

National Park Service
U.S. Department of the Interior

Northeast Region
Natural Resource Stewardship and Science



Long Term Monitoring of Woodlot Plant Communities at Gettysburg National Military Park

Technical Report NPS/NERCHAL/NRTR-04/092



ON THE COVER

Bushman Hill woodlot in 1992.
Photograph by Todd Bowersox.

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March 2004

Updated version of June 2004

U.S. Department of the Interior
National Park Service
Northeast Region
Philadelphia, Pennsylvania

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This technical report was produced by the School of Forest Resources at The Pennsylvania State University under Cooperative Agreement 4000-8-9028, Supplemental Agreement No. 26, with the Northeast Region of the National Park Service.

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Please cite this report as:

Bowersox, T. W., D. S. Larrick, A. T. Niewinski, G. L. Storm, and W. M. Tzilkowski. March, 2004. Long term monitoring of woodlot plant communities at Gettysburg National Military Park. National Park Service, Northeast Region. Philadelphia, PA. Technical Report NPS/NERCHAL/NRTR-04/092.

Table of Contents

	Page
List of Figures	v
List of Tables	ix
List of Appendices	xv
Summary	xvii
Introduction.....	1
Methods.....	3
Demonstration Plots.....	3
Long Term Monitoring Plots	3
Canopy Treatment Plots.....	4
Results.....	7
Demonstration Plots.....	7
Long Term Monitoring Plots	26
Canopy Treatment Plots.....	80
Discussion.....	97
Demonstration Plots.....	97
Long Term Monitoring Plots	102
Canopy Treatment Plots.....	104
Literature Cited	109
Appendices.....	111

List of Figures

	Page
Figure 1. Density of tree and shrub seedlings (≤ 150 cm tall) by height class in the Fenced and Unfenced 10 x 10 m Demonstration Plots in Biesecker woodlot, Gettysburg National Military Park, in 1989, 1991, 1994, and 1996.....	9
Figure 2. Density of tree and shrub seedlings (≤ 150 cm tall) by height class in the Fenced and Unfenced 10 x 10 m Demonstration Plots in Pitzer woodlot, Gettysburg National Military Park, in 1989, 1991, 1994, and 1996.....	13
Figure 3. Density of tree and shrub seedlings (≤ 150 cm tall) by height class in the Fenced and Unfenced 10 x 10 m Demonstration Plots in Spangler woodlot, Gettysburg National Military Park, in 1989, 1991, 1994, and 1996.....	16
Figure 4. Density of tree and shrub seedlings (≤ 150 cm tall) by height class in the Fenced and Unfenced 10 x 10 m Demonstration Plots in Bushman Hill woodlot, Gettysburg National Military Park, in 1989, 1991, 1994, and 1996.....	19
Figure 5. Density of tree and shrub seedlings (≤ 150 cm tall) by height class in the Fenced and Unfenced 10 x 10 m Demonstration Plots in Cobean woodlot, Gettysburg National Military Park, in 1989, 1991, 1994, and 1996.....	22
Figure 6. Density of tree and shrub seedlings (≤ 150 cm tall) by height class in the Fenced and Unfenced 10 x 10 m Demonstration Plots in Slyder woodlot, Gettysburg National Military Park, in 1989, 1991, 1994, and 1996.....	25
Figure 7. Density of small and large sapling (>1.5 m in height and <12 cm dbh) and overstory (>1.5 m in height and ≥ 12 cm dbh) trees by diameter class (cm) in thirty 20 x 20 m Long Term Monitoring Plots in Biesecker woodlot, Gettysburg National Military Park, 1996.	27
Figure 8. Density of small and large sapling (>1.5 m in height and <12 cm dbh) and overstory (>1.5 m in height and ≥ 12 cm dbh) shrubs by diameter class (cm) in thirty 20 x 20 m Long Term Monitoring Plots in Biesecker woodlot, Gettysburg National Military Park, 1996.	30
Figure 9. Density of small and large sapling (>1.5 m in height and <12 cm dbh) and overstory (>1.5 m in height and ≥ 12 cm dbh) selected tree species in thirty 20 x 20 m Long Term Monitoring Plots in Biesecker woodlot, Gettysburg National Military Park, 1996.	34

List of Figures (continued)

	Page
Figure 10. Density of small and large sapling (>1.5 m in height and <12 cm dbh) and overstory (>1.5 m in height and $\geq$ 12 cm dbh) shrub species in thirty 20 x 20 m Long Term Monitoring Plots in Biesecker woodlot, Gettysburg National Military Park, 1996.	35
Figure 11. Density of small and large sapling (>1.5 m in height and <12 cm dbh) and overstory (>1.5 m in height and $\geq$ 12 cm dbh) trees by diameter class in thirty 20 x 20 m Long Term Monitoring Plots in Pitzer woodlot, Gettysburg National Military Park, 1996.	44
Figure 12. Density of small and large sapling (>1.5 m in height and <12 cm dbh) and overstory (>1.5 m in height and $\geq$ 12 cm dbh) shrubs by diameter class in thirty 20 x 20 m Long Term Monitoring Plots in Pitzer woodlot, Gettysburg National Military Park, 1996.	45
Figure 13. Density of small and large sapling (>1.5 m in height and <12 cm dbh) and overstory (>1.5 m in height and $\geq$ 12 cm dbh) selected tree species in thirty 20 x 20 m Long Term Monitoring Plots in Pitzer woodlot, Gettysburg National Military Park, 1996.	51
Figure 14. Density of small and large sapling (>1.5 m in height and <12 cm dbh) and overstory (>1.5 m in height and $\geq$ 12 cm dbh) shrub species in thirty 20 x 20 m Long Term Monitoring Plots in Pitzer woodlot, Gettysburg National Military Park, 1996.	52
Figure 15. Density of small and large sapling (>1.5 m in height and <12 cm dbh) and overstory (>1.5 m in height and $\geq$ 12 cm dbh) trees by diameter class in fifteen 20 x 20 m Long Term Monitoring Plots in Herr Ridge woodlot, Gettysburg National Military Park, 1996.	60
Figure 16. Density of small and large sapling (>1.5 m in height and <12 cm dbh) and overstory (>1.5 m in height and $\geq$ 12 cm dbh) shrubs by diameter class in fifteen 20 x 20 m Long Term Monitoring Plots in Herr Ridge woodlot, Gettysburg National Military Park, 1996.	63
Figure 17. Density of small and large sapling (>1.5 m in height and <12 cm dbh) and overstory (>1.5 m in height and $\geq$ 12 cm dbh) selected tree species in fifteen 20 x 20 m Long Term Monitoring Plots in Herr Ridge woodlot, Gettysburg National Military Park, 1996.	66

List of Figures (continued)

	Page
Figure 18. Density of small and large sapling (>1.5 m in height and <12 cm dbh) and overstory (>1.5 m in height and $\geq$ 12 cm dbh) shrub species in fifteen 20 x 20 m Long Term Monitoring Plots in Herr Ridge woodlot, Gettysburg National Military Park, 1996.	68
Figure 19. Density of small and large sapling (>1.5 m in height and <12 cm dbh) and overstory (>1.5 m in height and $\geq$ 12 cm dbh) trees by diameter class in fifteen 20 x 20 m Long Term Monitoring Plots in Spangler woodlot, Gettysburg National Military Park, 1996.	70
Figure 20. Density of small and large sapling (>1.5 m in height and <12 cm dbh) and overstory (>1.5 m in height and $\geq$ 12 cm dbh) shrubs by diameter class in fifteen 20 x 20 m Long Term Monitoring Plots in Spangler woodlot, Gettysburg National Military Park, 1996.	73
Figure 21. Density of small and large sapling (>1.5 m in height and <12 cm dbh) and overstory (>1.5 m in height and $\geq$ 12 cm dbh) selected tree species present in fifteen 20 x 20 m Long Term Monitoring Plots in Spangler woodlot, Gettysburg National Military Park, 1996.	77
Figure 22. Density of small and large sapling (>1.5 m in height and <12 cm dbh) and overstory (>1.5 m in height and $\geq$ 12 cm dbh) shrub species in fifteen 20 x 20 m Long Term Monitoring Plots in Spangler woodlot, Gettysburg National Military Park, 1996.	77
Figure 23. Average number of seedlings per hectare of tree, shrub, and total (tree and shrub) species in the Fenced and Unfenced 10 x 10 m Demonstration Plots in Biesecker, Bushman Hill, Cobean, Pitzer, Slyder, and Spangler woodlots, Gettysburg National Military Park, during the 1986-87 to 1996 surveys.....	98
Figure 24. Average number of seedlings per hectare of tree, shrub, and total (tree and shrub) species by height class in the Fenced and Unfenced 10 x 10 m Demonstration Plots in Biesecker, Bushman Hill, Cobean, Pitzer, Slyder, and Spangler woodlots, Gettysburg National Military Park, in the 1989, 1991, 1994, and 1996 surveys.....	99

