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Protocol for Statistical Analysis of Vegetation Changes at Catoctin Mountain Park

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ON THE COVER
Staff from the National Park Service sampling vegetation in Catoctin Mountain Park, Maryland.
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Abstract

Vegetation data collected at Catoctin Mountain Park, Maryland, in a split-panel rotation design during 2004-2009 were analyzed for differences among three regions within the park and among years. Six plots were paired with plots fenced to exclude white-tailed deer (*Odocoileus virginianus*), and differences between open and exclosed plots were also investigated. Repeated measures analysis of variance (ANOVA) was used to test for differences in the following variables: percentage of twigs browsed, percentage of canopy cover, and number of tree and shrub seedlings in each of five height classes. Except for some differences in numbers of tree and shrub seedlings among height classes among the regions, no differences ($P > 0.05$) were found among the regions or over time in the variables measured. Recommendations for future sampling and analysis are discussed.

Keywords

Browse, Catoctin Mountain Park, Forest, *Odocoileus virginianus*, Vegetation, White-tailed deer.

Introduction

Catoctin Mountain Park consists of 5,882 acres of eastern deciduous forest in Frederick County, Maryland. Long-term vegetation plots were established by the National Park Service (NPS) in 1990, as part of a region-wide vegetation monitoring plan. One of the goals of the monitoring was to determine the effect of white-tailed deer (*Odocoileus virginianus*) populations on the native vegetation, since white-tailed deer are known to have a major impact on other native plant communities (Russell et al. 2001; Liang and Seagle 2002; Horsley et al. 2003; Rossell et al. 2005, 2007). The sampling design and protocol were developed by John Hadidian (personal communication, 1990) following Storm and Ross (1992); 45 20×20 m plots were monitored in three geographic regions of the park. Data collection and analysis from 1990-1995 and 2000-2002 were described by Russek-Cohen (2003).

In 2004, NPS decided to monitor just a subset of variables, based on the results of Russek-Cohen (2003), and went to a split-panel rotation design (McDonald 2003; NPS 2004). In this design, six plots were monitored in the first year of the panel rotation (panel 1, 2004 and 2007), 20 plots in the second year (panel 2, 2005 and 2008), and 19 plots in the third year of the rotation (panel 3, 2006 and 2009). Six additional 20×20 m plots, fenced to exclude deer, were set up to directly measure the effects of deer on the six plots in panel 1. Thus, deer exclosure plots were paired with the six open (unfenced) plots, two paired plots per region, and measured during 2004 and 2007. See Figure 1 for a map of the regions, plots, and exclosures.

The purpose of the current report was to develop a statistical protocol for analyzing the split-panel design set forth by NPS (2004) for 2004-2009. In addition, the 6 paired open and exclosed plots were also analyzed for 2004 and 2007.

