MEMORANDUM REGARDING RED OAK SEEDLINGS AND DEER BROWSE LEVELS

TO: Tom Crawford, City Administrator, Ann Arbor

FROM: Jacqueline Courteau, Ph.D., NatureWrite LLC

DATE: 25 September 2017

RE: **RED OAK "SENTINEL SEEDLING" METHOD: TARGET LEVEL FOR PROPORTION OF SEEDLINGS BROWSED**

No single ecological metric can fully represent a complex ecosystem, but managers need trackable and cost-effective metrics. The red oak experimental ("sentinel seedling") method being used in Ann Arbor provides a clear, easy-to-track metric (% of oak seedlings browsed) that can be used to compare across sites and years. Browsing on oaks is correlated with damage to wildflowers, but is easier to identify and assess. The method is less expensive than other methods; it has been published in the peer-reviewed literature (Blossey et al. 2017); and it is being studied in several locations in comparison with other deer browse monitoring methods.

Deer browsing on red oak seedlings will vary within and between sites depending on environmental factors (moisture, nutrients, light), amount of pedestrian traffic that affects when and where deer browse, other vegetation present (including suburban garden plants), past intensity and duration of deer browsing, etc. Deer browsing may vary from one year to the next depending on snow cover, spring rain, and other factors that affect the accessibility and quality of vegetation for deer to eat. However, the red oak sentinel seedling approach has been applied in natural areas in New York since 2010 (Blossey et al. 2017) and appears to offer a robust indicator of deer impacts on a range of ecological processes (such as tree regeneration) and species (sensitive plants and wildlife that rely on plants).

Challenges of this method are that because deer browse damage on any given species in any site may vary for many reasons as well as deer population (e.g., weather, availability of other food sources, etc.), it may take several years of trend data to distinguish natural variability from response to changing deer populations (when browse levels are on the low end).

Another challenge is in interpreting what the metric—proportion of seedlings browsed—indicates for management actions. What is the target? What is a tolerable level of browse, and what is a level beyond which deer populations should be managed? Blossey et al. (2014) suggests that oak regeneration is likely to decline when more than 15% of oak seedlings are browsed per year (3 of 20 planted seedlings). While tolerable browse rates may vary somewhat across sites, plant ecologist Don Waller (University of Wisconsin, pers. comm. 2016, 2017) notes this level is reasonable in view of his extensive research on deer exclosures and forest inventory data (e.g., Frerker, Sabo & Waller 2015; Bradshaw & Waller 2016). Tracking seedlings planted in Ann Arbor will, over time, allow us to assess whether local browse rates allow for successful oak regeneration.

In the meantime, lacking any research to the contrary, the 15% rate is the best available given existing literature on oak regeneration—and because in this method, red oaks are used not just for their own sake but also as "sentinels" or bio-indicators to suggest the likelihood of impacts on other species, including various wildflower species that are both more preferred by deer (more likely to be browsed) and less tolerant of deer browsing (more likely to be harmed).