List of Tables

	Page
Table 1. Density of tree and shrub seedlings (≤ 150 cm tall) by species and survey year in the Fenced and Unfenced 10 x 10 m Demonstration Plots in Biesecker woodlot, Gettysburg National Military Park, 1986-87 to 1996.	8
Table 2. Density of tree and shrub seedlings (≤ 150 cm tall) per hectare by species and survey year in the Fenced and Unfenced 10 x 10 m Demonstration Plots in Pitzer woodlot, Gettysburg National Military Park, 1986-87 to 1996.	11
Table 3. Density of tree and shrub seedlings (≤ 150 cm tall) per hectare by species and survey year in the Fenced and Unfenced 10 x 10 m Demonstration Plots in Spangler woodlot, Gettysburg National Military Park, 1986-87 to 1996.	14
Table 4. Density of tree and shrub seedlings (≤ 150 cm tall) per hectare by species and survey year in the Fenced and Unfenced 10 x 10 m Demonstration Plots in Bushman Hill woodlot, Gettysburg National Military Park, 1986-87 to 1996.	17
Table 5. Density of tree and shrub seedlings (≤ 150 cm tall) per hectare by species and survey year in the Fenced and Unfenced 10 x 10 m Demonstration Plots in Cobean woodlot, Gettysburg National Military Park, 1986-87 to 1996.	20
Table 6. Density of tree and shrub seedlings (≤ 150 cm tall) per hectare by species and survey year in the Fenced and Unfenced 10 x 10 m Demonstration Plots in Slyder woodlot, Gettysburg National Military Park, 1986-87 to 1996.	24
Table 7. Density, average diameter, and basal area of small sapling, large sapling, and overstory trees and shrubs in thirty 20 x 20 m Long Term Monitoring Plots in Biesecker woodlot, Gettysburg National Military Park, 1996.....	28
Table 8. Density, average diameter, and basal area of overstory tree and shrub species in thirty 20 x 20 m Long Term Monitoring Plots in Biesecker woodlot, Gettysburg National Military Park, 1996.....	29
Table 9. Density, average diameter, and basal area of large sapling tree and shrub species in thirty 20 x 20 m Long Term Monitoring Plots in Biesecker woodlot, Gettysburg National Military Park, 1996.....	31
Table 10. Density, average diameter, and basal area of small sapling tree and shrub species in thirty 20 x 20 m Long Term Monitoring Plots in Biesecker woodlot, Gettysburg National Military Park, 1996.	32
Table 11. Density of seedling tree and shrub species in eighteen 2 x 2 m Long Term Monitoring subplots in Biesecker woodlot, Gettysburg National Military Park, 1996.	36

List of Tables (continued)

	Page
Table 12. Average herbaceous coverage of grass, forb, vine, and total species in thirty 2 x 2 m Long Term Monitoring subplots in Biesecker woodlot, Gettysburg National Military Park, 1996.	36
Table 13. Density, average diameter, and basal area of overstory tree and shrub species by fence treatment in thirty 20 x 20 m Long Term Monitoring Plots in Biesecker woodlot, Gettysburg National Military Park, 1996.	37
Table 14. Density, average diameter, and basal area of large sapling tree and shrub species by fence treatment in thirty 20 x 20 m Long Term Monitoring Plots in Biesecker woodlot, Gettysburg National Military Park, 1996.	39
Table 15. Density, average diameter, and basal area of small sapling tree and shrub species by fence treatment in thirty 20 x 20 m Long Term Monitoring Plots in Biesecker woodlot, Gettysburg National Military Park, 1996.	40
Table 16. Density of seedling tree and shrub species by fence treatment in eighteen 2 x 2 m Long Term Monitoring subplots in Biesecker woodlot, Gettysburg National Military Park, 1996.	41
Table 17. Average herbaceous coverage of grass, forb, vine, and total species by fence treatment in thirty 2 x 2 m Long Term Monitoring subplots in Biesecker woodlot, Gettysburg National Military Park, 1996.	43
Table 18. Density, average diameter, and basal area of small sapling, large sapling, and overstory trees and shrubs in thirty 20 x 20 m Long Term Monitoring Plots in Pitzer woodlot, Gettysburg National Military Park, 1996.	46
Table 19. Density, average diameter, and basal area of overstory tree and shrub species in thirty 20 x 20 m Long Term Monitoring Plots in Pitzer woodlot, Gettysburg National Military Park, 1996.	47
Table 20. Density, average diameter, and basal area of large sapling tree and shrub species in thirty 20 x 20 m Long Term Monitoring Plots in Pitzer woodlot, Gettysburg National Military Park, 1996.	48
Table 21. Density, average diameter, and basal area of small sapling tree and shrub species in thirty 20 x 20 m Long Term Monitoring Plots in Pitzer woodlot, Gettysburg National Military Park, 1996.	49
Table 22. Density of seedling tree and shrub species in nineteen 2 x 2 m Long Term Monitoring subplots in Pitzer woodlot, Gettysburg National Military Park, 1996.	53

List of Tables (continued)

	Page
Table 23. Average herbaceous coverage for grass, forb, vine, and total species in thirty 2 x 2 m Long Term Monitoring subplots in Pitzer woodlot, Gettysburg National Military Park, 1996.	53
Table 24. Density, average diameter, and basal area of overstory tree and shrub species by fence treatment in thirty 20 x 20 m Long Term Monitoring Plots in Pitzer woodlot, Gettysburg National Military Park, 1996.	54
Table 25. Density, average diameter, and basal area of large sapling tree and shrub species by fence treatment in thirty 20 x 20 m Long Term Monitoring Plots in Pitzer woodlot, Gettysburg National Military Park, 1996.	56
Table 26. Density, average diameter, and basal area of small sapling tree and shrub species by fence treatment in thirty 20 x 20 m Long Term Monitoring Plots in Pitzer woodlot, Gettysburg National Military Park, 1996.	57
Table 27. Density of seedling tree and shrub species by fence treatment in nineteen 2 x 2 m Long Term Monitoring subplots in Pitzer woodlot, Gettysburg National Military Park, 1996.	58
Table 28. Average herbaceous coverage for grass, forb, vine, and total species by fence treatment in thirty 2 x 2 m Long Term Monitoring subplots in Pitzer woodlot, Gettysburg National Military Park, 1996.	58
Table 29. Density, average diameter, and basal area of small sapling, large sapling, and overstory trees and shrubs in fifteen 20 x 20 m Long Term Monitoring Plots in Herr Ridge woodlot, Gettysburg National Military Park, 1996.	61
Table 30. Density, average diameter, and basal area of overstory tree species in fifteen 20 x 20 m Long Term Monitoring Plots in Herr Ridge woodlot, Gettysburg National Military Park, 1996.	62
Table 31. Density, average diameter, and basal area of large sapling tree and shrub species in fifteen 20 x 20 m Long Term Monitoring Plots in Herr Ridge woodlot, Gettysburg National Military Park, 1996.	64
Table 32. Density, average diameter, and basal area of small sapling tree and shrub species in fifteen 20 x 20 m Long Term Monitoring Plots in Herr Ridge woodlot, Gettysburg National Military Park, 1996.	65

List of Tables (continued)

	Page
Table 33. Density of seedling tree and shrub species in thirteen 2 x 2 m Long Term Monitoring subplots in Herr Ridge woodlot, Gettysburg National Military Park, 1996.	69
Table 34. Average herbaceous coverage for grass, forb, vine, and total species in fifteen 2 x 2 m Long Term Monitoring subplots in Herr Ridge woodlot, Gettysburg National Military Park, 1996.	69
Table 35. Density, average diameter, and basal area of small sapling, large sapling, and overstory trees and shrubs in fifteen 20 x 20 m Long Term Monitoring Plots in Spangler woodlot, Gettysburg National Military Park, 1996.	71
Table 36. Density, average diameter, and basal area of overstory tree and shrub species in fifteen 20 x 20 m Long Term Monitoring Plots in Spangler woodlot, Gettysburg National Military Park, 1996.	72
Table 37. Density, average diameter, and basal area of large sapling tree and shrub species in fifteen 20 x 20 m Long Term Monitoring Plots in Spangler woodlot, Gettysburg National Military Park, 1996.	74
Table 38. Density, average diameter, and basal area of small sapling tree and shrub species in fifteen 20 x 20 m Long Term Monitoring Plots in Spangler woodlot, Gettysburg National Military Park, 1996.	75
Table 39. Density of seedling tree and shrub species in fifteen 2 x 2 m Long Term Monitoring subplots in Spangler woodlot, Gettysburg National Military Park, 1996.	78
Table 40. Average herbaceous coverage for grass, forb, vine, and total species in fifteen 2 x 2 m Long Term Monitoring subplots in Spangler woodlot, Gettysburg National Military Park, 1996.	78
Table 41. Density of seedling tree and shrub species in fifteen 2 x 2 m Long Term Monitoring subplots in Bushman Hill woodlot, Gettysburg National Military Park, 1996.	79
Table 42. Average herbaceous coverage for grass, forb, vine, and total species in fifteen 2 x 2 m Long Term Monitoring subplots in Bushman Hill woodlot, Gettysburg National Military Park, 1996.	79
Table 43. Density of seedling tree and shrub species in fifteen 2 x 2 m Long Term Monitoring subplots in Powers Hill woodlot, Gettysburg National Military Park, 1996.	81

List of Tables (continued)

	Page
Table 44. Average herbaceous coverage for grass, forb, vine, and total species in fifteen 2 x 2 m Long Term Monitoring subplots in Powers Hill woodlot, Gettysburg National Military Park, 1996.....	81
Table 45. Density of seedling (≤ 150 cm in height), sapling (> 150 cm in height and < 11 cm dbh), and overstory (> 1.5 m in height and ≥ 11 cm dbh) tree and shrub species in the Bushman Hill, Herr Ridge, and Powers Hill Canopy Treatment Plots four years after canopy treatment, Gettysburg National Military Park, 1996.	82
Table 46. Average number of species and density of overstory (> 1.5 m in height and ≥ 11 cm dbh) tree, shrub, and total species by woodlot, canopy treatment, and diameter class in Bushman Hill, Herr Ridge, and Powers Hill Canopy Treatment Plots four years after canopy treatment, Gettysburg National Military Park, 1996.	83
Table 47. Density of seedling (≤ 150 cm in height) and sapling (> 150 cm in height and < 11 cm dbh) tree and shrub species in Bushman Hill, Herr Ridge, and Powers Hill Canopy Treatment Plots two years after canopy treatment, Gettysburg National Military Park, 1994.	85
Table 48. Average number of species and density of sapling (> 1.5 m in height and < 11 cm dbh) tree, shrub, and total species by woodlot, canopy treatment, and diameter class in Bushman Hill, Herr Ridge, and Powers Hill Canopy Treatment Plots two years after canopy treatment, Gettysburg National Military Park, 1994.	86
Table 49. Average number of species and density of sapling (> 1.5 m in height and < 11 cm dbh) tree, shrub, and total species by woodlot, canopy treatment, and diameter class in Bushman Hill, Herr Ridge, and Powers Hill Canopy Treatment Plots four years after canopy treatment, Gettysburg National Military Park, 1996.	89
Table 50. Average number of species and density of seedling (≤ 150 cm in height) tree, shrub, and total species by woodlot, canopy treatment, and diameter class in Bushman Hill, Herr Ridge, and Powers Hill Canopy Treatment Plots two years after canopy treatment, Gettysburg National Military Park, 1994.....	91
Table 51. Average number of species and density of seedling (≤ 150 cm in height) tree, shrub, and total species by woodlot, canopy treatment, and diameter class in Bushman Hill, Herr Ridge, and Powers Hill Canopy Treatment Plots four years after canopy treatment, Gettysburg National Military Park, 1996.....	94
Table 52. Average herbaceous coverage of grass, forb, vine, and total species by woodlot and canopy treatment in Bushman Hill, Herr Ridge, and Powers Hill Canopy Treatment Plots two years after canopy treatment, Gettysburg National Military Park, 1994.	96

