective tool to monitor deer impacts on a woodland. This method was developed by researchers with the USDA Forest Service in Pennsylvania (Royo et al. 2016), but has also been tested in Indiana. In this method, small trees of certain woody indicator species are cut down and left to develop stump sprouts. Half of the stumps are protected from deer browse with metal wire cages, and half are left unprotected. As new growth emerges from the stumps (i.e., stump sprouts), the height of the tallest sprout is measured. The impact of deer can be gauged by comparing the height of protected and unprotected stump sprouts. Stump sprouts of hackberry and sugar maple were tested in Indiana and were effective in monitoring deer impact.

Equipment and Materials

The following equipment is required to implement the stump sprout method:

- Chainsaw and proper personal protective equipment (PPE) (if stumps are not already created)
- GPS or phone to mark stump locations
- DBH tape
- Measuring tape
- Metal stakes with ID tags
- Metal Pin flags
- Flagging
- Clipboard, writing utensils, and datasheets

Field Procedures

The field procedures for the stump sprout methods includes cutting stems of selected tree species, building and placing exclusion cages, and measuring stump sprout height of protected and unprotected species. Initially there can be a considerable amount of work involved with this method. However, if some trees are already being cut as a part of on-going forest stand improvement (such as midstory removal), cages can be placed on those stumps. Additionally, the unprotected stump sprouts serve as an additional food source for wildlife species.

SELECTING AND CUTTING INDIVIDUAL TREES

Hackberry and sugar maple make ideal target species for this method because they are often abundant and resprout readily. You can cut stems in the winter through early summer (June). Select individual stems that are 2 to 6 inches in DBH. You need to select at least 20 (preferably 30) stems of each species to cut over a 100-yard by 100-yard area. Cut the stem with a chainsaw as low as possible to the ground. Place a metal stake with a metal ID tag and a pin flag within 1-2 feet of each stump. Write the tree species and ID number on the ID tag and pin flag. You will need to return to these stumps later so record the GPS location of each stump on the datasheet.

FIGURE 25. Small trees like this hackberry can be cut close to the ground and allowed to regrow to create stump sprouts. Pin flags and metal stakes with tags should be used to mark the location and ID of each stump.

FIGURE 26. Cages should be placed around half of the stumps to protect the sprouts from browse.

PLACING EXCLUSION CAGES ON STUMPS

Exclosure cages are used to protect some of the stump sprouts from deer browse. Exclosure cages should be made of metal (e.g., chicken wire, welded wire, or similar fencing) and should be four feet tall by three feet in diameter. Exclusion cages should be placed on half of the stumps. Place metal stakes in the ground to hold the exclusion cages in place. Place a piece of flagging on the cage to aid in relocating the cage.

FIGURE 27. The height of protected (left) and unprotected (right) stump sprouts should be measured in the late summer.

MEASURING STUMP SPROUT HEIGHTS

Measure the stump sprouts in the later summer (August-September) the year after creating the stumps. Find the tallest stump sprout on each stump and measure its height from the ground. Record the height in inches on the datasheet and mark if the stump was protected (covered by a cage) or unprotected. For the unprotected stumps, record if the stump was browsed. If a stump died or did not resprout, indicate as such on the datasheet. Add more flagging to the cages or additional pin flags to mark stumps if needed.

REMEASURING STUMP SPROUT HEIGHTS

Remeasure stump sprout heights in August or September of the second growing season (and subsequent years) after creating the stumps. Follow the same procedure for measuring stump sprouts as before. Stump sprouts can be remeasured for as long as the sprouts are alive (several years). Additional stumps may need to be created if stems do not resprout or as resprouts die in subsequent years.

Data Entry and Interpretation

Data collected from stump sprouts can be entered into a spreadsheet using a program such as Microsoft Excel or Google Sheets. You can then calculate the average height of the tallest sprout of protected and unprotected stumps. Compare these heights to determine the impact deer are having on your woodland. The table below provides information on how to interpret browse rates from the stump sprout method.