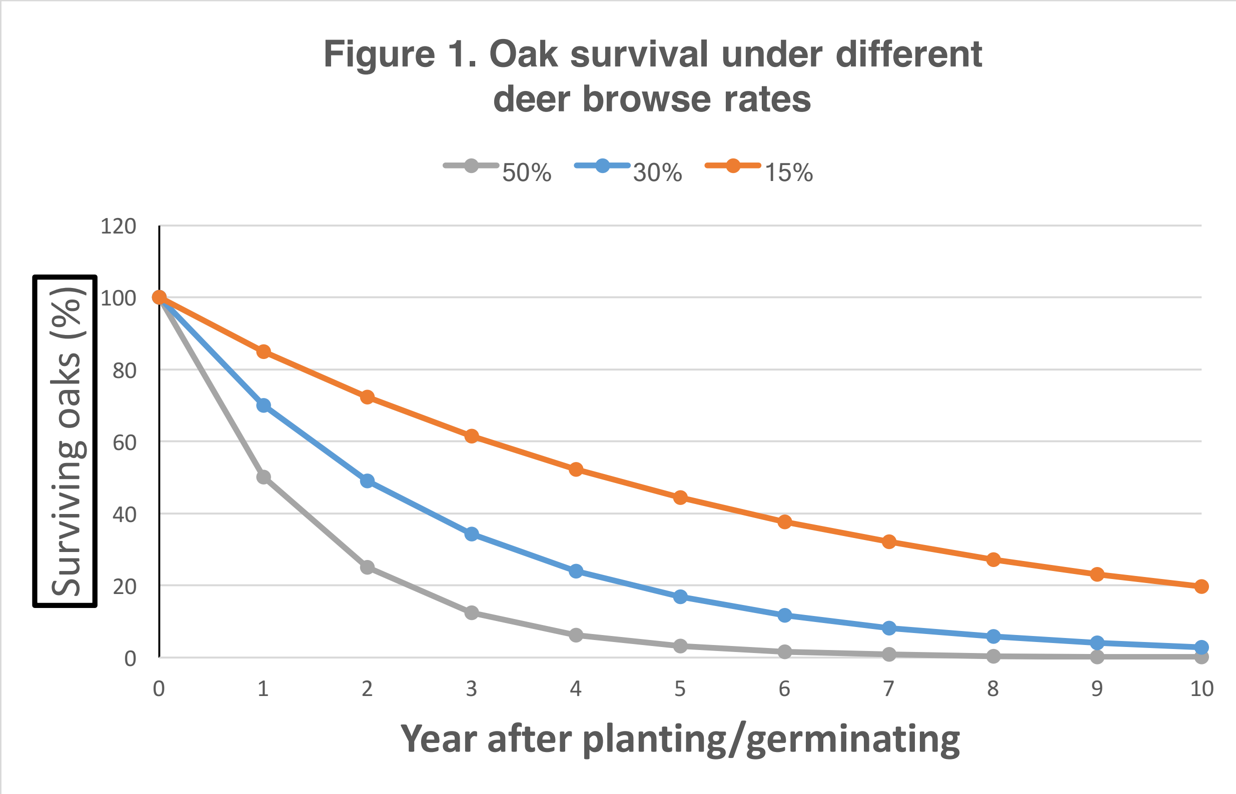
This memo reviews the 15% browse level as a target metric for vegetation damage, outlining in greater detail how that level was derived and its utility in considering impacts on oak regeneration, as well as correlations between that level of damage on oaks and damage on more sensitive wildflower species.

Oak regeneration and oak seedling demography

Long-term studies tracking deer browse damage on red oaks for 20–30+ years from germination to reproductive maturity have not been done that could experimentally demonstrate 15% as a "not-to-exceed" level of deer browsing. Blossey's 15% recommendation is inferred from growth rates and survival of browsed vs. unbrowsed oak seedlings over two to three years as published in peer-reviewed literature (Blossey et al. 2017).

Blossey has offered the following explanation of how the 15% level is deduced from experimentally obtained growth rates: "The 15% acceptable browse level is a best guess at present but 'reasonable' following common sense and logic:

1. There is no demographic model for red oaks--foresters have not developed one, consequently, there are no established models one could use. And there are none for white or chestnut oaks either.
2. Germinating oaks, or planted oaks that are a few months old, need to spend many years in the understory until they are well established and a light gap (in a forest situation) will allow them to grow.
3. Early oak grow rates are a few cm/year—more if the canopy is not fully closed. To get out of deer browse height (meaning the leader will not be browsed), oaks will need to be about 2 meters tall. That requires 1-2 decades [or more].
4. Being optimistic that growth rates may be higher, and other mortality factors can be ignored, at least a decade is needed for an oak under a forest canopy to be no longer in danger of being top-killed by deer.
5. Fig. 1 shows the survival rates of oaks under 3 different browse scenarios (15, 30, and 50%) over a decade. Neither 50%, nor 30% will allow sufficient oaks to reach an age and height. Even 15% browse rates cuts it close as the widely optimistic assumption is that there are no other mortality factors. This is clearly not the case as rodents, rabbits, insects, weather, poor soils, diseases etc. will over time take their toll. Lowering the threshold even further is probably ecologically prudent, but more data is needed to develop appropriate guidelines in different areas of the country with different fertility regimes, climates etc.
6. Although the method was indeed developed in a different state, the forest types are not fundamentally different, but are considered part of the same general "northern hardwoods forest" type in categories used by the U.S. Forest Service.
7. There is always a tremendous variation in oak browse rates, often in a single park based on deer travel pattern, other food sources, historic deer browse pressure, other plants, etc. No two parks will ever be totally alike" [but this is the best metric to date for cross-site comparisons that may differ in initial vegetation (pers. comm. 2017).]