List of Tables (continued)

	Page
Table 53. Average herbaceous coverage of grass, forb, vine, and total species by woodlot and canopy treatment in Bushman Hill, Herr Ridge, and Powers Hill Canopy Treatment Plots four years after canopy treatment, Gettysburg National Military Park, 1996.	96

List of Appendices

	Page
Appendix A. Scientific and common names of tree and shrub species in Biesecker, Bushman Hill, Cobean, Pitzer, Slyder, and Spangler woodlot Demonstration Plots, Gettysburg National Military Park, from 1986-87 to 1996.....	111
Appendix B. Scientific and common names of tree and shrub species in Biesecker, Bushman Hill, Herr Ridge, Pitzer, Powers Hill, and Spangler woodlot Long Term Monitoring Plots, Gettysburg National Military Park, from 1990-92 to 1996.....	113
Appendix C. Scientific and common names of tree and shrub species in Bushman Hill, Herr Ridge, and Powers Hill Canopy Treatment Plots, Gettysburg National Military Park, from 1992 to 1996.	115

Summary

Long-term vegetation monitoring at Gettysburg National Military Park (NMP) is being conducted in the following three types of plots: Demonstration, Long Term Monitoring, and Canopy Treatment plots. Vegetation monitoring was started in 1986 with un-replicated Demonstration plots in six woodlots (Biesecker, Bushman Hill, Cobean, Pitzer, Slyder, and Spangler). From 1990 to 1992, the Long Term Monitoring plots were established in six woodlots (Biesecker, Bushman Hill, Herr Ridge, Pitzer, Powers Hill, and Spangler) to determine the status of woodlot plant communities with closed canopies and the effects of white-tailed deer foraging on understory vegetation. A set of Canopy Treatment plots was installed in 1992 to measure understory responses to creating openings in the canopy of three woodlots (Bushman Hill, Herr Ridge, and Powers Hill). The 1986-87 to 1994 data from Demonstration plots, the 1990-92 data from Long Term Monitoring plots, and the 1992 data from Canopy Treatment plots served as the baseline for long term monitoring of changes in woody and herbaceous vegetation. This report (1) describes the status of woodlot plant communities in the Demonstration and Long Term Monitoring plots in 1996, and in the Canopy Treatment plots from 1994-1996, and (2) assesses the effects of various sized openings in the overstory canopy and foraging by white-tailed deer on understory vegetation prior to the park's Deer Management Program in 1995.

The Demonstration plots consist of six pairs of un-replicated fenced and unfenced 10 x 10 m plots that were intended to provide information on the development of vegetation with and without the presence of white-tailed deer. Surveys of tree and shrub seedling-sized stems were conducted in each of the six woodlots in 1986-87, 1989, 1991, 1994, and 1996, whereas herbaceous plants and vines were only surveyed in Biesecker and Bushman Hill woodlots in 1992.

The Long Term Monitoring plots used a fixed plot monitoring system to survey overstory, sapling, and seedling trees and shrubs and herbaceous, ground, and vine coverages in each of the six woodlots. For measuring overstory and sapling stems, thirty 20 x 20 m plots were established in each of Biesecker and Pitzer woodlots and fifteen 20 x 20 m plots were established in each of Herr Ridge, Spangler, Bushman Hill, and Powers Hill woodlots. For measuring seedlings and herbaceous, ground, and vine coverages, fifteen fenced 2 x 2 m subplots and fifteen unfenced 2 x 2 m subplots were established in each of Biesecker and Pitzer woodlots, and fifteen unfenced 2 x 2 m subplots were established in each of Herr Ridge, Spangler, Bushman Hill, and Powers Hill woodlots. In 1996, overstory and sapling tree and shrub stems were surveyed in Biesecker, Pitzer, Herr Ridge, and Spangler woodlots, while seedlings and herbaceous coverage were surveyed in all six woodlots.

The Canopy Treatment plots consisted of three 0.20 ha circular canopy treatments (closed, partially open, and open canopies). Each treatment was replicated three times within each of the three woodlots. Each canopy treatment area contained a 20 x 20 m plot and a 2 x 2 m subplot. Overstory stems were surveyed in 1992 and 1996 in each 0.20 ha treatment area, whereas sapling stems were surveyed in 1992, 1994, and 1996 in each 20 x 20 m plot. Seedling stems and herbaceous vegetation were surveyed in 1992, 1994, and 1996 in each 2 x 2 m subplot.

In the Demonstration plots, general trends from 1986-87 to 1996 were (1) the number of tree and shrub seedling species increased, (2) tree seedling density decreased, and (3) shrub seedling density increased. In the Long Term Monitoring plots, general trends from 1990-92 to 1996 were (1) overstory, large sapling, and small sapling tree species decreased, (2) large and small sapling tree densities decreased, (3) overstory and sapling densities of oak species decreased, (4) total tree seedling and oak seedling densities decreased, and (5) seedling densities of non-native Japanese barberry and multiflora rose increased. In summary, the general trends over all Canopy Treatments from 1994 to 1996 for herbaceous plants, seedlings, and saplings were (1) grass, forb, vine, and total herbaceous coverage increased (except vine coverage decreased in the open canopy treatments), (2) seedling tree species and density decreased, seedling shrub species increased (except in the partially open canopy treatments), and seedling shrub densities decreased (except in the open canopy treatments), and (3) sapling tree species decreased (except in the open canopy treatments), sapling shrub species decreased, and sapling tree and shrub densities decreased.

From the collective data of Demonstration, Long Term Monitoring, and Canopy Treatment plots, it is recommended that (1) creating openings in the canopy, (2) controlling deer herd densities, and (3) reducing non-native herbaceous and shrub species should be considered in order to maintain the mixed oak woodlots with native species diversity at Gettysburg National Military Park.

Introduction

Gettysburg National Military Park (NMP) was established in 1895 to commemorate the July 1863 Civil War battle. Before the battle, the woodlots were important resources for the residents. Historic photographs and documents and recent reports (Fairweather and Cavanaugh 1990, Storm *et al.* 1995) suggest a general pattern to the 1863 condition and subsequent development of these woodlots. Open-grown white oak (*Quercus alba* L.) was the dominant vegetation in the 1863 woodlots that were being used as pastures. The park presently incorporates about 2,423 ha, with 799 ha occupied by woodlots and woodlands ranging in size from 2 to 24 ha (USDI 1999).

Woodlot management practices and foraging by white-tailed deer (*Odocoileus virginianus*) may be influencing the species composition of the understory at Gettysburg NMP (Bowersox *et al.* 1993, Tzilkowski *et al.* 1993). Before the battle, the woodlots had an uneven-aged structure that was maintained by frequent partial cutting. However, when the park was established all tree cutting practices in the woodlots were ended. This allowed for the development of second and third groups of trees, mainly oaks (*Quercus* spp.), hickories (*Carya* spp.), cherries (*Prunus* spp.), flowering dogwood (*Cornus florida* L.), and white ash (*Fraxinus americana* L.). There were virtually no white-tailed deer at Gettysburg NMP between 1863 and 1970. The deer population of a 2,862 ha area on and around the park has been monitored since 1987 according to procedures described by Storm *et al.* (1992). From 1990-1995, the deer density was 1.47 deer/ha of forested land. In comparison, the park's deer density goal is 0.10 deer/forested ha (USDI National Park Service 1996).

Long-term vegetation monitoring was started at Gettysburg NMP in 1986 with Demonstration plots in six woodlots (Biesecker, Bushman Hill, Cobean, Pitzer, Slyder, and Spangler). Six pairs of un-replicated fenced and unfenced plots were intended to demonstrate differences in the development of vegetation with and without the presence of deer. To describe the status of closed canopy woodlot plant community conditions and the effects of deer foraging on understory vegetation, sets of Long Term Monitoring plots were established in 1990-92 in six woodlots (Biesecker, Bushman Hill, Herr Ridge, Pitzer, Powers Hill, and Spangler). Finally, to evaluate understory responses to creating openings in the canopy, replicated Canopy Treatment plots (closed, partially open, and open canopy) were installed in three woodlots (Bushman Hill, Herr Ridge, and Powers Hill) in 1992.

The 1986-1994 data from Demonstration plots and the 1990-92 data from Long Term Monitoring plots were summarized in Storm *et al.* (1995). The 1992 data from Canopy Treatment plots were presented in Bowersox *et al.* (1992). Results specific to the regeneration response to the canopy treatments are summarized in Bowersox *et al.* (2002). These studies provided reference data by which future changes in woody and herbaceous vegetation could be assessed. The present study describes the 1996 status of woodlot plant communities in the Demonstration and Long Term Monitoring plots and the 1994-1996 status of the Canopy Treatment plots. Further, data from the present study were evaluated in conjunction with those from previous surveys to determine the long-term effects of variable light levels and foraging by white-tailed deer on the development of understory vegetation at Gettysburg National Military Park.

