REGIONAL ASSESSMENT OF BROWSE AND ITS IMPACTS ON FOREST VEGETATION

Regional Assessment of Browse and its Impacts on Forest Vegetation

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Executive Summary

The benefits, drawbacks, specific applications, and costs associated with different deer browse assessment methods are not well documented across northeastern forests. With many existing methods to monitor deer browse (AVID, ten-tallest, twig-aging, oak/maple sentinel, FIA, exclosures, etc.), it can be difficult to select a single method to use. Additionally, the use of different methods in different locations and contexts means that findings across regions and agencies cannot be easily compared.

In 2021 the Forest Ecosystem Monitoring Cooperative (FEMC) initiated a regional scoping project to address this issue, focused on identifying the most complete and accurate methods for measuring deer browse that could be undertaken by researchers, land managers, and forest stewards. The project also aimed to develop a regional database of protocols and data that forest researchers, practitioners, and decision-makers can use to understand browse impact patterns across the region.

The first steps of the project included a comprehensive literature review of browse methods, establishing and field testing a combination of methods, and tracking time and effort needed to implement each method. We identified a field protocol that pulled from the AVID, 10-tallest, twig-aging, and maple sentinel protocols and fit it into our existing regional forest health monitoring plot formations (based upon the FIA protocol). After a second field season of sampling in 2023 to evaluate the feasibility of the protocol and data, we did find issues with variability in survival of small seedlings and our ability to track individual seedlings year to year. However, we found that overall the twig aging, 10-tallest, and sentinel methods are all low cost, easy to implement protocols that can be adjusted for smaller scale use depending on environmental factors such as deer pressure and species composition. The AVID protocol is also an accessible and well-tested protocol, but when planning to track individual young seedlings at larger scales, managers and researchers should consider materials and costs, as resource needs for this protocol are high. Due to time and monetary constraints, the FEMC did not test methods using exclosures, but these methods are well studied as tools to monitor deer browse.

In conclusion, the FEMC's initiative has provided valuable insights into the feasibility and practicality of various deer browse assessment methods, laying the groundwork for informed decision-making in the management and preservation of northeastern forest ecosystems.

Introduction

In 2019, the Forest Ecosystem Monitoring Cooperative (FEMC) developed a regional portal to facilitate exploration of research and management efforts related to forest regeneration in the Northeast. This project, REGEN: The Northeastern Forest Regeneration Data Network, focused on aggregating regeneration-related datasets, including those documenting density, mortality and biomass of seedlings and saplings. This process revealed that information about the effects of deer browse on regeneration is lacking across most of the region. The intensity of browse is considered an important determinant of forest regeneration, but there are limited and disparate resources on the best methods to accurately assess the direct impacts. To address this gap, the FEMC undertook a regional project to identify and test the most complete and effective methods for assessing deer browse.

At the 2021 FEMC Annual Conference, Sarah Garlick (Hubbard Brook Research Forest) and Pia Ruisi-Besares (FEMC) led a working session to discuss the issue of assessing the impacts of browse on forest vegetation in the Northeast and the need for support in choosing between the many available methods. Participants emphasized the need for a simple, non-subjective method that can be implemented across the region, but recognized that a single method might not be feasible across different habitats and regions. To address this challenge, the group recommended choosing an assessment method based on a larger question that the agency or group is looking to answer. Additionally, participants affirmed that a browse impact assessment method should not only focus on plant regeneration, but a protocol should also assess plant community composition, forest health, and other ecological health metrics to determine whether and how these factors may play a role. This collaborative effort highlighted the necessity of not only addressing the gaps in current knowledge about deer browse effects but also establishing practical methods for comprehensive and regionally applicable assessments.

In the summers of 2022 and 2023, the FEMC implemented a browse survey into our existing forest health plot network to monitor the impact of browse on woody seedlings using components of the AVID (Assessing Vegetation Impacts from Deer), ten-tallest, twig aging, and sentinel indicator methods. Our goal for this project was to identify widely used browse survey methods, compare across protocols, and field test these methods on a regional scale using a combined protocol that would work best on our existing Forest Health FIA style plots for continued monitoring. Comparing these established methods, we began a field campaign using our already established Forest Health Monitoring (FHM) plot network to establish a browse survey that would be feasible to measure at a regional scale.

Browse Assessment Methods Summary

Several methods exist to monitor deer browse, each with their own benefits and drawbacks. Considerations when deciding which method to use include financial cost, plant identification skill of the data collector, time available for data collection, and specificity of information needed. The FEMC conducted a literature review to identify current deer browse impact assessment methods and determine which method is appropriate for different goals. The following methods were reviewed: AVID, FIA (Forest Inventory and Analysis deer impact index), forest survey, sentinel indicator (Indicator Species: Oaks, Multiple Species, & Trillium), ten-tallest, and twig aging.

