Palmer Woods Forest Reserve
Deer Exclosure Survey Protocol

Introduction

"In addition to exotic species, changes in management and land use have led to uncharacteristic expansion of a few native taxa, such that they have become problem species. The most notable example of this is the irruption of the native white-tailed deer population. Browsing pressure by deer has reduced the abundance of certain native plant species (e.g., Canada yew (Taxus canadensis), eastern hemlock (Tsuga canadensis), and many broad-leaved forest wildflower species to a fraction of their previous abundance. Further, overbrowsing by deer is driving change at the community level by promoting the biotic homogenization of Great Lakes forests. For these reasons, white-tailed deer is the major problem vertebrate threatening the health of Great Lakes forests." –Great Lakes Inventory and Monitoring Network (Sanders et al 2008)

To better understand the effects of deer herbivory on northern hardwood forests in Leelanau County, two large deer exclosures were constructed at Palmer Woods Forest Reserve (PWFR) in the fall of 2016. These exclosures will serve as a research site for monitoring vegetation change in the absence of deer browse, and as a public demonstration and educational opportunity for regional schools. Though the impacts of deer on Great Lakes forest vegetation are broadly understood (Rooney & Waller 2003; White 2012; Bradshaw & Waller 2016), studies show that effects on forest composition, structure, and regeneration success can vary depending on vegetation community, deer density, and other site-specific factors, and many areas do not have regionally-specific studies (Russell et al 2001). Impacts of deer browse have long been documented in Leelanau County by comparing vegetation on the North Manitou Island (deer present) and South Manitou Island (deer absent) (i.e. Hazlett & Vandekopple 1983; Hurley & Flaspohler 2005). However these island forests are within the Sleeping Bear Dunes National Lakeshore and are permanently protected from extractive uses, differing from mainland forests which are typically managed for timber. Deer exclosures established at PWFR will monitor impacts of deer on actively managed timber forests. These sites will be available to University researchers and local schools to utilize the data collected by the Leelanau Conservancy and to collect their own data. Findings will be used to educate the public and other organizations on the impacts of deer on forests and guide forest management decisions.

Questions of interest are:

- How does deer herbivory impact understory species' diversity and abundance?
- How does deer herbivory impact forest structure?
- How does deer herbivory impact tree recruitment and growth?

Of particular interest to management at PWFR is the impact of deer on 1) native herbaceous diversity such as spring ephemeral flowers (trillium, spring beauty, trout lily,

etc) which fosters the majority of vascular plant biodiversity in northern hardwoods; 2) low and tall shrub growth, including species such as elderberries, which provide foraging and nesting habitat for birds; 3) tree seedling recruitment and growth to sizes that escape browse height, particularly for preferentially browsed species and timber species such as red oak and sugar maple; 4) indirect effects such as changes in invertebrate, bird, or mammal composition and abundance.

Two deer exclosures have been built at PWFR, a 13-acre area in the northern portion of the Reserve and a 22-acre area in the southern portion of the Reserve. The area inside the deer exclosure is referred to in this document as the "fenced" area (no deer, experimental treatment) and the surrounding forest that is open to deer access, referred to as the "unfenced" area (control treatment, deer density to be determined). In both exclosures, there is a two-track bisecting them with an access gate at each end to allow for vehicle movement. The exclosures are broken up into two management zones on either side of the access road: an "active management treatment" and a "passive management treatment." The active management areas will receive specialized treatments to reduce the number of beech saplings, which have been regenerating densely in the wake of beech bark disease and timber management. A perimeter of active beech thicket management will occur outside of the exclosure in the corresponding unfenced (control) area. This design creates 8 separate treatments: 2 forest treatment x 2 deer treatment x 2 management types (Table 1). Tree, shrub, and herbaceous abundance, composition, and structure will be measured at multiple-year intervals in each of the treatments in permanent plots.