Deer Impact Monitoring Method	*High Browse Intensity*	*Medium Browsing Intensity*	*Low Browsing Intensity*
Stump Sprout (% difference in protected and unprotected stump sprout height)	>49%	22-49%	<22%

Additional Resources

- Royo, A., D. W. Kramer, K. V. Miller, N. P. Nibbelink, and S. L. Stout. 2016. The canary in the coal mine: Sprouts as a rapid indicator of browse impact in managed forests. Ecological Indicators. 69: 269-275. 69:269–275.

Stump Sprouts Datasheet

Observers:	Date(s) of stump creation:	Property:
		Woodlot or Stand #:

					First Measurement Date		Remeasure Date		Remeasure Date	
Stump Number	Species	X Coordinates	Y Coordinates	Caged?	Height (in)[1]	Browsed?	Height (in)[1]	Browsed?	Height (in)[1]	Browsed?

[1] measure the height of the tallest sprout. Do not bend the sprout. If the stump did not resprout or there are no living sprouts, mark "D."

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					First Measurement		Remeasure		Remeasure	
					Date		Date		Date	
Stump Number	Species	X Coordinates	Y Coordinates	Caged?	Height (in)[1]	Browsed?	Height (in)[1]	Browsed?	Height (in)[1]	Browsed?
[1] measure the height of the tallest sprout. Do not bend the sprout. If the stump did not resprout or there are no living sprouts, mark "D."					Percent of uncaged sprouts browsed		Percent of uncaged sprouts browsed		Percent of uncaged sprouts browsed	
					Avg height of caged stumps		Avg height of caged stumps		Avg height of caged stumps	
					Avg height of uncaged stumps		Avg height of uncaged stumps		Avg height of uncaged stumps	
					Caged-uncaged height		Caged-uncaged height		Caged-uncaged height	

Appendix 7. Oak Sentinel Method Protocol

Introduction

Researchers at Cornell University developed the oak sentinel method (Blossey et al. 2019). In this method, red oak seedlings are planted within a woodland and half of those seedlings are protected from deer browse with fencing, either a deer exclosure or metal wire cages. The height of the oak seedlings (both protected and unprotected) and the browse rate (percent of seedlings browsed) of unprotected seedlings are measured at the same time each year. Deer impact is gauged by looking at the difference in height between the protected and unprotected seedlings and determining the browse rate and growth rate of unprotected seedlings.

When tested on Indiana woodlands, the browse rate of unprotected seedlings was the best metric for monitoring deer impacts. This means the oak sentinel method can be used in Indiana just by planting unprotected seedlings and comparing browse rates, eliminating the need to create exclosures which are expensive and time consuming.

Equipment and Materials

The following equipment and materials are needed to conduct the oak sentinel method.

- 10-50 red oak seedlings
- Dibble bar, planting spade, or drill auger
- GPS or smartphone
- Flagging and/or pin flags
- Metal stake and ID tag
- Clipboard, datasheet, and writing utensils