Assessing Vegetation Impacts from Deer (AVID)

The full AVID method (Curtis et al. 2021) requires marking individual seedlings (or herbaceous plants) in four to six 6-ft radius plots containing 20-30 total seedlings of a target species. These sites are visited annually to monitor tagged individuals for browse damage. When monitoring herbaceous plants, plots are established to track spring ephemerals that are commonly browsed by deer. The height of the plant, whether it is/has/will flower this season, and browse damage is recorded. When monitoring woody plants, established plots should have five or more seedlings/saplings of a species of interest, ideally with two species of interest present on the same plot (one being highly preferred by deer and one that is less preferred). Individuals selected for measuring should be no taller than 5 feet. Browse presence and height are recorded for each seedling/sapling within the plot each year until they become taller than 5 feet. Since plots are only measured once per year, this method is fairly comprehensive without requiring a heavy time commitment. However, tracking and tagging individual plants over time is required, and can be expensive depending on the scale of the experiment.

Ten-Tallest

The ten-tallest method (Rawinski 2018) requires measuring the ten tallest seedlings of a target species within an 18.5-ft radius (100 sq meter) plot, and is designed to be easy to implement and cost efficient. Plots can be established to monitor any specific species depending on management goals. This method is most effective when paired with exclosures to act as a control, but like other methods, can be used without exclosures if time or cost is a limiting factor. The primary metric used to quantify herbivory is sapling height, specifically assessing whether saplings can grow beyond the reach of deer, which is typically defined as exceeding 5 feet.

Plots are established that contain at least ten individuals of a species of interest. Researchers should establish some plots to monitor species that are preferred by deer and some focusing on species that are less preferred. Heights of the ten tallest individuals of the plot's focal species are measured (note: only saplings that are less than five feet tall are measured). Then stems are examined for any evidence of browse damage, which is recorded as present or absent. There is also an alternate plotless method in which individuals of certain species like spicebush, witch hazel, and winterberry are tagged and monitored for the development of root sprouts, and the height of the tallest root sprout is measured each year.

Sentinel Indicator

The sentinel indicator method uses a specific species as an indicator for deer browse pressure and measures seedlings over time for signs of browse. Exclosures are recommended for comparison with this method but are not required. Heights are often also measured to quantify browse impacts over time. This method is useful in areas with high preference browse species like oak and maple and is relatively adaptable to different goals and resources. This method can be limiting when trying to expand to a larger sampling area where species ranges and abundance differ.

This method is a generalization of method employed in a study in Leopold Reserve near Baraboo, Wisconsin and which used oaks as indicators; that version is typically referred to as the “oak sentinel method” (Winner & Waller 2017).

Twig Aging

The twig aging method (Waller 2018, Waller et al. 2017) measures time instead of measuring size, browse, or growth. This method uses terminal bud-scale scars to age twigs on a sample of deciduous tree seedlings of intermediate palatability, such as maples. Where deer browse is heavy, twigs that sprout following browsing may only grow for 1 to 3 years before being browsed again. Twig ages thus directly measure the race between growth and consumption that will determine seedling survival. Data for each seedling can be collected quickly (1-2 individuals per minute), so large sets of data can be generated at each plot.

For this method, 40-60 seedlings/saplings are recommended per plot. Transects are typically used, but circular plots can also be utilized. In the initial study employing this method, the researchers walked a loose, spontaneous transect through a patch of woods north of Marquette, Michigan in the Huron Mountain Club (Waller et al. 2017). They sampled saplings of the same species spaced at least one meter apart. Counting bud scars back from twig tips to the point where the twig branches from a browsed parent twig allowed the researchers to estimate the minimum “time between bites” for that seedling.

The effectiveness of this method was tested by assessing and comparing the twig ages both inside and outside of an exclosure that had been established for several years, effectively eliminating herbivory within its boundaries. The mean twig age was consistently higher inside the enclosure than outside of it. The mean twig age of different species of maple also seemed to track the palatability of each species (Waller et al. 2017). The study's authors suggest that twig age may reflect browse pressure more accurately than just measuring sapling height.

FIA (Forest Inventory and Analysis deer impact index)

To assess deer browse impact the US Department of Agriculture Forest Service updated the Forest Inventory and Analysis (FIA) protocol to include a method to monitor seedlings and indicator plants in the Midwest and Northeast. FIA inventory plots consist of four 7.32-m fixed radius subplots for a total plot area of approximately 0.07 ha where standing tree and site attributes are measured. All live and standing dead trees with a diameter at breast height (DBH) of at least 12.7 cm are measured on these subplots. Within each subplot, a 2.07-m microplot is established, where saplings (live trees with a DBH between 2.5 and 12.7 cm) and seedlings (live conifers and hardwoods that are at least 15.2 and 30.5 cm in height, respectively, with a DBH ≤ 2.5 cm) are measured. Browse presence is recorded at the general plot level on an observational scale of 1-5, with 1 being no browse (i.e., within an exclosure) and 5 being high browse impact observed. Seedling and sapling abundance and diversity can be combined with this metric to draw conclusions about the impact of browse on forest species composition and regeneration (e.g. Russell et al. 2017).