Other lines of evidence show that deer herbivory reduces oak regeneration, but I could locate no published studies that look specifically at deer browse rates (% of seedlings browsed) on small red oak seedlings (those 1–5 years old and less than 50 cm tall.)

- One published study specifically looks at deer browse rates on red oaks is Reo & Carl 2012, which compared red oak regeneration in Wisconsin oak forests under tribal management vs. public (state forest), Deer densities were low on tribal land (2–3/km^2, or 5–8 deer/mile^2) vs. higher on state forests (>10/ km^2, or >26/ mile^2). Along with environmental parameters, they measured deer browse rates on red oak saplings, but **only on saplings taller than 50 cm (20").** Oak regeneration was successful in tribal areas where saplings were browsed at rates of around 45%, which might be interpreted to suggest that higher levels are acceptable.
    - However**, it is essential to remember that this browse rate is on LARGER seedlings than those used in red oak sentinel seedling method, so these figures are not comparable to the measurements obtained on first-year seedlings used in the Ann Arbor studies.**
    - Reo notes that "**the older and more robust that these young trees get, the more resilient they become to herbivory**. When these oaks are under 50 cm tall, there are so many aspects of the understory environment limiting their chance for survival. Herbivory is a big one, but you have many other risk factors to consider, so the threshold would be lower for smaller young trees (especially true seedlings) than for larger ones" (pers. comm. 2017).
    - Blossey has also noted that larger oak seedlings/saplings can tolerate more browse damage without mortality, but points out that small seedlings that are top-killed are unlikely to grow to sizes at which they can escape browse damage (pers. comm. 2017).

- After assessing a range of environmental factors in addition to browse levels, Reo & Karl found that "even given sufficient light, few seedlings survived beyond the browseline (i.e., low densities of seedlings >137 cm) on state forests where deer densities are high"—that is, above 26 deer per square mile.
- For reference, the 2017 deer count conducted by White Buffalo found 315 deer in 28 square miles of Ann Arbor, around 40% of which they consider deer habitat (11.2 square miles), suggesting a total of 28 deer per square mile; White Buffalo estimates that their observed count of 315 detects 50–60% of the actual population, so deer density is likely higher than 28 deer per square mile, perhaps up to 56 deer per square mile. (https://www.a2gov.org/departments/community-services/Documents/Final%20Combined%20Report%2010%20March%202017%20Ann Arbor%20FINAL.pdf)

- Bradshaw & Waller (2016) approached the issue from the opposite direction, looking at 30 years of periodic forest inventories from the U.S. Forest Service Forest Inventory & Analysis program, with data collected from randomly selected forest plots across northern Wisconsin, and correlating tree regeneration success of 11 tree species (including red oak) with deer population estimates from Wisconsin state Deer Management Units. Using large data sets (tens of thousands of trees) and a landscape scale, they found that abundance of red oak saplings (greater than 2.54 cm, 1 inch, in diameter at breast height) was significantly skewed lower as deer densities increased (from <5 to >20 deer per square kilometer, or <13 to >52 deer per square mile). Although red oak is considered to be of intermediate palatability to deer, its abundance has declined in patterns similar to more palatable species, such as birch. This large-scale study was focused on saplings rather than seedlings, and correlated tree seedling abundance with estimated deer populations, so there is no direct comparison with the browse proportion (% of seedlings browsed) yielded by the red oak sentinel seedling method. However, this study offers strong evidence for landscape-level deer impacts on red oak regeneration at densities similar to those found in Ann Arbor according to White Buffalo.

- My own research on other oaks provides evidence that small seedlings are vulnerable to mortality from browse damage—black oak seedlings up to 4 years and less than 25 cm (10 inches) tall had increased significant increases in mortality in the season following browse damage from any kind of browser, whether deer or small mammal (Courteau 2005).