Methods

Demonstration Plots

A pair of fenced and unfenced plots was established in each of three woodlots [Slyder (Granite Farm), Pitzer, and Spangler] during 1985 and in each of three woodlots (Biesecker, Bushman Hill, and Cobean) during 1986. Fenced plots were 10 x 10 m, constructed of 5 x 10 cm welded mesh wire, and supported by cedar posts and steel pipes. Each fence was 2.4 m in height. Detailed survey procedures and locations of all Demonstration plots are presented in Storm *et al.* (1995).

Surveys of tree and shrub seedlings were conducted in 1986-87, 1989, 1991, 1994, and 1996. The 1986-87 and 1991 surveys were conducted in subplots within the 10 x 10 m plots. In 1986-87, seedling stems ≤ 100 cm tall were recorded by species in four circular 2.0 m² subplots, whereas in 1991, the number of seedlings (stems ≤ 150 cm tall) was surveyed in four square 1.0 m² subplots. In 1989, 1994, and 1996, the number of stems was counted in each of the entire 10 x 10 m plots. Height classes were <26, 26-50.9, 51-75.9, and 76-100.9 cm in 1989. Two additional height classes, 101-125.9 and 126-150 cm, were included for the 1994 and 1996 surveys. In Biesecker and Bushman Hill woodlots, species composition and abundance of herbaceous plants and vines were measured in 1992 in two square 1.0 m² subplots within each 10 x 10 m plot.

Long Term Monitoring Plots

In 1990-92, a fixed plot monitoring system (Storm and Ross 1992) was implemented to survey herbaceous vegetation, shrubs, trees, and ground cover condition in Biesecker, Bushman Hill, Herr Ridge, Pitzer, Powers Hill, and Spangler woodlots. White oak-black oak (*Q. velutina* Lam.)-northern red oak (*Q. rubra* L.) was the primary forest type associated with each of the six woodlots. Detailed survey procedures and locations of Long Term Monitoring plots were presented in Storm *et al.* (1995). For measuring overstory, large sapling, and small sapling trees and shrubs, thirty 20 x 20 m (0.04 ha) plots were established in each of Biesecker and Pitzer woodlots and fifteen 20 x 20 m plots were established in each of Herr Ridge, Spangler, Bushman Hill, and Powers Hill woodlots. Overstory stems were >1.5 m in height and ≥ 12 cm dbh (diameter at 1.35 m above ground). Large saplings were >1.5 m in height and 2-11.9 cm dbh. Small saplings were >1.5 m in height and <2 cm dbh. For measuring seedling (≤ 150 cm in height) tree and shrub stems, and herbaceous, ground, and vine coverage values, fifteen fenced 2 x 2 m subplots and fifteen unfenced 2 x 2 m subplots were established within the 20 x 20 m plots in each of Biesecker and Pitzer woodlots and fifteen unfenced 2 x 2 m subplots were established within the 20 x 20 m plots in each of Herr Ridge, Spangler, Bushman Hill, and Powers Hill woodlots. Herbaceous coverage included grass, sedge, forb, and moss-lichen. Ground coverage included rock/mineral soil, litter, dead and down woody material, and non-woody (inorganic) material. Vine coverage was estimated in two height zones (≤ 2 m above ground and >2 m above ground). Biesecker and Pitzer woodlots were initially surveyed from 1990-1991. Spangler woodlot was first surveyed from 1991-1992. Bushman Hill, Herr Ridge, and Powers Hill were initially surveyed in 1992.

In 1996, overstory, large sapling, and small sapling trees and shrubs were surveyed in each 20 x 20 m plot in Biesecker, Pitzer, Herr Ridge, and Spangler woodlots (not in Bushman Hill or Powers Hill). The diameter of each stem was used to calculate an average diameter and basal area (m^2 per ha) for each species. Density (stems per ha) was also calculated for each overstory, large sapling, and small sapling tree and shrub species. Average diameter was the summation of the diameters of all stems of the specified component divided by the appropriate number of stems. Density and basal area values for overstory and sapling components of each woodlot were determined by summing over all stems in the appropriate plots and dividing by the appropriate area. For Biesecker and Pitzer woodlots, density, average diameter, and basal area were calculated for each species by fence treatment. Analysis of variance was used to test for significant ($\alpha = 0.05$) differences in density and basal area between the fenced and unfenced treatments. In Biesecker, Pitzer, Herr Ridge, Spangler, Bushman Hill, and Powers Hill woodlots, the number of tree and shrub seedlings and coverage of grass, forb, vine, and total herbaceous vegetation were surveyed in each 2 x 2 m subplot. Densities and coverages were calculated for fenced and unfenced subplots in Biesecker and Pitzer woodlots and analysis of variance was used to determine the effects of fencing treatment on seedling stems and herbaceous vegetation.

Canopy Treatment Plots

In 1992, replicated plots were installed in three woodlots (Bushman Hill, Herr Ridge, and Powers Hill) to evaluate understory responses to creating openings in the canopy. Three 0.20 ha circular canopy treatments (closed, partially open, and open) were assigned within each woodlot. Each treatment was replicated three times within each woodlot. There was a total of 27 treatment units. Directional felling was used to uniformly distribute the residue over the treatment units. To preserve the archeological resources in each woodlot, no disturbance to the soil was permitted when the canopy trees were felled. Therefore, no material was removed from the treatment units. Boles and branches were cut to place all material within 1.0 m of the ground. No trees were felled in the closed canopy treatments, whereas all stems >2 cm dbh were cut down in the open canopy treatments. In the partially open treatments, single-tree felling achieved a modified q of two (5 cm in diameter classes) structure (Bowersox *et al.* 1993), with the goal at 50 to 60% of the fully stocked level. Average stocking levels (Roach and Gingrich 1968) in the closed canopy treatments were 115, 110, and 99% for Bushman Hill, Herr Ridge, and Powers Hill woodlots, respectively. In the partially open treatments, average stocking levels by woodlot were 53, 55, and 52%, respectively. The 1992 pre-treatment data were presented in Bowersox *et al.* (1992) and Bowersox *et al.* (2002). Two additional surveys were completed in 1994 and 1996.

Each 0.20 ha canopy treatment area contained a 20 x 20 m plot and a 2 x 2 m subplot. Overstory tree and shrub stems (>1.5 m in height and ≥ 11 cm dbh- diameter at 1.35 m above ground) were surveyed in 1992 and 1996 in each 0.20 ha treatment area. Sapling trees and shrubs (>1.5 m in height and <11 cm dbh) were surveyed in 1992, 1994, and 1996 in each 20 x 20 m plot. Seedling trees and shrubs (≤ 150 cm in height) and herbaceous vegetation were surveyed in 1992, 1994, and 1996 in each 2 x 2 m subplot. From the 1994 and 1996 data, density (stems per ha) was calculated for the overstory, sapling, and seedling tree and shrub species, and percent coverage was determined for grass, forb, vine, and total herbaceous vegetation. Analysis of variance ($\alpha = 0.05$) was used to determine the effects of woodlot and canopy treatment on

number of species and density of overstory, sapling, and seedling tree, shrub, and total species, by size class. For grass, forb, vine, and total herbaceous vegetation, the main effects tested were woodlot and canopy treatment. Average separations were performed on appropriate parameters with Tukey's method of multiple comparisons.

Results

Demonstration Plots

Biesecker Woodlot

The number of tree seedling species recorded in the fenced plot was nine in 1986-87, nine in 1989, seven in 1991, eleven in 1994, and eight in 1996, indicating species richness was similar during the sampling period (Appendix A). The density of tree seedlings in the fenced plot declined from 102,000 stems per ha in 1986-87 to 14,000 stems per ha in 1996 (Table 1). Black cherry (*Prunus serotina* Ehrh.) was the most abundant tree seedling in the fenced plot from 1986-87 through 1996; however, the density of black cherry decreased from 73,000 to 9,000 stems per ha over the 10-year period (Table 1).

The number of tree seedling species recorded in the unfenced plot was five in 1986-87, seven in 1989, three in 1991, six in 1994, and three in 1996, indicating changes in tree species richness over the inventory period. The density of tree seedlings in the unfenced plot decreased from 49,000 stems per ha in 1986-87 to 2,000 stems per ha in 1996 (Table 1). In 1986-87, the most abundant tree seedlings in the unfenced plot were ash (*Fraxinus spp.*) (28,000 stems per ha) and white oak (14,000 stems per ha). By 1996, ash totaled <1,000 stems per ha, while white oak was not recorded in the unfenced plot (Table 1).

The number of shrub seedling species recorded in the fenced plot was two in 1986-87, four in 1989, two in 1991, seven in 1994, and seven in 1996, indicating an increasing trend in shrub species richness during the sampling period. In the fenced plot, the density of shrub seedlings increased from 1,000 stems per ha in 1986-87 to 6,000 stems per ha in 1996 (Table 1). In 1991 and 1994, *Rubus* was the dominant shrub species in the fenced plot (13,000 and 6,000 stems per ha, respectively). In 1996, shrubs exhibited uniform seedling densities among the seven species present (Table 1).

The number of shrub seedling species recorded in the unfenced plot was one in 1986-87, four in 1989, two in 1991, four in 1994, and three in 1996, indicating a slight increase in shrub species richness over the inventory period. In the unfenced plot, total shrub seedling density was 1,000 stems per ha in the 1986-87, 1994, and 1996 surveys. The greatest unfenced shrub seedling density was 6,000 stems per ha recorded in 1991 (Table 1). *Rubus* was the most abundant species in the unfenced (4,000 stems per ha) plot in 1991. During the other surveys, the shrub seedling density was evenly distributed among the species.