Of note, one study compared the effectiveness of the FIA browse protocol vs. measurements/counts of seedlings and wildflowers (Begley-Miller et al. 2018). This study found that the FIA 1-5 scale ranking system was the least reliable method of assessing browse impact at a site, while data that relied on seedling/herbaceous plant identification and seedling/herbaceous plant counts were far more reliable and consistent.

Forest Survey

Forest surveying is a general term used to describe methods in which all vegetation—as opposed to a specific target species—is surveyed in the designated area. A deer exclosure may be included in the survey but is not a requirement. These surveys may be designed to measure impacts by deer on herbaceous plants or woody species. Forest survey approaches typically establish several plots, and all plants meeting the study's criteria (e.g. seedlings, saplings, and/or herbaceous plants, or all plants) within the plots are counted. These data may be combined with known deer abundance data (e.g. Kain et al. 2011, Rutherford & Schmitz 2010), and/or observance of browse on plants (e.g. Collard et al. 2010). When exclosures are used, vegetation must be allowed to grow for a few years before plots are established within and outside the exclosures and plants are counted (e.g. Collard et al. 2010).

Choosing a method

The abundance of available methods to assess deer browse presence and impact of deer browse on forests can present a challenge for managers and researchers who may be unsure which method is best for their project or study. Here we provide a decision tree as a tool to guide these decisions (Figure 1).