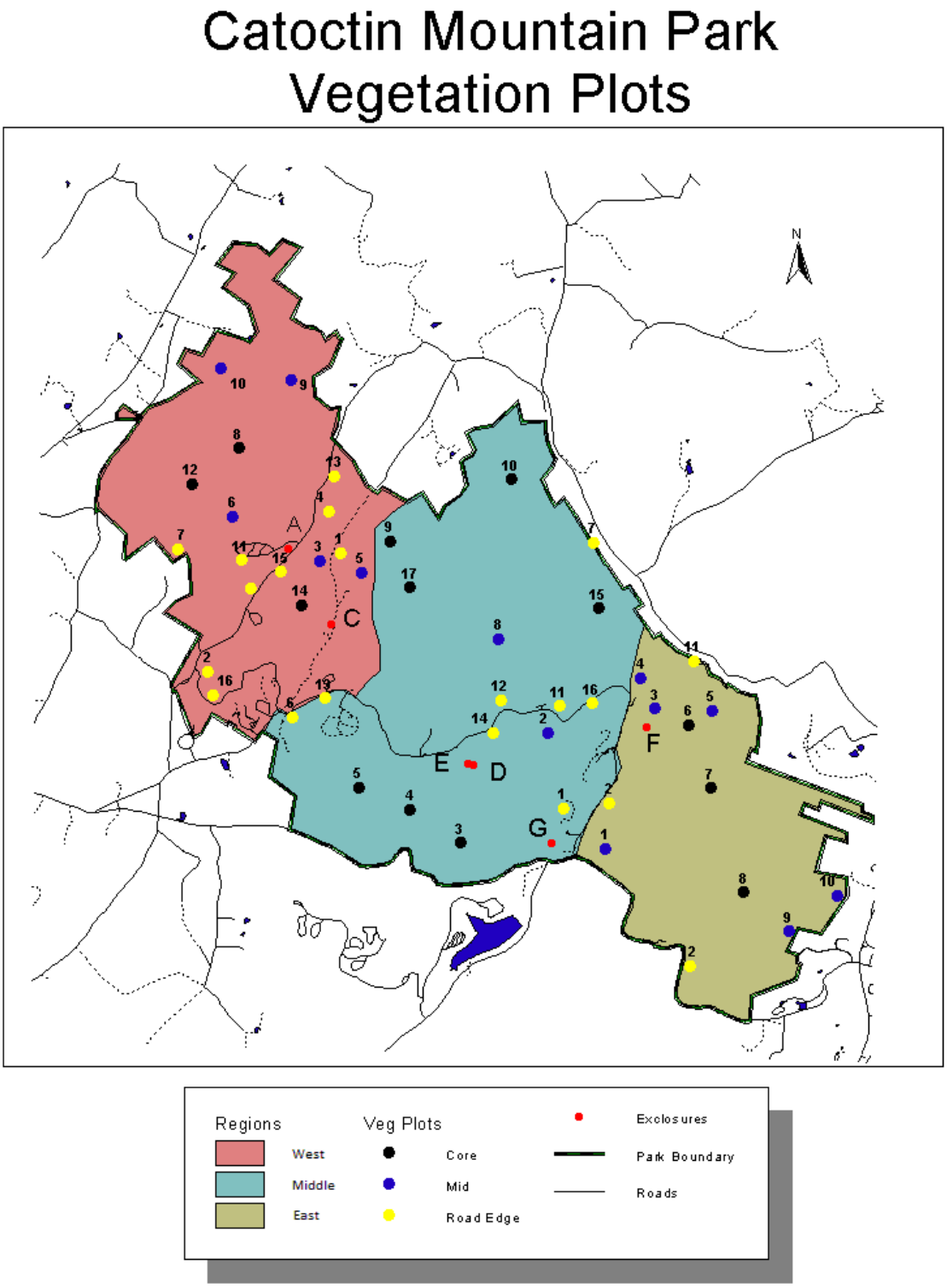

Figure 1. Map of study area showing location of regions, vegetation plots, and exclosures.

Methods

Data Collection and Summary

***Canopy Cover*:** The density of the canopy was measured using a densiometer (NPS 2004). Four measurements were taken in each plot, one per subplot (quarters). The Canopy Cover Percent within each of the four subplots was averaged by plot for analysis.

***Herbaceous Plants*:** Herbaceous plants and various cover categories were measured in cover classes (NPS 2004). These data were not analyzed here because they are categorical and need a custom analysis (Bayesian?) to test for changes over time. Such an analysis should be considered in the future.

***Tree and Shrub Seedlings*:** In each of four 2×2 m subplots per plot, tree and shrub seedlings and saplings were identified and counted, and the height of all woody seedlings and saplings was categorized into one of five Height Classes as defined by Hadidian (Height Class 3: 25-50 cm; 4: 50-75 cm; 5: 75-100 cm; 6: 100-125 cm; 7: 125-150 cm). Thus, the Height Class and Number of Individuals (within each height class) were measured for each woody species identified (NPS 2004).

For seedlings and saplings, the following data were totaled for each plot:

- Species and form (i.e., tree or shrub). Note that *Amelanchier*, *Carpinus* and *Cornus* are counted as trees in this analysis, to be consistent with Stout (1998) and Hatfield and Krafft (2009). Other sources may consider these genera to be shrubs.
- Height Class.
- Summarized as Number of Individuals per Height Class for trees and shrubs separately.

***Browsing*:** Two circular subplots (1.7 m radius) were established at randomly selected direction and distance from the plot center each year sampled. The numbers of browsed and unbrowsed twigs of each woody species were counted and recorded. Twigs were defined as growth from the most recent year that is at least 1” in length and within 1.5 m of the ground (NPS 2004). Unfortunately, browse was not recorded in the exclosures during 2007, so changes in browse differences between open and exclosed plots cannot be evaluated over time.

The following data were recorded and totaled across the two subplots per plot:

- Species.
- Number of twigs browsed.
- Number of twigs unbrowsed.
- Summarized as Percent of Twigs Browsed per plot.