The density of tree seedlings <26 cm in height in the fenced plot decreased slightly from 22,000 stems per ha in 1989 to 19,000 stems per ha in 1994, but by 1996, tree seedling density dropped to 5,000 stems per ha (Figure 1). Density of tree seedlings $\geq$ 26 cm in height in the fenced plot decreased from 15,000 stems per ha in 1989 to 9,000 stems per ha in 1996. In the unfenced plot, density of tree seedlings <26 cm in height increased slightly from 1989 (26,000 stems per ha) to 1994 (29,000 stems per ha), but significantly decreased to 2,000 stems per ha in 1996. No tree seedlings $\geq$ 26 cm in height were recorded in the unfenced plot in 1996 (Figure 1).

Table 1. Density of tree and shrub seedlings (≤ 150 cm tall) by species and survey year in the Fenced and Unfenced 10 x 10 m Demonstration Plots in Biesecker woodlot, Gettysburg National Military Park, 1986-87 to 1996.^a

Species	Survey Year									
	1986-87		1989		1991		1994		1996	
	Fenced	Unfenced	Fenced	Unfenced	Fenced	Unfenced	Fenced	Unfenced	Fenced	Unfenced
	-----Seedlings (x1000) per hectare-----									
Ash	6	28	2	24	2	19	3	28	1	b
Blackgum							b		1	
Cedar, eastern red			b				b			
Cherry, sweet	14	2	3	b	9		4	1	b	
Cherry, black	73	6	26	3	44	6	12	1	9	b
Elm	1		1		1		1		1	
Hickory, mockernut		1			1	1	2	1	2	1
Hickory, pignut	1		1	1			b			
Hickory, shagbark	1		b	b	1					
Maple, Norway								b		
Maple, red	2						b			
Oak, black				1				b	b	
Oak, chestnut	1									
Oak, northern red			b		1		b			
Oak, white	8	14	3	2			2		1	
Total Tree	102	49	37	29	60	26	29	31	14	2
Barberry, Japanese			2	b						
Blackhaw, smooth			b	1			b	b	1	b
Dogwood, flowering			b				b		1	b
Grape							b		1	
Greenbriar									b	
Rosa					2		b			
Rubus					13	4	6	b	1	
Sassafras	1	1					1		2	b
Serviceberry	1		2	b		2	5	1	b	
Spicebush				b				b		
Total Shrub	1	1	4	2	14	6	13	1	6	1
Total Tree and Shrub	103	50	41	31	74	32	42	32	19	2

^a Values for the 1986-87 survey were averages from four circular 2.0 m² subplots in each 10 x 10 m plot in 1986 and 1987 (16 m²); 1989 and 1994 survey values were from the entire 10 x 10 m plot (100 m²); and 1991 survey values were averages from four square 1.0 m² plots at four locations in each 10 x 10 m plot (16 m²). Values within columns may not add up to the value for Total Tree, Total Shrub, or Total Tree and Shrub due to rounding.

^b Present but <1.

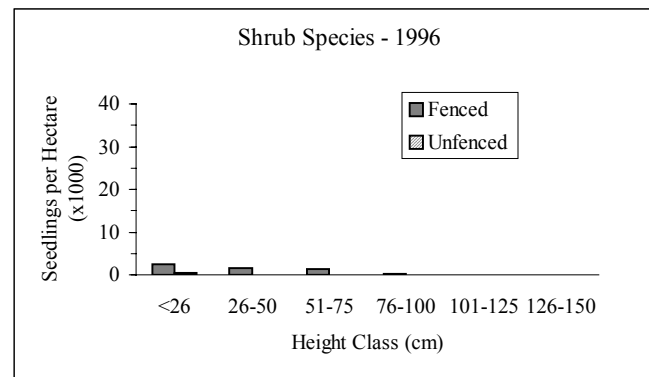
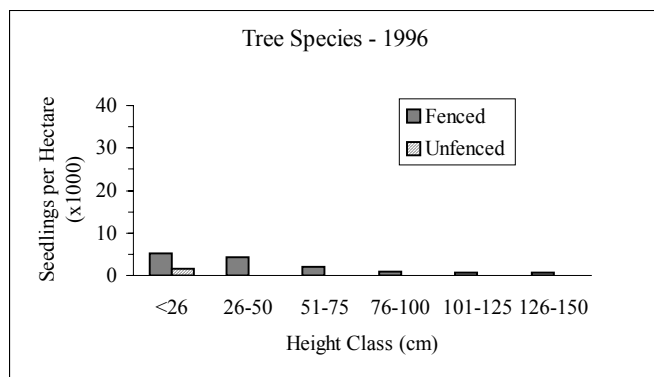
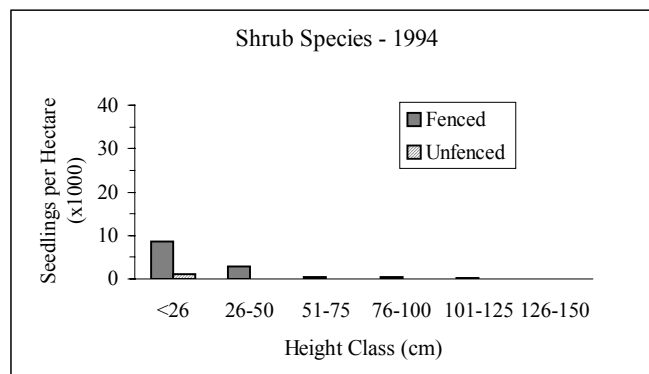
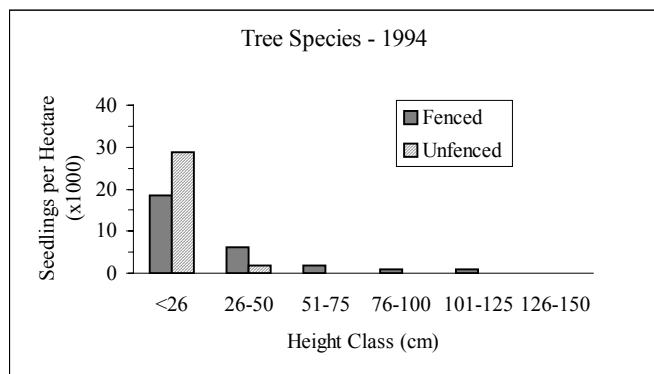
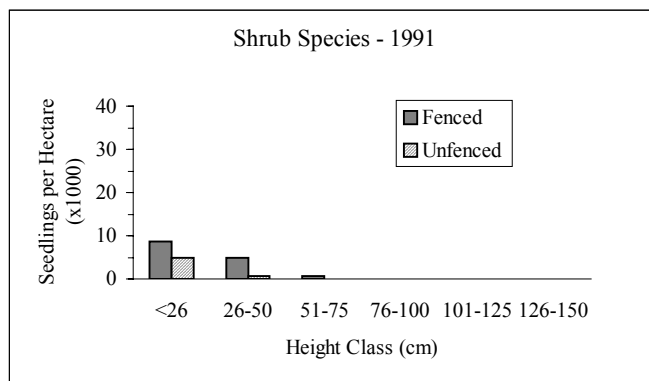
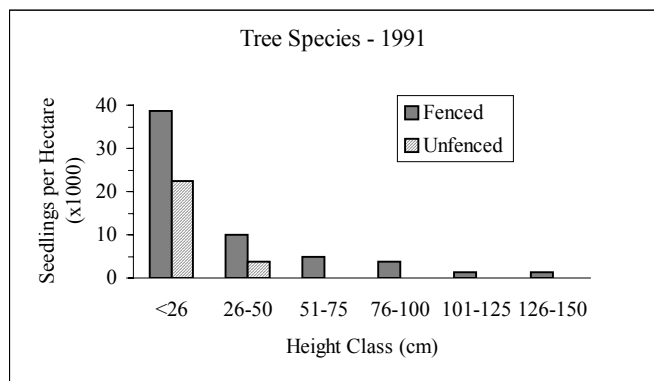
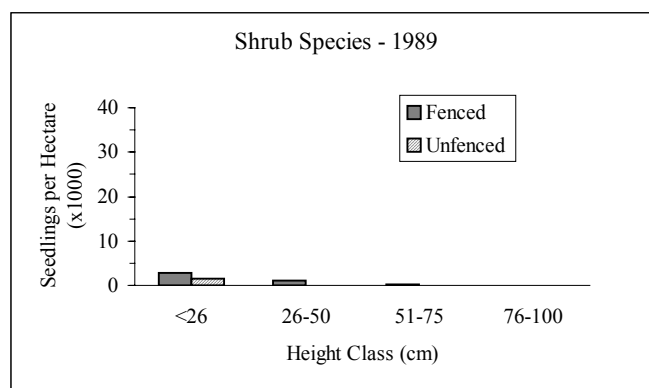
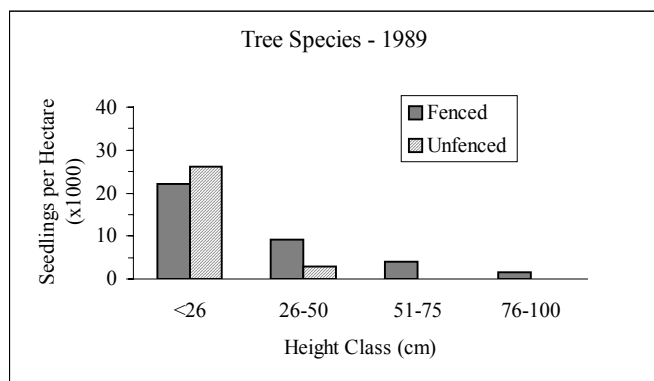


Figure 1. Density of tree and shrub seedlings (≤ 150 cm tall) by height class in the Fenced and Unfenced 10 x 10 m Demonstration Plots in Biasecker woodlot, Gettysburg National Military Park, in 1989, 1991, 1994, and 1996.

The density of shrub seedlings <26 cm in height in the fenced plot was 3,000 stems per ha at each of the 1989 and 1996 surveys (Figure 1). Density of shrubs ≥ 26 cm in height increased from 1,000 stems per ha in 1989 to 3,000 stems per ha in 1996 in the fenced plot. In the unfenced plot, shrub seedling density decreased from 1989 (2,000 stems per ha) to 1996 (1,000 stems per ha) for stems <26 cm in height. After 1991, no shrub seedlings ≥ 26 cm in height were recorded in the unfenced plot (Figure 1).