Table 1. *Eight different treatments will be monitored at PWFR.*

Treatment #	Forest Treatment	Deer Treatment	Management Treatment
1	Northern Forest	Fenced	Active
2	Northern Forest	Fenced	Passive
3	Northern Forest	Unfenced	Active
4	Northern Forest	Unfenced	Passive
5	Southern Forest	Fenced	Active
6	Southern Forest	Fenced	Passive
7	Southern Forest	Unfenced	Active
8	Southern Forest	Unfenced	Passive

Site Description

Palmer Woods Forest Reserve covers 706 forested acres in eastern Glen Arbor and western Cleveland Townships, Leelanau County, Michigan. The parcel is contiguous with several thousand acres of protected forest, fields, and dunes within the Sleeping Bear Dunes National Lakeshore. Despite a history of human use, much of the native flora is intact and it is home to several high conservation value species.

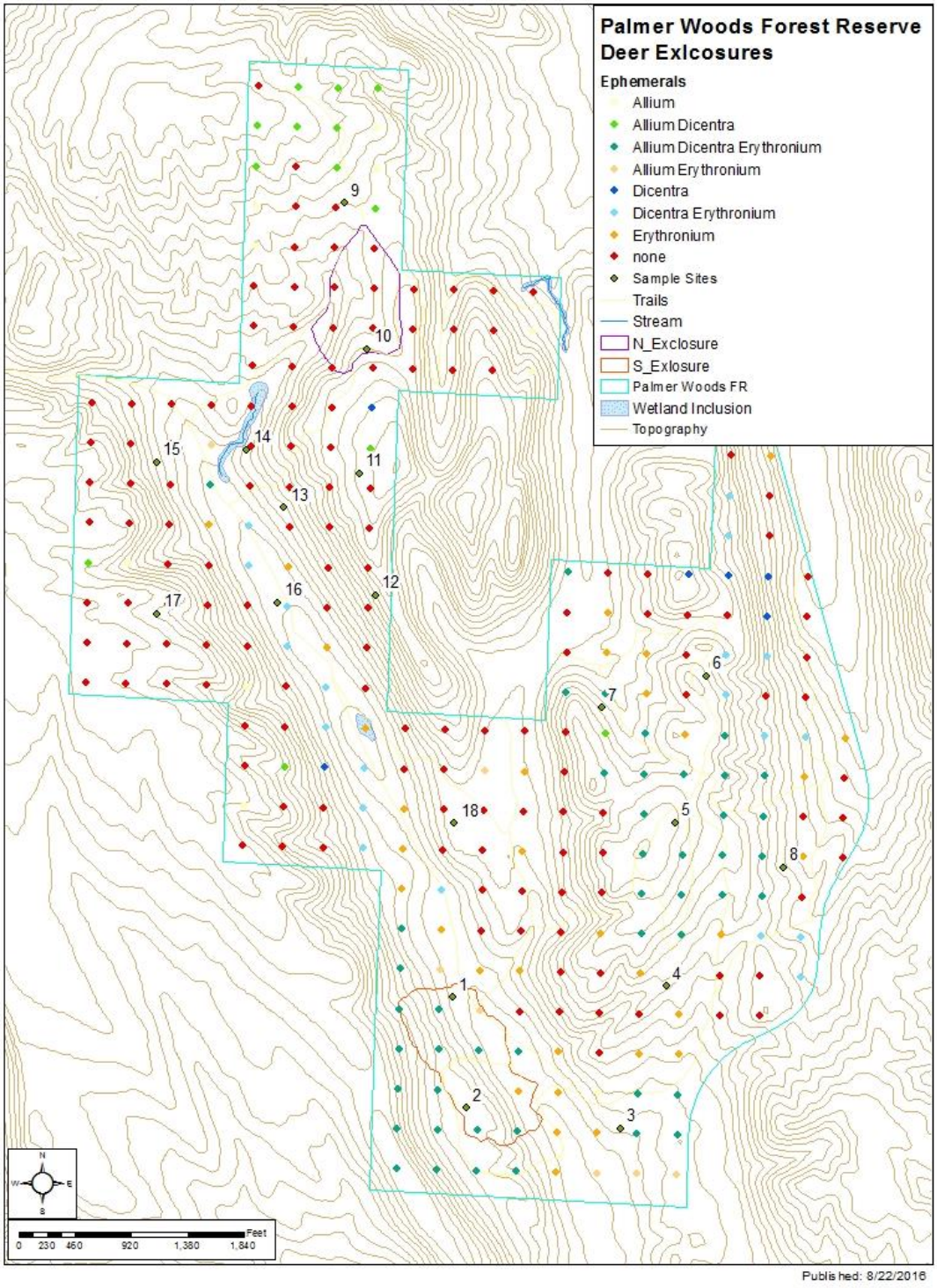
Vegetation is primarily beech-sugar maple forest with hemlock, black cherry, and yellow birch in low-lying valleys and steep hillsides, and northern red oak and red maple common on well-drained slopes. Red and eastern white pine with northern red oak and red maple can be found on the dry sandy and exposed ridges. Incidental stands of aspen and birch, as well as planted red pines, European larch, and blue spruce can also be found. Sugar and red maples are most abundant and appear to have healthy population numbers. Beech bark disease related mortality and salvage cutting has lead to widespread thickets of beech saplings but low adult basal area. American basswood, black cherry, and white ash have low adult and seedling abundances; red oak can be dominant in stands however few saplings were found. Conifer regeneration is limited to areas with abundant seed sources. Forest basal areas range from 90-215 ft^2/acre. Live woody biomass (above and below ground) ranged from less than 100 Mg/ha in harvested areas to greater than 500 Mg/ha in well stocked stands. See the PWFR Rapid Ecological Assessment and Forest Inventory Analysis on file with the Leelanau Conservancy for more information on stocking and forest composition and structure.

