Impact of deer density on the abundances
of ten indicator tree species
in northern Wisconsin

Background

Wisconsin has a large deer population that has grown from pre-hunt levels of around 400,000 in 1960 to about 1.5 million in 2010. This increasing deer population applies pressure on the plant communities that feed them. Deer are herbivores and eat many types of plants including small trees. Previous enclosure studies show that deer have preferences for different types of trees, but with a large deer population, deer may be forced to eat less palatable species due to scarcity of food. The primary question of this study is to describe a statistical relationship between the abundances of small trees from ten key species and deer density. Tree species with different palatability to deer may respond differently to the pressure of deer density. Many variables other than deer density also affect the abundance of trees. Environmental variables factors such as soil, light, precipitation, and temperature will affect tree abundances, but are not available for this study. One potential explanatory variable of interest that is available is the type of owner of the forest. Knowledge about the relationship between deer and abundances of these species may be helpful to inform forest management practices and to guide public policy about deer hunting. Deer hunting in Wisconsin is strongly regulated and the annual hunt has a large impact on the deer population.

The ten key marker species are tabulated here. The label *Picea spp.* is actually a combination of two different spruce species, *Picea mariana* and *Picea glauca* (black and white spruce, respectively). Each species is in a palatability class with values from 1 to 4 where 1 is least palatable (deer prefer other food) and 4 is most (a deer favorite), as shown from prior research.

Scientific Name	Common Name	Palatability Class
Abies balsamea	balsam fir	1
Picea spp.	spruce (black and white)	1
Acer rubrum	red maple	2
Acer saccharum	sugar maple	2
Populus tremuloides	aspen	2
Pinus strobus	white pine	3
Quercus rubra	northern red oak	3
Betula alleghaniensis	yellow birch	4
Thuja occidentalis	northern white cedar	4
Tsuga canadensis	eastern hemlock	4

Study Design

The state of Wisconsin is divided into many deer management units (DMUs). The designations changed prior to the 2014 hunt to largely match county borders, but we have data from before this change. The study area consists of the DMUs from the northern third of the

state, approximately. Over a period of several decades, the US Forest Service sampled many plots across the region and recorded the width and species of every tree larger with diameter at breast height (DBH) larger than one inch. These plots were later grouped by their DMU. A single plot is typically sampled at four 24-foot diameter circles (some plots in the study use a different geometry for sampling, but have a total area that can be considered to be equal). The data for this study comes from four decades, but the sampling effort and procedure changed partway through. In each of the years 1983 and 1996, one plot was sampled for about every 1500 hectares (ha) of forest land. Beginning in 2000, fewer plots were sampled annually, about one per 7000 ha. We have data from 2000–2004 and 2009–2013. The total number of plots in each of these five-year intervals is comparable to the total number of plots sampled in one of the earlier years. In addition, the labeling system for plots changed so it is not possible to match the plots from before and after the year 2000. The tree-level data has been aggregated so that for each plot, year, and species, there is a count of the number of small, medium, and large trees. Small trees have a DBH from 1 to 2 inches, medium trees are from 2 to 4 inches, and large trees are larger than four inches DBH. Note that plots for which a species did not appear are not included in the data set.

Hypotheses

The primary problem is to find a statistical model to relate deer density with the abundance of small trees in each species, or the total of small trees in each palatability class, while controlling for other explanatory variables. Here are some specific questions:

1. How does deer density relate to small tree abundance?

2. How does palatability affect the relationship between small tree abundance and deer density?

3. How does ownership affect the relationship between small tree abundance and deer density? In particular, is there something different happening in DMUs that are largely contained within Indian reservations? Are there differences between plots on private and public lands?

4. Are there any geographic trends of interest?

5. How do the presence of large and medium trees affect the abundance of small trees from the same species?

Data

The data set consists of 41,823 rows. Each row corresponds to the counts of small, medium, and large trees of a single species in a single plot in a single year. Note that if a species does not appear in a plot in a given year, then there is no observation. It may be that this species of tree is not present in the area around the sample plot, but could also mean that trees are nearby, but no trees fell within the sample area.

Here are details about each variable. Note in particular that deer density (**ddens**) is measured at the DMU level, not the plot level, and that **Palatability** and **Shade** are characteristics of the plant species, not the plot.

Index A unique identifier for each plot and year.

Plot Index for the plot. Note, indices are unique within DMUs, but plots in different DMUs may have the same index. Also, the same plot may be denoted differently between the pre- and post-2000 sample times.

CountyID Code for county.

Year The actual year that the data was collected.

Decade A single year label for the 'decade' in which the data was collected: one of 1983, 1996, 2002 (for 2000–2004) , and 2011 (for 2009–2013).

Species One of the ten species labels.

DeerDensity Deer density (number of deer per square mile). This variable is measured at the DMU level on an annual basis.

DMU Label for the deer management unit.

Owner Factor with levels Federal, IR (Indian Reservation), Private, and State.

Palatability Factor with values from 1 to 4, as in table above; refers to the plant.

Shade Factor with values from 1 to 3; measures shade tolerance of the plant: 1 = shade intolerant (needs full sun), 2 = medium intolerance, 3 = shade tolerant.

Large Number of trees with DBH greater than 4 inches.

Medium Number of trees with DBH from 2 to 4 inches.

Small Number of trees with DBH from 1 to 2 inches.