In 1992, four herbaceous and vine species were found along the line-transects in the fenced subplot and none were found in the unfenced subplot. For the line-transect data in the fenced subplot, the Shannon Diversity and Evenness indices were 0.561 and 0.932, respectively. Five herbaceous and vine species were found in the fenced subplot and two herbaceous species were found in the unfenced subplot, based on the line-transect data and a complete search of the two subplots. Spring beauty (*Claytonia virginica* L.) was the only species common to both fenced and unfenced subplots.

Pitzer Woodlot

The number of tree seedling species recorded in the fenced plot was four in 1986-87, eight in 1989, five in 1991, nine in 1994, and eight in 1996, indicating no consistent trend in tree species richness during the sampling period (Table 2). The density of tree seedlings decreased from 23,000 to 14,000 stems per ha in the fenced plot over the 10-year sampling period. White oak and black cherry were consistently the most abundant tree seedlings in the fenced plot, with the exception of ash in 1986-87 (Table 2). The densities of white oak and black cherry seedlings were generally higher in the fenced plot compared to the unfenced plot from 1986-87 to 1996. In 1996, black cherry seedling density was 4,000 stems per ha in the fenced plot, compared to <1,000 stems per ha in the unfenced plot. White oak fenced seedling density was 8,000 stems per ha in 1996, whereas white oak was not present in the unfenced plot (Table 2).

The number of tree seedling species recorded in the unfenced plot was five in 1986-87, nine in 1989, four in 1991, eight in 1994, and four in 1996, indicating no consistent trend in tree species richness during the sampling period. The density of tree seedlings decreased from 16,000 to 1,000 stems per ha in the unfenced plot over the 10-year sampling period (Table 2).

The number of shrub seedling species recorded in the fenced plot was one in 1986-87, two in 1989, one in 1991, four in 1994, and five in 1996, indicating a slight increase in shrub species richness during the sampling period (Table 2). The density of shrub seedlings in the fenced plot increased from 1,000 stems per ha in 1986-87 to 9,000 stems per ha in 1994, then decreased to 3,000 stems per ha in 1996. *Rubus* and smooth blackhaw (*Viburnum prunifolium* L.) were the most abundant shrub species, with seedling densities generally higher in the fenced plot than in the unfenced plot (Table 2).

The number of shrub seedling species recorded in the unfenced plot was three in 1986-87, one in 1989, three in 1991, four in 1994, and one in 1996, indicating an undulating trend in species richness over time (Table 2). Shrub seedling density in the unfenced plot exhibited a similar trend as in the fenced plot. The density increased from 3,000 to 7,000 stems per ha between 1986-87 and 1991, but then decreased to <1,000 stems per ha in 1996 (Table 2).

Table 2. Density of tree and shrub seedlings (≤ 150 cm tall) per hectare by species and survey year in the Fenced and Unfenced 10 x 10 m Demonstration Plots in Pitzer woodlot, Gettysburg National Military Park, 1986-87 to 1996.^a

Species	1986-87		1989		1991		1994		1996	
	Fenced	Unfenced	Fenced	Unfenced	Fenced	Unfenced	Fenced	Unfenced	Fenced	Unfenced
-----Seedlings (x1000) per hectare-----										
Ash	8		1	b	1		1	1	b	b
Cedar, eastern red	1		2	b	1	1	1	b	1	b
Cherry, sweet		1	b	b			2	1	b	
Cherry, black	3	4	4	2	14	4	5	5	4	b
Elm			b							
Hickory, mockernut					2	2	1	b	b	b
Hickory, shagbark		1	1	1			1	3		
Locust, black				b						
Oak, black			1	b			1		b	
Oak, chestnut		1								
Oak, northern red				b			1	1	b	
Oak, white	19	3	11	3	11	3	10	1	8	
Total Tree	23	16	19	7	28	9	21	12	14	1
Barberry, Japanese									b	
Black-haw, smooth	1	1	2	1			2	b	2	b
Dogwood, flowering							b		b	
Grape		1						b		
Honeysuckle, Tartarian						b				
Redbud, eastern		1								
Rosa						b				
Rubus					3	7	5	2	1	
Serviceberry			b				1	b	b	
Total Shrub	1	3	2	1	3	7	9	3	3	b
Total Tree and Shrub	24	18	21	8	31	16	30	15	17	1

^a Values for the 1986-87 survey were averages from four circular 2.0 m² subplots in each 10 x 10 m plot in 1986 and 1987 (16 m²); 1989 and 1994 survey values were from the entire 10 x 10 m plot (100 m²); and 1991 survey values were averages from four square 1.0 m² plots at four locations in each 10 x 10 m plot (16 m²). Values within columns may not add up to the value for Total Tree, Total Shrub, or Total Tree and Shrub due to rounding.

^b Present but <1.

The density of tree seedlings <26 cm in height decreased in the fenced plot from 18,000 stems per ha in 1989 to 8,000 stems per ha 1996 (Figure 2). Conversely, the density of tree seedlings ≥ 26 cm in height increased in the fenced plot from 1989 (1,000 stems per ha) to 1996 (6,000 stems per ha). Density of unfenced tree seedlings <26 cm in height decreased from 6,000 to 1,000 stems per ha from 1989 to 1996. The density of unfenced tree seedlings ≥ 26 cm in height generally was <1,000 stems per ha from 1989 to 1996, with no recorded stems ≥ 51 cm in height over the sampling period (Figure 2).

The density of shrub seedlings <26 cm in height increased in the fenced plot from 1989 (2,000 stems per ha) to 1994 (4,000 stems per ha), then sharply decreased in 1996 (1,000 stems per ha) (Figure 2). Likewise, density of fenced shrubs ≥ 26 cm in height increased from 1989 (<1,000 stems per ha) to 1994 (4,000 stems per ha), then decreased in 1996 (2,000 stems per ha). In 1991, density of unfenced shrubs <26 cm in height was 7,000 stems per ha, but in 1996, shrub density had decreased to <1,000 stems per ha. In 1994, unfenced shrub density was 1,000 stems per ha for seedlings ≥ 26 cm in height. In 1996, no unfenced shrubs ≥ 26 cm in height were recorded (Figure 2).

Spangler Woodlot

The number of tree seedling species recorded in the fenced plot was five in 1986-87, seven in 1989, six in 1991, ten in 1994, and six in 1996, indicating a doubling in species richness between the first and fourth surveys, but then a slight decrease in 1996 (Table 3). The density of tree seedlings increased from 57,000 stems per ha in 1986-87 to 96,000 stems per ha in 1989; however, it decreased substantially to only 7,000 stems per ha in 1996. In 1986-87, white oak, ash, and black cherry were the most abundant tree seedling species in both the fenced and unfenced plots. The density of white oak seedlings in the fenced plot steadily declined over the sampling period from 20,000 stems per ha in 1986-87 to zero seedlings in 1996. The density of ash and black cherry did not decrease significantly until 1996, when the fenced and unfenced plots contained 5,000 and 0 stems per ha, respectively, of ash species and 1,000 and 0 stems per ha, respectively, of black cherry (Table 3).

The number of tree seedling species recorded in the unfenced plot was five in 1986-87, ten in 1989, four in 1991, seven in 1994, and zero in 1996, indicating consistent change in the species richness during the sampling period (Table 3). The density of tree seedlings in the unfenced plot steadily decreased from 55,000 stems per ha in 1986-87 to zero stems recorded in 1996. The density of white oak seedlings in the unfenced plot steadily declined over the sampling period from 20,000 stems per ha in 1986-87 to zero seedlings in 1991 (Table 3).

The number of shrub seedling species recorded in the fenced plot was two in 1986-87, five in 1989, three in 1991, seven in 1994, and five in 1996, indicating an overall increase in shrub species richness during the sampling period (Table 3). The density of shrub seedlings increased from 4,000 stems per ha in 1986-87 to 12,000 stems per ha in 1994, but then decreased to 1,000 stems per ha in 1996. Smooth blackhaw and *Rubus* were the dominant shrub seedling species in both the fenced and unfenced plots between 1986-87 and 1994. In 1996, Japanese barberry was the most abundant shrub in the fenced plot (1,000 stems per ha) and was the only recorded shrub (<1,000 stems per ha) in the unfenced plot (Table 3).