A total of 309 vascular plant species were found at Palmer Woods Forest Reserve; 230 (74%) of the species are native and 79 (26%) are non-native. Of these, ten plant species are of the highest conservation concern, and one (log fern, *Dryopteris celsa*) is state-threatened, though the population has been planted. The floristic quality index is 54.5 indicating an "extremely rare area and significant component of Michigan's biodiversity and natural landscapes." One state-threatened animal, the Red-shouldered Hawk, was observed in June and July in 2015 and 2016 in the southeastern section of the property.

Two deer exclosures have been constructed in PWFR (Fig. 1). The northern exclosure is a 13-acre area extending from the low-slope to the top-slope of a steep, undulating, northwest-facing hillside. A salvage timber harvest was performed in 2014 across an 80-acre parcel, which included the exclosure area, to remove declining red oak, American beech, and white ash. The canopy is mostly open, varying from <25% to 50% cover. Remaining trees are a mixture of mature red oak, red maple, American beech, sugar maple and occasionally Eastern hemlock and yellow birch. The understory is a mixture of canopy trees and striped maple. Soils are sandy and there is erosion in some areas from heavy machinery operation. This area is exposed to the prevailing wind patterns and afternoon sun, creating dry-mesic conditions and little herbaceous diversity.

The southern exclosure is situated along the main valley floor and extends up a steep northeast-facing hillside encompassing a bench ridge mid-slope. The canopy is a mixture of sugar maple and American beech with occasional black cherry, Eastern hemlock, yellow birch, American basswood, and white ash. Red maple and red oak are rare to absent. The position in the landscape is sheltered from prevailing wind and afternoon sun, and soils are mesic, supporting a higher diversity of spring ephemeral species than the northern site. There has been significant windthrow and subsequent salvage harvest (2015) on the valley floor and bench ridge (<25%-50% canopy cover), while the slope remains largely intact (60-80% canopy cover).

Figure 1. *Map of PWFR showing relative richness of understory species (colored dots) and locations of deer exclosures (polygons). Sample sites (numbered dots) have associated vegetation data in the Rapid Ecological Assessment (2015).*



Monitoring

Exclosure Fencing

Fences should be checked for damage year-round. Any damage should be repaired immediately to keep deer from entering exclosures and damaging the integrity of the plots. If fence has been damaged, any impacts should be immediately assessed and noted with a GPS (i.e. browse on winter buds, digging for young shoots, tracks, etc).