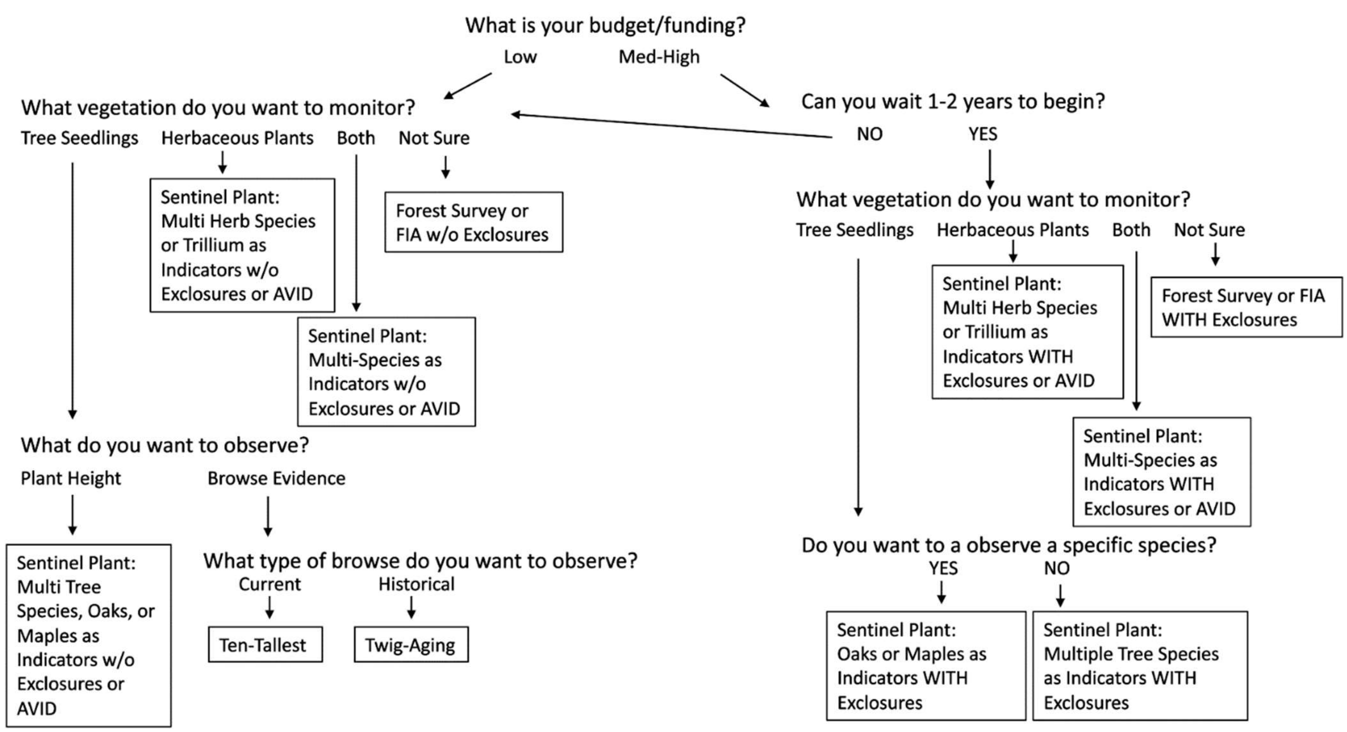

Figure 1. Browse Assessment Methods Decision Tree

FEMC Browse Assessment Trial

Field Methods

Adapting methods to fit within the FEMC's existing Forest Health Monitoring (FHM) plot network and microplot size, we combined components of the AVID, ten-tallest, sentinel indicator, and twig aging protocols so we could compare common methods during the 2022 and 2023 field season (June to September). In addition to collecting browse data using the FIA protocol at each plot, we also used metal tags and wire stakes to mark the eight tallest red maple seedings present in each microplot for a total of at least 20-30 seedlings/saplings per plot area. For each seedling we also recorded azimuth and distance from microplot center as an alternative way to locate each seedling in the future. Each seedling was marked for browse presence, height, and twig age (see Appendix C for an example datasheet). We did not include exclosures in our methods due to budgetary and time constraints.

Establishing Plots

We used the microplots from our existing FHM plots located in seven northeastern states (CT, MA, ME, NH, NY, NY, RI, and VT) to conduct this survey. Alternatives to this approach could include establishing larger radius plots (18-ft radius) or using transects. Reflecting plot styles of each state, the microplots we used had a 6-ft (nested style) radius for Connecticut, Maine, Massachusetts, and New York, and 6.8-ft (FIA Style) for New Hampshire, Rhode Island, and Vermont (Figure 2).

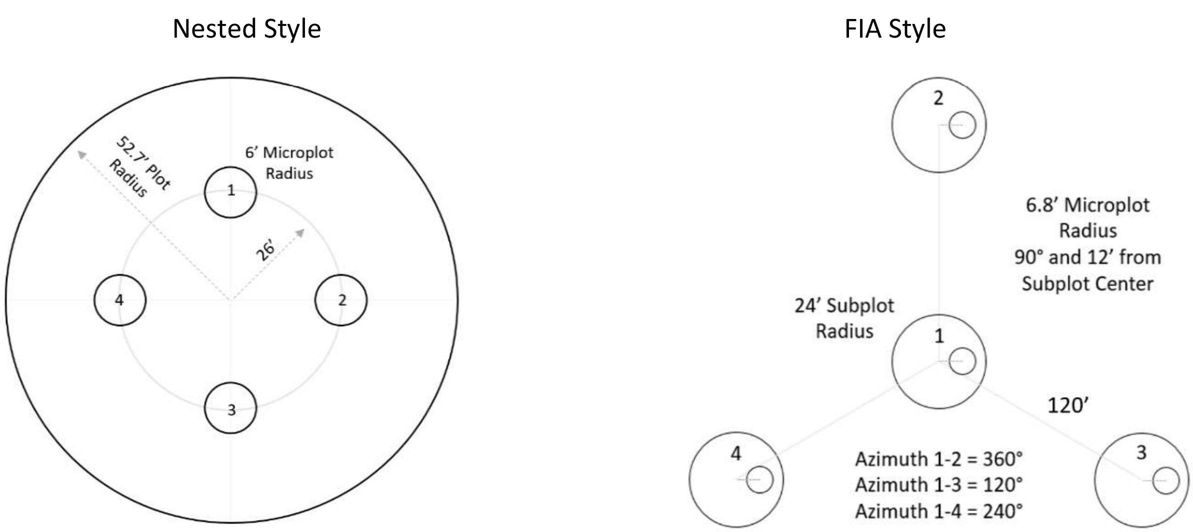

Figure 2. Layout of Nested Style plots (left; MA DCR 2014) and FIA Style plots (right; Tallent-Hasell 1994) showing the overstory plot and four regeneration microplots (smaller circles within) for each plot layout style.

Choosing a Target Species

Following the AVID and the sentinel indictor protocols, we identified microplots with five or more target species seedlings; for this project, we chose red maple (*Acer rubrum*) as our target species because red maple is preferred by white-tailed deer and has abundant seedling counts across all participating states (Appendix A). As described previously, a maximum of eight tallest red maple seedlings were then marked (i.e., if there were more than eight red maple seedlings, only the eight tallest were marked). The large geographic scope of our program was a limiting factor when choosing a target species. At smaller state and local scales, different higher-preference species could be used as indicators.