- Other studies have also approached the issue from the perspective of deer population levels that allow persistence of diverse forest tree and wildflower species, but have not assessed specific browse levels on indicator species such as oaks. Nuttle et al. (2014) provides one overview:
  - "[A] landmark 10-year experiment investigating the effects of white-tailed deer (*Odocoileus virginianus*) in large enclosures ranging in density from 3.9 to 31.2 deer km^2 in northern hardwood forests of Pennsylvania, USA (Tilghman 1989; Horsley, Stout & deCalesta 2003) … established that deer densities over ca. 8 deer km^2 [21 deer/$mile^2$] caused dramatic shifts in vegetation during the stand initiation stage (the first 10 year) compared to lower densities. Specifically, higher densities of deer caused forests to be increasingly dominated by unpalatable tree species and understoreys to be increasingly dominated by ferns and grasses."

University of Pittsburgh scientist Walter Carson, who has conducted research suggesting that deer herbivory affects forest species diversity more than either invasive species and fire suppression (Carson et al. 2017) and that these effects can have long-lasting legacies (Pendergast et al. 2016), suggests that it will likely be hard to find more studies delineating precise browse levels linked to oak regeneration declines, because "academic scientists no longer find deer herbivory interesting" after many studies over many years have found clear deer impacts; researchers have moved on to study other issues (pers. comm. 2017).

In the absence of published data, demographic modeling can be used to predict how different levels of deer browse will affect red oak seedling generation. Although predictive models are only as good as the data available—including oak survival and growth rates, and links between deer browse and mortality or reduced growth—modeling can be used to explore consequences of different browse scenarios and growth assumptions. University of Michigan ecologists Deborah Goldberg and John Vandermeer have written one of the primary college textbooks in population ecology, and I will request their input in thinking about whether and how a demographic model for oaks could be used to explore implications of the 15% browse level compared to other levels (such as 30% or 50%).

Oaks as a "sentinel" or bio-indicator: what browse levels on oaks are correlated with damage to other species?

Apart from the significance of the 15% browse level for oak regeneration, the experimental red oak seedling approach is using oaks to indicate damage to other species as well. Existing studies suggest that damage on experimental oak seedlings is correlated with significant damage to various wildflower species as well as to overall diversity (Blossey et al. 2017, Nuzzo et al. 2017). Because deer impacts on particular areas depend on local factors and site context, general studies cannot calibrate precisely how this metric—proportion of experimental red oak seedlings browsed—will reflect damage to other species in any given site.

Blossey has gathered data (under review for publication) offering evidence that red oaks are a conservative estimator of browse damage to wildflower species. He notes, that even at "15% oak browse rates, browse of more deer sensitive species, including white and red Trillum (*Trillium grandiflorum*, *T. erectum*), false Solomon's seal (*Maianthemum racemosum*) and many other species will experience significant mortality" (pers. comm 2017). Even small mortality rates and reproductive declines in such species can lead to population declines and local extinction.

Knight (2004, 2009) used a combination of field data collection and demographic modeling to find that that deer herbivory of 15% on trillium plants was leading to population declines, especially among flowering and fruiting individuals, that would ultimately lead to populations disappearing from the site—that is, local extinctions (extirpation). This study did not correlate the level of browse damage on other species (such as red oaks) with that on trilliums, but does supply a clear, peer-reviewed study and metric of a "not-to-exceed" browse proportion of 15%.

Observations that I recorded during monitoring to date in other parks suggests that red oaks are a conservative estimator of impacts on other species, which have been noted as heavily browsed adjacent to oak seedlings that are not browsed (including species such as jewelweed and Virginia creeper). More systematic data from wildflower studies now being done in Ann Arbor parks will provide data on existing trillium populations and on experimental wildflower plantings, to be reported in fall 2017, that will allow calibration of deer browse levels on oaks with damage to other species in local sites.

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Personal communication by phone and/or email with Bernd Blossey (Cornell University), Walter Carson (University of Pittsburgh), Nicholas Reo (Dartmouth University), Don Waller (University of Wisconsin), September 2017; personal communication with Blossey and Waller, April, May, September 2016.