Plot Monitoring Frequency and Timing

Baseline vegetation data will be collected in early May 2017 at the peak of the spring ephemeral plant bloom and before full leaf-out of overstory trees (approx. May 5 – 15th). During the baseline vegetation data phase, permanent plots will be set up and marked with permanent markers at the corners, and all compositional and structural data will be recorded. After the completion of setting up plots and collecting baseline data, a return visit (late May or early June 2017) will occur after canopy leaf-out to take canopy photos and soil samples. All data will be entered into an Excel spreadsheet (in the field if possible) and stored at the Leelanau Conservancy. A summary may be produced if desired.

Future monitoring can begin several years after establishment of vegetation plots and baseline survey, depending on the temporal resolution of the data desired. All monitoring should occur during the same two-week period of year as the baseline survey to ensure consistency in data. Shorter monitoring intervals (3-5 years) are more appropriate for understanding initial change in seedlings, shrubs, and herbaceous cover, while longer intervals (10-30 years) are more useful for measuring changes in saplings and adult trees. Monitoring of hardwood forests typically occurs at 5-20 year intervals. Six year intervals were found to be reasonable for the GLKN Vegetation Monitoring (Johnson et al 2006) Protocol to capture incremental changes in herbaceous and shrub diversity and growth, which change at a faster rate than tree diversity and growth (Sanders et al 2008). An initial 3-year interval after the baseline survey may be useful for capturing early shifts in herbaceous abundance and seedlings and sub-sapling growth.

Materials

- clipboard
- pencil
- field data sheet / tablet
- GPS w/ plot locations
- herb quadrat grid
- DBH tape
- field measuring tape
- flagging tape
- permanent plot markers

Plot Design and Sampling Protocol

Site Selection & Plot Establishment

Plot locations were randomly stratified across abiotic gradients, with plots located in equivalent conditions inside and outside the treatments (elevation, topographic position, canopy cover). The top of each plot will be oriented to the north. Each corner will be permanently marked with a bright orange corner stake to insure perfect relocation. Perfect relocation of plots is essential to the integrity of the data. Shifting plots will result in incorrect assessment of species growth and turnover. Witness trees may be marked with metal tags to aid in location.

Abiotic / Environmental Variables

Within each plot it is important to measure the abiotic components of the site (topographic position, soil, light, etc). Abiotic conditions determine species' growth and reproduction, so they are important to factor in both site selection and analysis of growth. Abiotic variables can also change with management decisions (i.e. removing canopy trees increases light) or time (canopy growth decreases light). Recording the baseline and any change in abiotic conditions will help explain changes in forest composition and structure beyond our experimental variable, deer browse. Additionally, changes in deer browse rates will have indirect effects on abiotic variables. For example, deer abundance can affect nitrogen mineralization rates through preferential browsing, shifting forests towards browse-tolerant species. Browse-tolerant species often have high lignin concentrations and are mineralized more slowly, causing leaf litter to accumulate and soils to have higher C:N ratios, further shifting demographics (Rooney & Waller 2003).