Field Protocol

Marking, Counting, and Aging Seedlings

- Locate FHM microplot and flag border using a 6' or 6.8' long PVC stick or tape measure, depending on plot type (Figure 2)
- Begin stopwatch (to record time/effort)
- Recorder will stand in microplot center with compass and observer will locate and measure seedlings and saplings with tape or ruler
- Locate the eight tallest red maple seedlings in the plot and mark them with pin flags. Saplings taller than five feet are not sampled. Do not record heights until you have identified the eight tallest red maple seedlings. If there are not eight, record however many are present.
- Once marked, begin recording height, azimuth, and distance from center of microplot for each seedling beginning at due north and moving clockwise
- Age each seedling according to the twig aging protocol below:
    - Choose a random twig with leaves on each seedling and then work backwards down the stem of that twig counting terminal bud scale scars to age that twig until you come to a "parent" twig that was browsed or come to the main stem (Figure 3)
    - Record this age under "Twig 1" on the data sheet as a number between 1 and 5. Do not try to count beyond five years
    - Next, choose a random second live terminal twig on the opposite side of the plant. Record its age under "Twig 2." Finally, check the sapling for any evidence that the sapling was (freshly) browsed this year
- Record Y or N under the "Browsed?" column
- Mark general seedling location and seedling ID on the circular map on the datasheet for future reference
- If marking seedlings with tags, place each tag at the base of each seedling and record tag # on datasheet
- Stop the stopwatch when completed and record how long it took to sample the microplot
- Repeat for the other 3 microplots

Figure 3. One year of growth pointed out on the twig of a red maple sapling from the Wisconsin Department of Natural Resources Twig-Age Method overview.

Cost and Effort

Financial Cost

Table 1. Financial cost of materials used extrapolated across our 196 plot regional network.

Item	Cost	Number used per plot	Total project cost	Notes
Metal tags	$0.14	32	$880	Can tag 6 plots with 200 tags ($27/box)
PVC 1"x24"	$5	4	$3500	For marking microplot centers. Four microplots for 196 plots. $5 for each 1"x24" PVC. Can reduce costs with bulk purchase.
Measuring tape	$5	1 (5 total)	$25	5 measuring tapes for a crew of 10
Compass	$10	1 (5 total)	$50	5 compasses for a crew of 10
TOTAL			**$4,455**	

Time

Time will vary depending on site access and driving time, but technicians took an average of one hour to complete each plot (4 microplots). Extra time for data entry should be considered if data will be digitized.

Considerations

Individual seedlings measured for browse assessments may not survive. We found seedling counts from our FEMC FHM plots reveal large variation for a given species from year to year (Figure 4). If one is planning to track individual seedlings from year to year, focusing on larger more established seedlings rather than younger seedlings may be prudent.

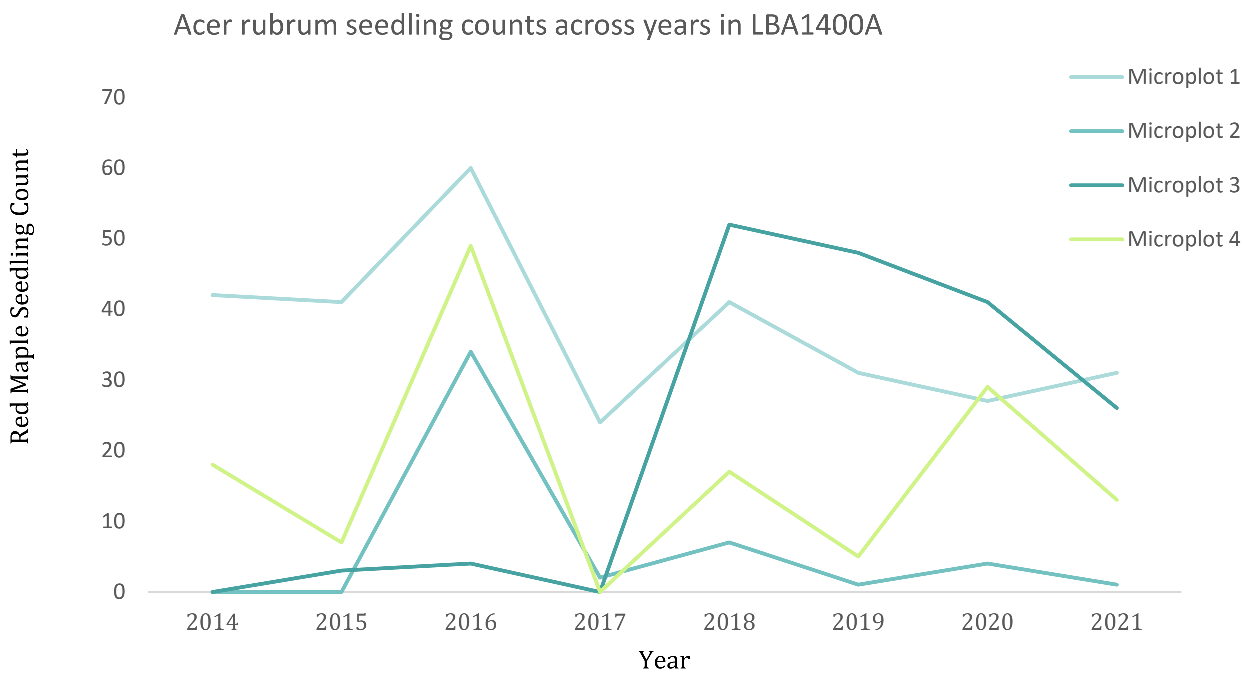

Figure 4. Red maple seedling counts from the four microplots within FEMC FHM plot LBA1400A in Sunderland, Vermont, from 2014-2021.