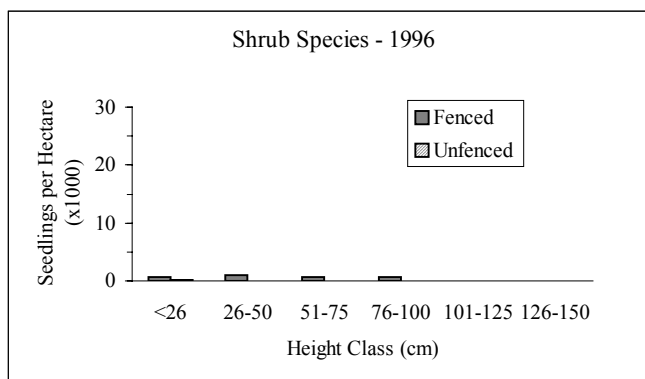
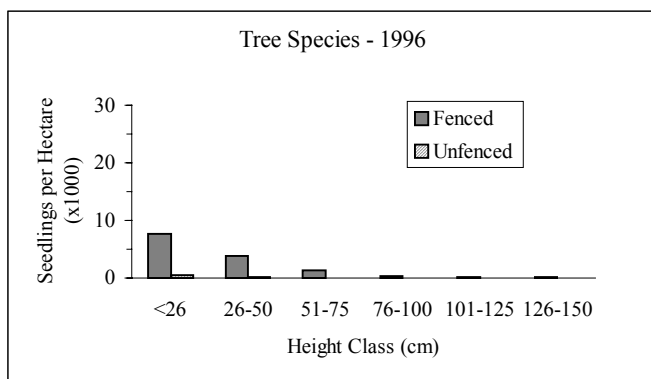
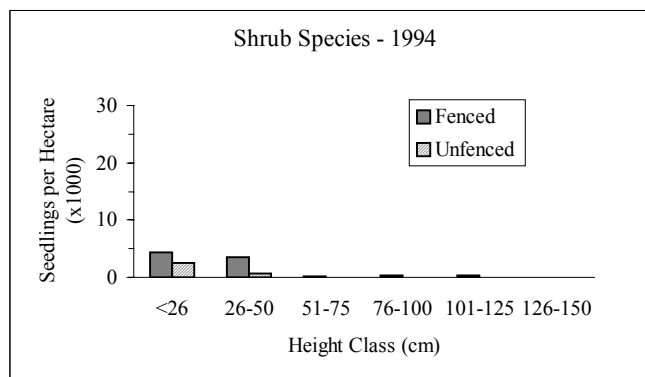
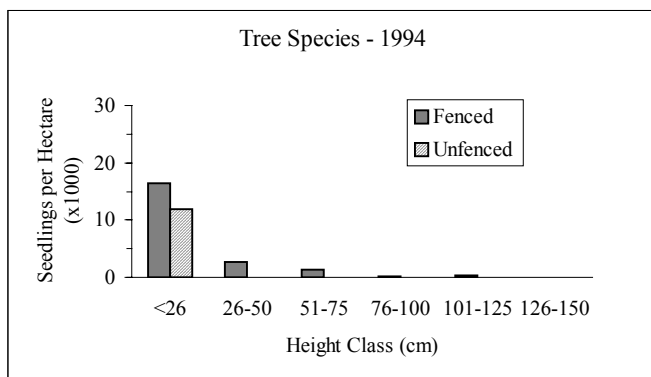
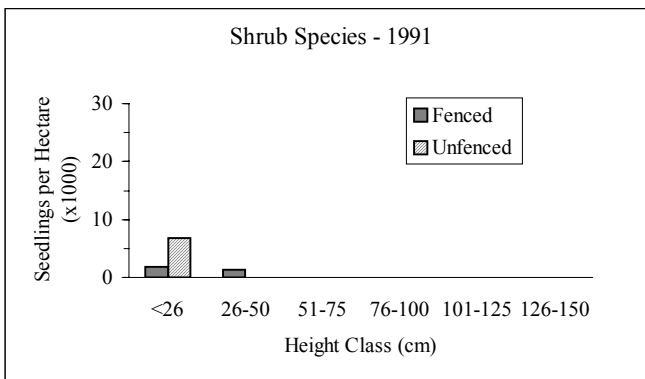
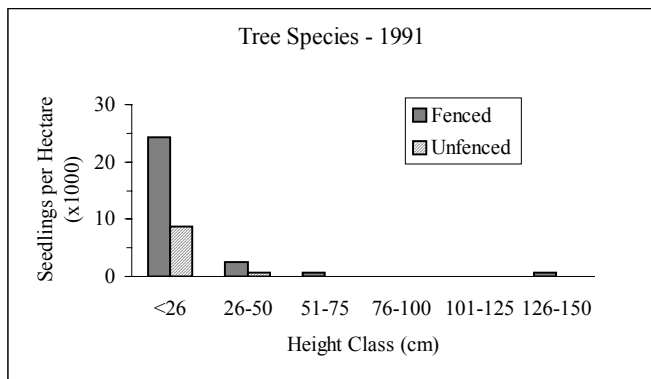
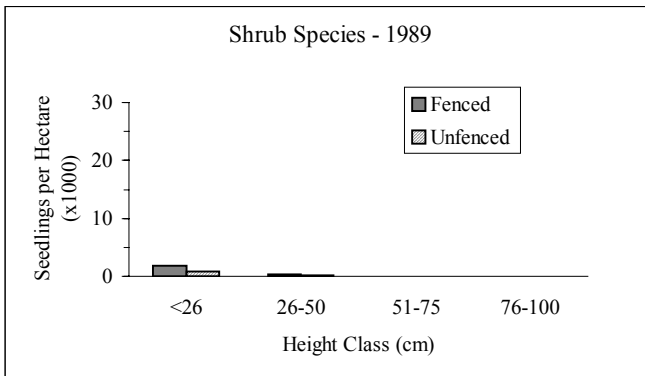
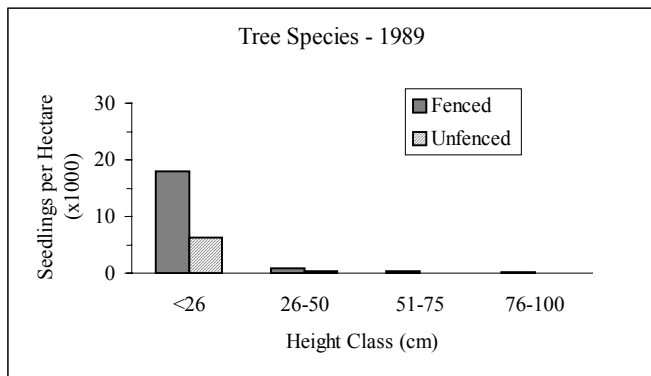


Figure 2. Density of tree and shrub seedlings (≤ 150 cm tall) by height class in the Fenced and Unfenced 10 x 10 m Demonstration Plots in Pitzer woodlot, Gettysburg National Military Park, in 1989, 1991, 1994, and 1996.

Table 3. Density of tree and shrub seedlings (≤ 150 cm tall) per hectare by species and survey year in the Fenced and Unfenced 10 x 10 m Demonstration Plots in Spangler woodlot, Gettysburg National Military Park, 1986-87 to 1996.^a

Species	1986-87		1989		1991		1994		1996	
	Fenced	Unfenced	Fenced	Unfenced	Fenced	Unfenced	Fenced	Unfenced	Fenced	Unfenced
-----Seedlings (x1000) per hectare-----										
Ash	23	18	82	20	41	11	36	b	5	
Cedar, eastern red	b			b						
Cherry, sweet	1		6	1	4	1	4	1	1	
Cherry, black	4	13	1	1	1	3	13	2	1	
Elm				b			b			
Hickory, mockernut		1			2	1	1		1	
Hickory, shagbark		1	b	1			b	b		
Maple, Norway							b			
Maple, red			1	b	1		1	3	b	
Oak, black				b				b		
Oak, northern red			b	b			b	b	b	
Oak, white	20	20	4	1	3		1			
Total Tree	57	55	96	23	54	15	46	4	7	
Barberry, Japanese			b	b			1		1	b
Black-haw, smooth	1		3	2	1	1	7	1	b	
Dogwood, flowering								1	b	
Greenbriar	3				1	1	b	b		
<i>Rubus</i>			b	b	6	1	3	b	b	
Sassafras			b			1	b		b	
Serviceberry			b				b	b		
Spicebush							b	b		
Total Shrub	4	b	4	2	9	4	12	4	1	b
Total Tree and Shrub	61	55	100	25	63	19	58	8	8	b

^a Values for the 1986-87 survey were averages from four circular 2.0 m² subplots in each 10 x 10 m plot in 1986 and 1987 (16 m²); 1989 and 1994 survey values were from the entire 10 x 10 m plot (100 m²); and 1991 survey values were averages from four square 1.0 m² plots at four locations in each 10 x 10 m plot (16 m²). Values within columns may not add up to the value for Total Tree, Total Shrub, or Total Tree and Shrub due to rounding.

^b Present but <1.

The number of shrub seedling species recorded in the unfenced plot was one in 1986-87, three in 1989, four in 1991, six in 1994, and one in 1996, indicating an increase in species richness between the first and fourth surveys, but then a decrease in 1996 (Table 3). The density of shrub seedlings in the unfenced plot was <1 stems per ha in the 1986-87 and 1996 surveys (Table 3).

The density of tree seedlings <26 cm in height steadily decreased in the fenced plot from 86,000 stems per ha in 1989 to 2,000 stems per ha in 1996 (Figure 3). Density of fenced tree seedlings ≥ 26 cm in height decreased from 10,000 stems per ha in 1989 to 5,000 stems per ha in 1996. Density of unfenced tree seedlings <26 cm in height decreased from 23,000 stems per ha in 1989 to 0 stems per ha in 1996. After 1989, no tree seedlings ≥ 26 cm in height were recorded in the unfenced plot (Figure 3).

The density of shrub seedlings in the <26, 26-50.9, 51-75.9 and 76-100.9 cm height classes increased from 1989 to 1994 in both the fenced and unfenced plot, but by 1996, shrub densities had decreased in each of these four height classes (Figure 3). Conversely, in 1994, no shrub seedlings were recorded in either the 101-125.9 or the 126-150 cm height classes, but by 1996, shrub densities for these two combined height classes were <1,000 stems per ha in the fenced plot and 1,000 stems per ha in the unfenced plot (Figure 3).

Bushman Hill Woodlot

The number of tree seedling species recorded in the fenced plot was six in 1986-87, nine in 1989, nine in 1991, nine in 1994, and eight in 1996, indicating a mostly stable species richness of tree seedlings during the sampling period (Table 4). The density of tree seedlings in the fenced plot decreased from 133,000 stems per ha in 1986-87 to 26,000 stems per ha in 1996. White oak, ash, and elm (*Ulmus spp.*) were the most abundant tree seedling species in the fenced plot over the 10-year period. There was a white oak seedling density of 81,000 stems per ha in 1986-87, but it decreased to 3,000 stems per ha in 1996. Likewise, the density of ash and elm decreased in the fenced plot between 1986-87 and 1996 (Table 4).