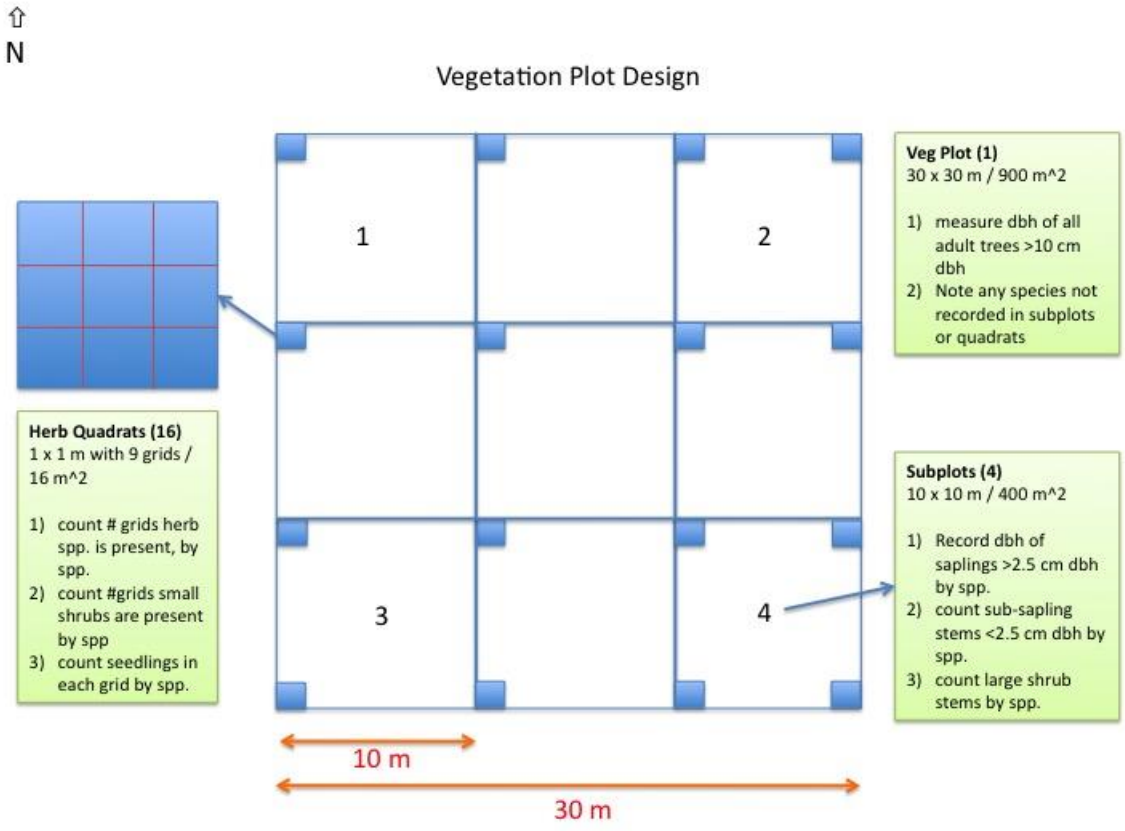
Topographic position – record relative position of plot in landscape (topslope, midslope, flat, etc), grade of slope, aspect of slope, and elevation.

Soil samples – take one sample from the approximate center of each subplot (9) by clearing away leaf litter and coarse woody debris, hammer soil core into root zone (PVC piping), carefully remove core and mix with all samples in one soil bag. After 9 samples are taken and mixed well, one half-cup sample can be removed and sent to the MSU Extension soil lab for analysis.

Coarse woody debris – measure the percent of surface area covered by coarse woody debris (sticks, logs) in each quadrat.

Light – Measure canopy cover / light by taking fish eye photographs directed upwards at sunset or sunrise. Process data with UM Forest Ecology lab software. This must be done when all trees have fully leafed out (late May).

***Figure 2**. Vegetation plots will be 30x30 m (900 m^2) squares divided into nine 10x10 m (100 m^2) sub-plots. Adult trees will be measured across the entire plot and saplings and large shrubs will be measured in four of the sub-plots. Within the plot there will be sixteen 1x1m quadrats to measure herbaceous cover, small shrubs, and tree seedlings.*



Adult Tree Measurements (Main Plot)

Adult trees are all trees >10 cm dbh (diameter at breast height). The species and dbh of all adult trees will be recorded across the entire 900 m^2 vegetation plot, noting what quadrat they are within (#1-9). This will allow calculation of basal area and biomass per tree, per species, per plot, and extrapolation to per area units.

Sapling, Sub-sapling, and Tall Shrub Measurements (Subplots)

Saplings are generally measured as trees >2.5 cm dbh and <10 cm dbh (White 2012; McGarvey et al. 2013, Bressette et al. 2012). These trees are generally well-established, 3-5 m tall, and have most of their foliage above the point where deer browse occurs (Kelty and Nyland 1981), making them far less vulnerable to deer impacts. Previous studies in PWFR have shown that sapling distribution is extremely clumpy due to beech root-sprouts, creating patchy thickets; this is the reasoning behind spreading out the sapling subplots across the main plot. The species and dbh of saplings will be

recorded for all saplings in each of the four 100 m^2 subplots (located in the corners of the larger plot) for a total sample area of 400 m^2. Results will be given in basal area and biomass per tree, per species, per plot, and extrapolation to per area units.