Additionally, tagging seedlings with metal tags (as in AVID) can become expensive at larger scales and it can be difficult to find tags in the second season under leaf litter and duff. Sod stakes and plastic tags may be a better option, but cost is still prohibitive when dealing with large quantities of seedlings in a large plot network. Marking azimuth and distance and drawing a map of seedlings was used as an alternative to tagging, and did help with locating buried tags, but was not always an effective solution for finding individual seedlings without tags. FEMC's crews had a ~50% success rate in locating tagged seedlings in the second field season.

Another consideration is that our student technicians did not always feel confident in their twig aging skills; if this method is to be used with less experienced technicians, additional efforts in training may be warranted.

Finally, we suggest considering the addition of wildflowers as indicator species, though this would require additional plant ID skills and extra training. It would also not be feasible on a regional scale, due to the large variability in species.

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Appendices

Appendix A – Deer browse assessment methods overview and cost/effort breakdown

Method	Exclosures?	Cost	Time	Plant ID Skill	Setup Requirements
AVID (Assessing Vegetation Impacts from Deer)[1,9,10]	No	Medium, requires PVC, stakes and plant tags	Low, can observe in Year 1 and continue onward	Low-Med, need to be able to ID to species level for browse sensitive tree seedlings or species/genus for herbaceous plants that are commonly found in area	Select plot locations where 5 target species are 6 inches to 3 feet tall for each of 6 plots. Assess area for ideal site (**15 minutes**). **Hammer** the **6 2ft PVC monuments** for each circular plot center or corners of plot to relocate the following year. Attach an **individually numbered tag** to each plant.
Deer Exclosures	Yes	High, depending on study size, number of plots and price/quality of materials to build exclosures and plots	Med-High, need to wait 1-2 years to observe within exclosures and continue observing for 3-5+ years for results	Med-High, need to ID to species or at least Genus of all woody and herbaceous plants	Fencing material: **4+ posts**, **4-8ft high fencing**, **zip ties**. Exclosure size can range from 2 sq meters to entire property. Control site(s): Monument (**2ft PVC** and **hammer**) circular plot center or corners of plot
FIA (Forest Inventory and Analysis deer impact index)[2,3]	No, but can be used	Med-High, depending on study size, number of plots and price/quality of materials to build exclosures and plots	Med-High, need to wait 1-2 years to observe within exclosures and continue observing for 3-5+ years for results. Can be low if not using exclosures.	Med-High, need to ID to species or at least Genus of all woody and herbaceous plants	Establish 4 6.8ft microplots using FIA layout (**30 minutes**). Monument the subplot centers and their corresponding microplot (**8 2ft PVC stakes** and **hammer**).
Forest Survey[4,5,6]	Yes	Med-High, depending on study size, number of plots and price/quality of materials to build exclosures and plots	Med-High, need to wait 1-2 years to observe within exclosures and continue observing for 3-5+ years for results	Med-High, need to ID to species or at least Genus of all woody and herbaceous plants	Most flexibility in habitat selection and plot set up, but requires most effort to collect data. If using exclosures: Fencing material: **4+ posts**, **4-8ft high fencing**, **zip ties**. Exclosure size can range from 2 sq meters to entire property. Survey all plants.
Multiple Species as Indicators[2,3,4,5,6]	No, but exclosures can and probably should be used	Low- Can be high dependent on use of exclosures	Low-Med/High, realistically can start right away, but also depends on use of exclosures, and needing 3-5+ for results	Low-Med, need to be able to ID to species level for browse sensitive tree seedlings or species/genus for herbaceous plants that are commonly found in area	Select plot locations where target species are 6 inches to 3 feet tall for each of the plots. Assess area for ideal site (**15 minutes**). **Hammer** the **2ft PVC monuments** for each circular plot center or corners of plot to relocate the following year. Attach an **individually numbered tag** to each plant. If exclosures are used: : **4+ posts**, **4-8ft high fencing**, **zip ties.**
Sentinel Indicator[7]	No, but exclosures can and probably should be used	Low-Med/High, dependent on use of exclosures	Low-Med/High, realistically can start right away, but also depends on use of exclosures, and needing 3-5+ for results	Low-Med, need to be able to ID to species level for oaks or other chosen plant species, possibly genus, that are commonly found in area	Same as indicators
Ten-tallest Method[8]	No	Low, requires PVC, stakes and plant tags	Low, can observe in Year 1 and continue onward	Low-Med, need to be able to ID to species level for browse sensitive tree seedlings are commonly found in area and are	Locate area with 20-30 seedlings or saplings 6”-3 feet tall. Establish plot layout (15-**30 minutes**). Monument the plot center (**2ft PVC stakes** and **hammer**). Count and measure ten tallest individuals.
Trillium as Indicators[9,10]	No, but exclosures can and probably should be used	Low-Med/High, dependent on use of exclosures	Low-Med/High, realistically can start right away, but also depends on use of exclosures, and needing 3-5+ for results		Same as indicators above in an area with enough trillium to count.
Twig Aging[11,12]	No	Low, requires plant tags and measuring tape	Low, can observe in Year 1 and continue onward	Med-High, need to be able to ID to species level for browse sensitive tree seedlings are commonly found in the area and be able to identify deer browse as well as browse scars.	Can be done in a plot or transect. Need 20-30 individuals to measure.