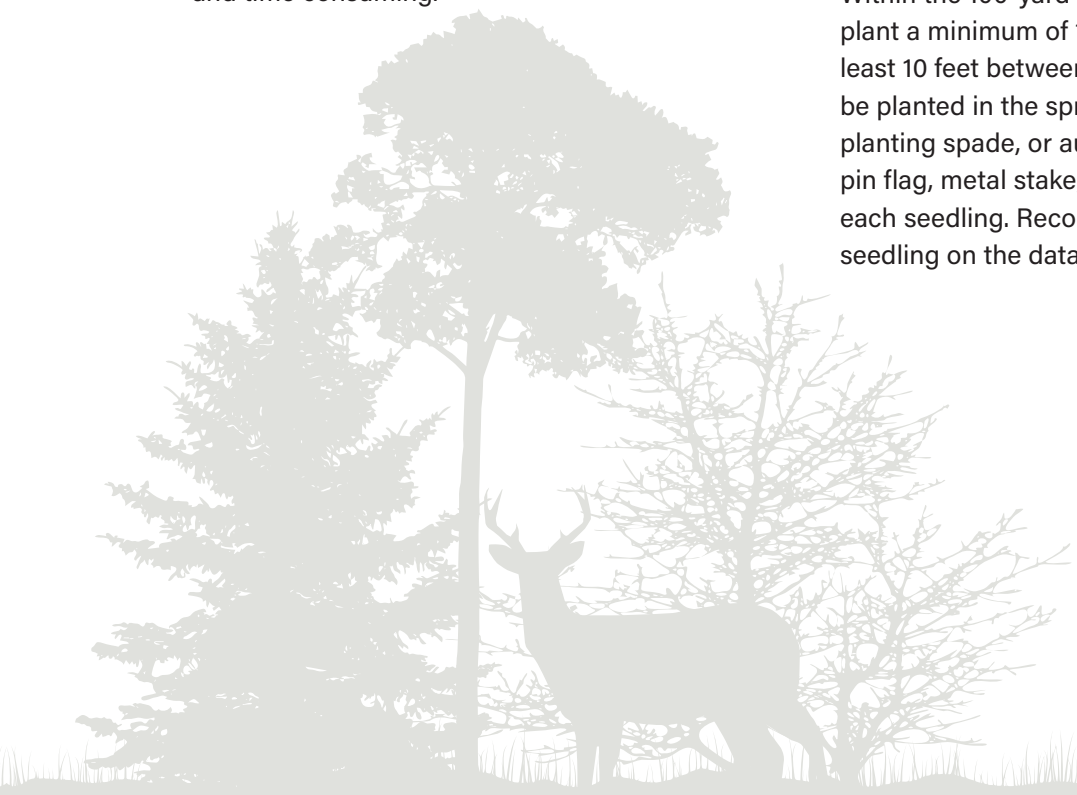
Field Procedures

IDENTIFYING A PLANTING SITE

Within your woodland, find suitable locations to plant trees, such as areas free of debris and away from large boulders, fallen trees, or steep slopes. You will be planting the red oak seedlings over a 100-yard by 100-yard area in your woodlot.

PLANTING OAK SEEDLINGS

Within the 100-yard by 100-yard planting area, plant a minimum of 10 red oak seedlings with at least 10 feet between seedlings. Seedlings should be planted in the spring using a dibble bar, tree planting spade, or auger bit on a drill. Place a pin flag, metal stake, and ID tag within 1-2 feet of each seedling. Record the GPS location of each seedling on the datasheet.



SAMPLING

In August or September of the first growing season, find each seedling and determine if the seedling was browsed by a deer. Record the presence or absence of browse for each seedling on the datasheet. Mark on the datasheet if the seedling was dead, missing, or could not be located. Place new pin flags or metal stakes at each tree if necessary.

RESAMPLING

The area can be revisited and resampled (checked for browse) in the late summer (August or September) each year as long as the seedlings remain alive and within the reach of deer (less than 6 feet tall). Seedlings should be resampled using the same techniques as the initial sampling. Additional seedlings can be planted on the site as needed.

Data Entry and Interpretation

Data can be entered in a spreadsheet using programs such as Microsoft Excel or Google Sheets. You can calculate the percent of seedlings browsed each year (browse rate) by dividing the number of browsed seedlings by the total number of seedlings. The browse rate of these red oak seedlings correlates to deer impact levels in woodlands. The table below provides information on how to interpret browse rates from the oak sentinel method. The data in the table comes from a recent research project conducted by Purdue University and the Indiana DNR.

Deer Impact Monitoring Method	*High Browse Intensity*	*Medium Browsing Intensity*	*Low Browsing Intensity*
Oak Sentinel (% of red oak seedlings browsed	>57%	29-57%	0-28%

Additional Resources

- Blossey, B., P. Curtis, J. Boulanger, and A. Dávalos. 2019. Red oak seedlings as indicators of deer browse pressure: Gauging the outcome of different white-tailed deer management approaches. Ecology and Evolution 9:13085–13103.

Oak Sentinel Datasheet

Observers:	Date of seedling planting	Property:
Species planted		Woodlot or Stand #:

			First sampling	Resampling	Resampling	Resampling	Resampling
			Date:	Date:	Date:	Date:	Date:
Seedling number	X Coordinates	Y Coordinates	Browsed?	Browsed?	Browsed?	Browsed?	Browsed?
Percent Browsed							

Notes

Notes

Find out more at
THE EDUCATION STORE
edustore.purdue.edu

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