Data Analysis

Repeated measures analysis of variance (ANOVA), implemented with the mixed models procedure within SAS (2003), was used to test for differences among Regions, Panels, Years

nested within Panels, and their interactions for each variable (Littell et al. 1996) in the split-panel rotation design. The subject factor for each ANOVA was plot nested within region. Years were nested within Panels in order to get the appropriate tests for the split-panel rotation design.

Thus, the Year factor simultaneously compares 2004 to 2007 for panel 1, 2005 to 2008 for panel 2, and 2006 to 2009 for panel 3. Least square means and Tukey's multiple comparison procedure could be used to sort out significant differences ($P < 0.05$) among Years(Panels) for all variables, but since Year(Panel) was never significant (see below), these procedures were not necessary.

Four variance-covariance structures were modeled (compound symmetry, autoregressive, Toeplitz, and unstructured) and the best model was selected via AIC_c comparisons (Littell et al. 1996). Residuals were tested for normality (Kery and Hatfield 2003) and, for some variables (i.e., Canopy Cover Percent, Tree and Shrub Seedling Counts), a natural log transformation of the measurement + 1 was used to help achieve normality.

For the Tree and Shrub Seedling Counts, Height Class was also included in the model, along with the various interactions.

We hoped to calculate tree seedling Stocking Rates, following the recommendations of Stout (1998), similar to Hatfield and Krafft (2009), but this calculation was not possible since Height Classes 1-2 and 8 were not measured in this study.

We also ran all ANOVAs separately for native vs. exotic species, but we do not report these results below because the data from exotic species were too sparse for ANOVA analyses, and the ANOVA results for the native species data were qualitatively similar to the results for natives and exotics combined. Hence, we only report results for natives and exotics combined.

For the six paired open and exclosed plots, differences were computed of the open minus exclosed variables for each pair of plots. For the Percent of Twigs Browsed, however, only a paired t-test was used to compare open and exclosed plots for 2004, because browse data were not collected in the exclosures in 2007. For the other variables (i.e., Canopy Cover Percent, Tree and Shrub Seedling Counts), a repeated measures ANOVA (Factors: Region, Year, and their interactions) was used to compare the difference of open-exclosed plots between years 2004 and 2007.

Results and Discussion

The results of the ANOVAs for each model selected are reported in Table 1. For the Canopy Cover Percent, compound symmetry was the best model according to AIC_c. There was a significant difference among panels, with panel 2 being highest, although panel is a nuisance variable and not of biological interest, except to control for it in the analysis. For the difference between open and exclosed plots for the Canopy Cover Percent, again compound symmetry was the best model, but no significant differences were found (Table 1). Inspection of the least square means and associated t-tests showed no difference between open and exclosed plots for 2004 (P=0.7381) or 2007 (P=0.5600) for this variable.

Table 1. Summary statistics (*F*-values and *P*-values) from the repeated measures analysis of variance (ANOVA) for each variable. See text for descriptions of the vegetation variables and for details concerning the ANOVA models.

	Fixed Effects Terms in ANOVA Model													
	Region[1]		Panel[2]		Region × Panel		Year[3]		Region × Year[3]		Height Class[4]		Region × Height Class[4]	
Variable	*F*	*P*	*F*	*P*	*F*	*P*	*F*	*P*	*F*	*P*	*F*	*P*	*F*	*P*
Canopy Cover (Log of Mean Densiometer % + 1)	0.10	0.9079	20.07	<0.0001	1.25	0.3046	1.14	0.3452	0.67	0.6712				
Difference (Open-Exclosed) in Log Canopy Cover %	3.02	0.1910					0.03	0.8717	0.73	0.5515				
Tree Seedling Counts (Log of Plot Count + 1)	0.63	0.5349	0.53	0.5920	1.79	0.1484	0.61	0.6108	0.27	0.9483	3.93	0.0053	0.26	0.9775
Difference (Open-Excl.) in Log Tree Seedling Counts	0.53	0.6360					1.50	0.2317	1.50	0.2418	0.31	0.8673	0.31	0.9546
Shrub Seedling Counts (Log of Plot Count + 1)	9.26	0.0006	0.06	0.9408	0.05	0.9951	3.96	0.0155	1.39	0.2440	4.53	0.0050	2.10	0.0558
Difference (Open-Excl.) in Log Shrub Seedling Counts	0.33	0.7343					0.31	0.5993	1.21	0.3723	0.50	0.7390	0.49	0.8315
Twigs Browsed (%)[5]	1.18	0.3181	0.03	0.9736	1.83	0.1432	0.61	0.6142	1.32	0.2738				

[1]Three geographic regions within Catoctin Mountain Park (East, Middle, and West).