Appendix A references

[1]Curtis et al. 2021
[2]Russell et al. 2017
[3]Begley-Miller et al. 2018
[4]Kain et al. 2011
[5]Rutherford et al. 2010
[6]Collard et al. 2010
[7]Winnter & Waller
[8]Rawinski 2018
[9]Anderson 1994
[10]Koh et al. 2010
[11]Waller 2018
[12]Waller et al. 2017

APPENDIX B – TARGET SPECIES FOR FEMC FHM DEER BROWSE ASSESSMENT TRIAL

Table 2a. Potential target species for browse assessments on FEMC FHM plots.

Species	Deer Preference	Seedling Count per FEMC FHM Plot (Avg ± SD)
Red maple	High	82 ± 20
Sugar maple	High	71 ± 20
Balsam fir	None	60 ± 25
A. mountain-ash	None	49 ± 22
Striped maple	Low	41 ± 15
Eastern white pine	Low	40 ± 17

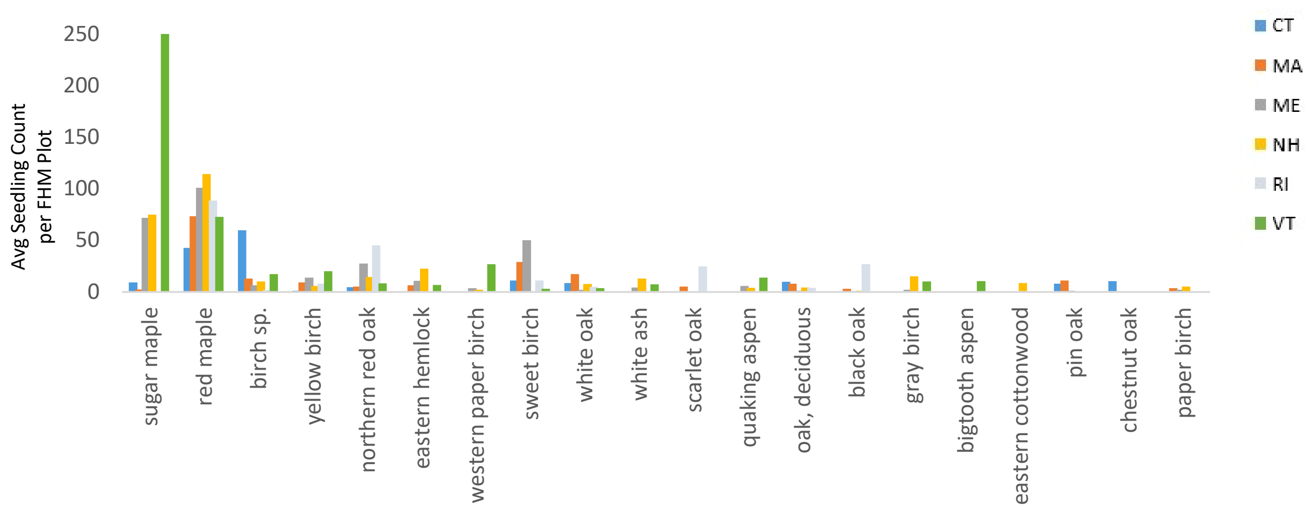

Figure 1a. High preference browse species present in FEMC FHM plots.