Sub-saplings are trees that are no longer seedlings but are below the minimum sapling size of 2.5 cm dbh; they are tentatively defined as >40 cm tall and <2.5 cm dbh. These are generally heavily browsed, repressed saplings. For example, they may be several years old but, because of deer browse, only one third of their expected normal height. This class varies in age structure and is defined by size-class. This size-class is expected to show the most significant initial growth after fencing. This class is also expected to shrink in size inside the exclosures after multiple years, as deer will no long be repressing sapling growth creating an unusual abundance of this size sapling. Sub-saplings will be measured by counting the number of individual stems per species across each subplot, giving a final figure in species' stem count per unit area.

Tall shrubs will also be measured in the four subplots. For our purposes, tall shrubs include all species of shrubs whose maximum height is higher than 2 m in normal growing conditions. Common tall shrub species known to PWFR include elderberries *(Sambucus canadensis, S. racemosa),* chokecherry *(Prunus virginiana),* witchhazel *(Hamamelis virginiana),* yew *(Taxus canadensis),* juniper *(Juniperus communis),* and non-natives honeysuckle *(Lonicera spp.)* and autumn olive *(Elaeagnus umbellata).* Tall shrubs are recorded by counting the number of stems for each species, in each of the four subplots, giving a final figure in species' stem count per unit area.

Herb, Seedling, and Short Shrub Measurements (Quadrats)

Herbaceous diversity, seedlings and small shrubs will all be measured in the 1x1 m quadrats. Sixteen quadrats will be spaced evenly across the main plot sampling a total of 16 m^2 per plot.

Seedlings will be considered young trees <40 cm tall. Germinating seeds without true leaves will not be counted. Seedlings will be counted in each of the 1 x 1 m quadrats, with species and number of stems recorded for each of the 9 grid points. This will give a mean and variance for each of the quadrats in units of stems per area, which will be used to calculate mean and variance for seedlings at the plot level.

Herbaceous diversity will be sampled using the *frequencies of occurrence* method in each quadrat. A grid with 9 sections will be placed atop the quadrat and the number of grid spaces that an herbaceous species occurs in will be summed; this will be repeated for each herbaceous species present, giving an abundance range of 0-9 for each quadrat (Table 2). "0" represents 0% cover while "9" represents 100% cover. From this data a mean and variance for cover can be calculated at the plot level, and this will be used calculate Shannon's diversity index (H) and evenness (E). Additional method options include plot-wide searches for species not included in the 1 x 1 m areas to more accurately calculate diversity.

Table 2*. Sample herbaceous data collection table for one plot; Each species' abundances are calculated by the number of grid points they are in at each quadrat.*

Plot 1 Quadrat #	***Allium triccocum***	***Dicentra cucullaria***	***Trillium grandiflorum***	***Additional species***
1	*1*	*4*	*9*	*…*
2	*7*	*0*	*0*	*…*
3	*3*	*5*	*2*	*…*
4	*1*	*9*	*9*	*…*
…	…	…	…	…

Short shrubs are defined in this study as a shrub whose normal maximum size is usually less than 2 m. At PWFR, short shrubs include Canadian or fly honeysuckle *(Lonicera canadensis)*, red raspberry *(Rubus strigosus)*, black raspberry *(Rubus alleghaniensis)*, dwarf raspberry *(Rubus pubescens)*, bristly sarsaparilla *(Aralia hispida)*, gooseberry *(Ribes cynosbati)*, and snowberry *(Symphoricarpos albus).* Short shrubs will be tallied in the same way as herbaceous vegetation, with a tally for each grid point and an abundance from 0-9 for each quadrat. Only grids in which stems are growing out of will be counted (i.e. stems arching over and covering, but not growing out of, grid points will not count). Final abundances will be given in mean and variance of percent cover.

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