[2]Three panels of plots were measured in the split-panel rotation design for the 45 open (un-exclosed) plots. Six plots were measured in panel 1, 20 plots in panel 2, and 19 plots were measured in panel 3. Panel is not included in the analysis of differences between open and exclosed plots, because only panel 1 was measured for these plots.

[3]For the split-panel rotation design, there were six years of data collection (2004-2009) with years 2004 and 2007 measured in panel 1, 2005 and 2008 measured in panel 2, and 2006 and 2009 measured in panel 3. Thus, year is nested within panel in the split-panel rotation analysis. For the comparison of the differences between open and exclosed plots, only 2 years of data were collected, 2004 and 2007, for panel 1 only. Thus, year is not nested within panel for that analysis.

[4]Tree and shrub seedling counts only, 5 Height Classes (3-7). Interaction terms for Height Class with Panel, Year, and Height Class × Region × Panel and Height Class × Year(Panel) are not shown because none were significant ($P>0.05$). However, all these terms were included in the analyses.

[5]The full analysis of the differences in percent of twigs browsed could not be run, because browsing was not measured in the exclosures in 2007.

For Tree Seedling Counts, Toeplitz was the best model, and there were no significant differences except among Height Classes (Table 1). This is expected, with inspection of least square means showing that most seedlings were in Height Class 3, with many fewer in the larger height classes. For the difference between open and exclosed plots in Tree Seedling Counts, compound symmetry was the best model, but no significant differences were found. Inspection of least square means and associated t-tests showed no difference between open and exclosed plots for 2004 (P=1.000) or 2007 (P=0.2627) for this variable.

Concerning the Shrub Seedling Counts, unstructured was the best model, and there were significant differences among Regions, Height Classes (as expected), and Year(Panel) (Table 1). Multiple comparisons have not been performed, but inspection of least square means shows that the West Region had much higher counts, and concerning Years, 2007 and 2008 were higher than 2004 and 2005, respectively, but 2009 had slightly lower counts than 2006. Multiple comparisons (i.e., Tukey's multiple comparison procedure) could be performed if it is of interest to sort out these differences. Concerning the difference between open and exclosed plots for the Shrub Seedling Counts, Toeplitz was the best model, but there were no significant differences (Table 1). Inspection of least square means and associated t-tests showed no difference between open and exclosed plots in 2004 (P=0.6847) or 2007 (P=0.7489) for this variable.

For the Percent of Twigs Browsed, compound symmetry was the best model, but no significant differences were found (Table 1). A paired t-test was performed for the 2004 data for this variable, and again, open and exclosed plots were not significantly different (P=0.1781).

It should be noted that the year 2004 was the baseline year for the six exclosures. When they were measured that year the fence was not even installed yet. The fencing was put up after the plots were measured and now we are capturing differences between the baseline (open) plots and plots with deer excluded. Therefore, we expect year 2004 to show no differences between open and exclosed plots and, thus, no significant interaction with year.

Recommendations for Future Sampling and Analysis

Several sampling recommendations come about from these analyses of the Catoctin Mountain Park vegetation data collected for 2004-2009. First, if it is of interest to compare Percent of Twigs Browsed between open and exclosed plots, then this variable must be measured in the future in the exclosures. Failure to do so in 2007 prevented comparison of differences in browse over time between open and exclosed plots.

Second, if it is desired to calculate Stocking Rates for tree seedlings and saplings (Stout 1998, Hatfield and Krafft 2009), then Height Classes 1-2 and 8 must be measured in the future.

Lastly, it is noteworthy that so few significant differences are shown in Table 1. Power of the split-panel rotation design is much lower than if all 45 open plots were measured every year. Similarly, power may be low in the comparison of open and exclosed plots, due to the small number of pairs (n=6) and because only 2 years have been measured to date (2004 and 2007). Power will increase as more years and rotations are measured. Additional power could also be achieved for the split-panel rotation design if data from earlier years (i.e, 1990-1995, see Russek-Cohen 2003) were incorporated into the analyses. This should be considered for future analyses.

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