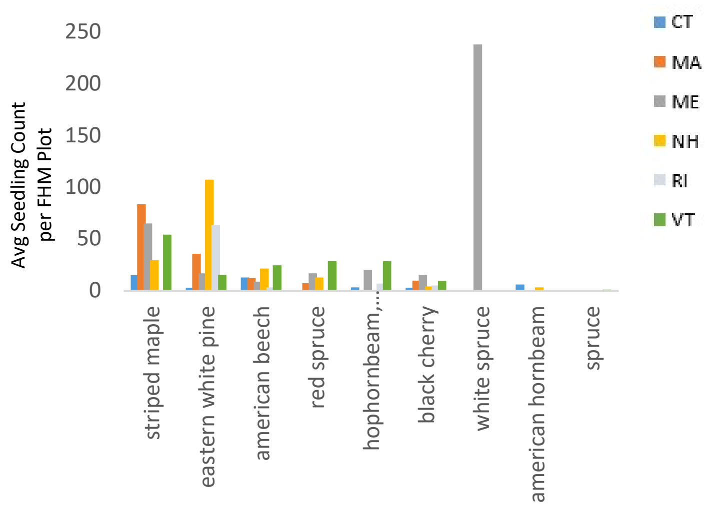

Figure 2a. Low preference browse species present in FEMC FHM plots.

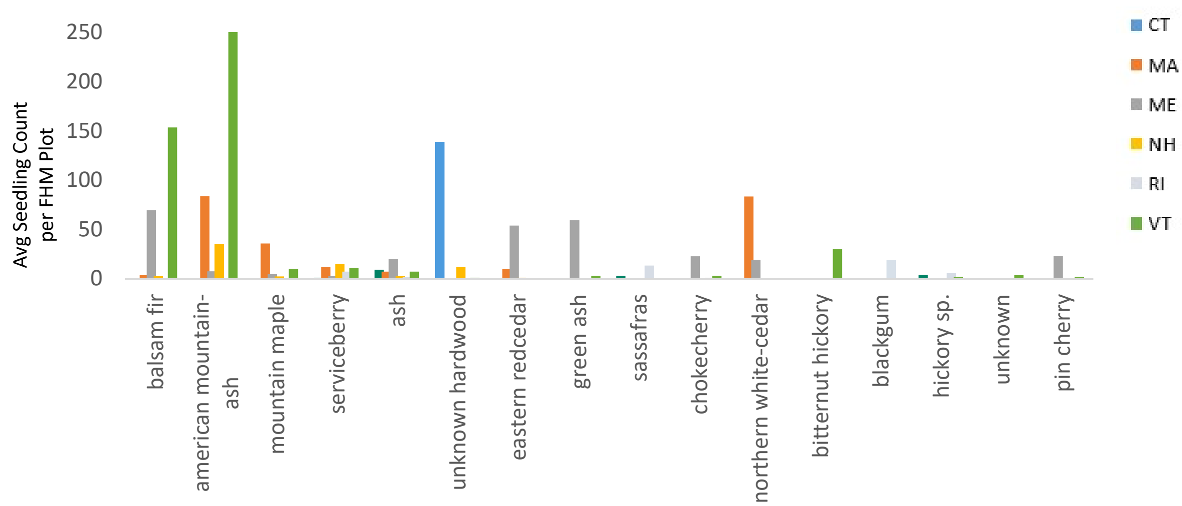

Figure 3a. Non-preference browse species present in FEMC FHM plots.

APPENDIX C – DATA SHEET

Sample datasheet

FEMC FHM Browse Field Sheet   Crew__________________   Date__________________

Plot ID:

SEEDLINGS

Microplot	Seedling ID	Species Code	Species	Height (cm)	Browsed (Y/N)	Distance	Azimuth
1	1						
1	2						
1	3						
1	4						
1	5						
1	6						
1	7						
1	8						

Notes:

Time to complete:______

Map of seedling location seedlings in Microplot 1:

Twig-Aging

Twig 1	Twig 2

Microplot	Seedling ID	Species Code	Species	Height (cm)	Browsed (Y/N)	Distance	Azimuth
2	9						
2	10						
2	11						
2	12						
2	13						
2	14						
2	15						
2	16						

Notes:

Time to complete:______

Map of seedling location seedlings in Microplot 2:

Twig-Aging

Twig 1	Twig 2

Microplot	Seedling ID	Species Code	Species	Height (cm)	Browsed (Y/N)	Distance	Azimuth
3	17						
3	18						
3	19						
3	20						
3	21						
3	22						
3	23						
3	24						

Notes:

Time to complete:______

Map of seedling location seedlings in Microplot 3:

Twig-Aging

Twig 1	Twig 2

Microplot	Seedling ID	Species Code	Species	Height (cm)	Browsed (Y/N)	Distance	Azimuth
4	25						
4	26						
4	27						
4	28						
4	29						
4	30						
4	31						
4	32						

Notes:

Time to complete:______

Map of seedling location seedlings in Microplot 4:

Twig-Aging

Twig 1	Twig 2

Heights for dead/missing seedlings

Code	Description
D	Dead
NR	Not relocated

Height examples Twig-aging