The number of tree seedling species recorded in the unfenced plot was six in 1986-87, eight in 1989, three in 1991, eight in 1994, and three in 1996, indicating undulating changes in species richness during the sampling period. The density of tree seedlings declined from 98,000 stems per ha in 1986-87 to 5,000 stems per ha in 1996 in the unfenced plot (Table 4). Ash and white oak were consistently the most abundant tree species in the unfenced plot, although both species experienced decreases in density over time. Ash went from 23,000 stems per ha in 1986-87 to 4,000 stems per ha in 1996. Similarly, white oak seedling densities decreased from 68,000 stems per ha in 1986-87 to <1,000 stems per ha in 1996 (Table 4).

The number of shrub seedling species recorded in the fenced plot was three in 1986-87, five in 1989, four in 1991, eight in 1994, and nine in 1996, indicating an increase in shrub species richness during the sampling period (Table 4). The density of shrub seedlings in the fenced plot increased from 8,000 stems per ha in 1986-87 to 41,000 stems per ha in 1991, then decreased to 17,000 stems per ha in 1996. In 1986-87, spicebush (*Lindera benzoin* (L.) Blume), eastern redbud (*Cercis canadensis* L.), and smooth blackhaw were the only shrub species recorded in the fenced plot. *Rubus* was the

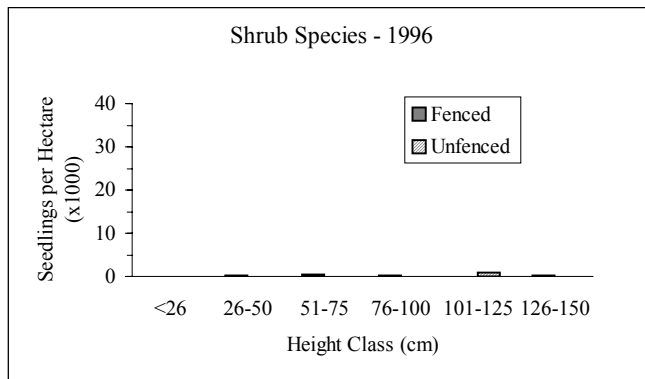
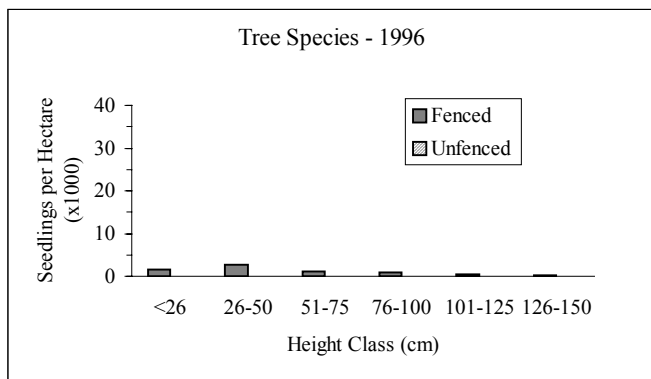
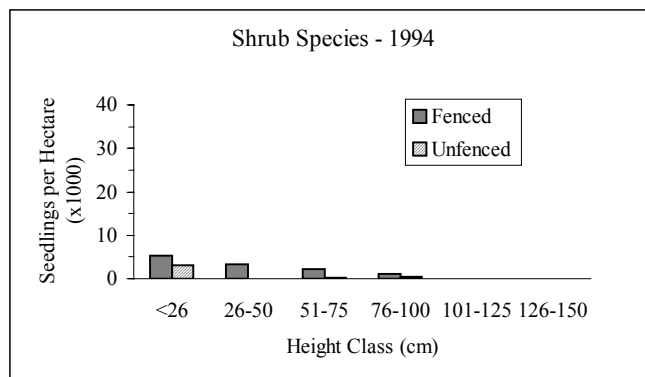
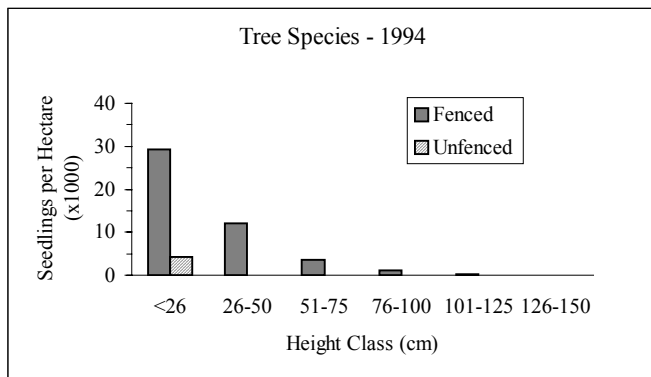
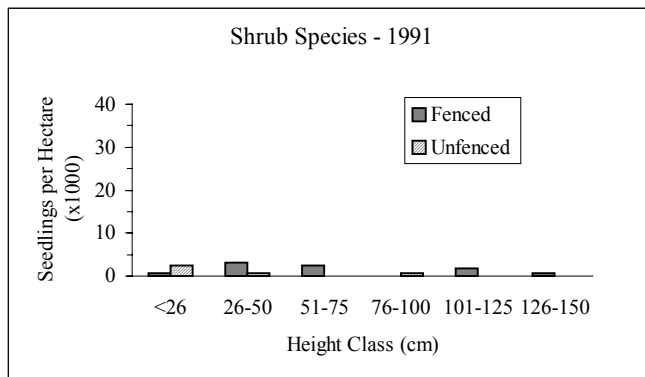
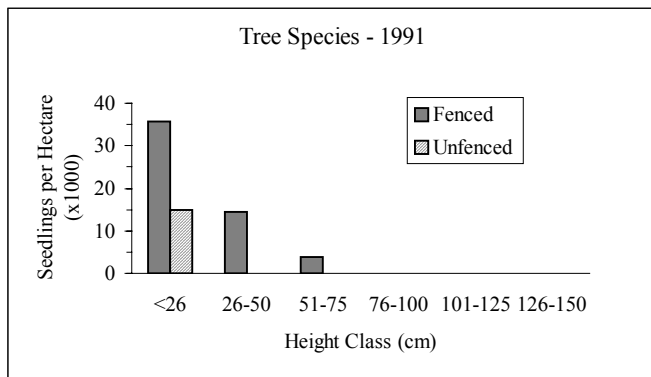
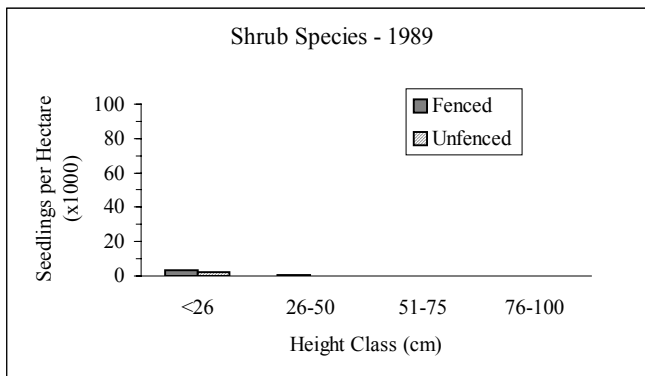
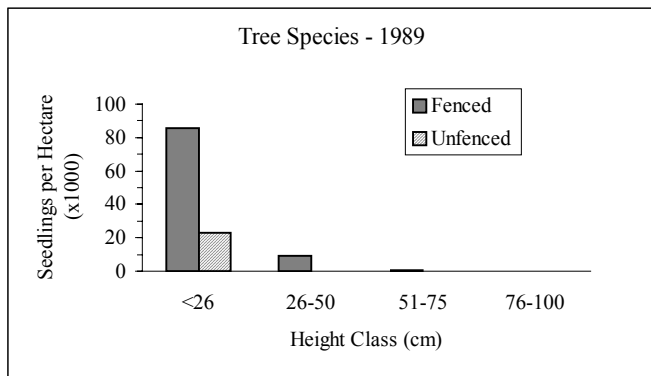


Figure 3. Density of tree and shrub seedlings (≤ 150 cm tall) by height class in the Fenced and Unfenced 10 x 10 m Demonstration Plots in Spangler woodlot, Gettysburg National Military Park, in 1989, 1991, 1994, and 1996.

Table 4. Density of tree and shrub seedlings (≤ 150 cm tall) per hectare by species and survey year in the Fenced and Unfenced 10 x 10 m Demonstration Plots in Bushman Hill woodlot, Gettysburg National Military Park, 1986-87 to 1996.^a

Species	1986-87		1989		Survey Year 1991		1994		1996	
	Fenced	Unfenced	Fenced	Unfenced	Fenced	Unfenced	Fenced	Unfenced	Fenced	Unfenced
-----Seedlings (x1000) per hectare-----										
Ailanthus							b			
Ash	28	23	26	33	20	37	25	14	8	4
Cherry, sweet			b	6			b			
Cherry, black	6	5	2	1	2		2	2	1	
Elm	15	1	11	b	19	1	17	1	12	
Hickory, mockernut					2		3	1	2	b
Hickory, pignut	1	1	3	1	2					
Hickory, shagbark					2					
Maple, Norway									b	
Maple, red	1	1	b		1		1	b	1	
Oak, black			b	b	1				b	
Oak, northern red			b	b			1	1		
Oak, white	81	68	24	35	25	22	12	9	3	b
Yellow poplar								b		
Total Tree	133	98	66	73	74	62	62	30	26	5
Barberry, Japanese									1	4
Blackhaw, smooth	2	2	7	2	3	5	10	3		
Dogwood, flowering			b	1			b	b	3	
Grape							3	10	b	
Redbud, eastern	2		7	3		1	1	4	b	1
Rosa					6	1	4		7	
Rubus					28	8		b	b	b
Sassafras				b		1	b	b	b	
Serviceberry			b				1	1	b	
Spicebush	4		8	5	4	8	9	14	6	9
Total Shrub	8	2	21	11	41	23	32	38	17	14
Total Tree and Shrub	140	99	93	48	116	84	94	69	43	20

^a Values for the 1986-87 survey were averages from four circular 2.0 m² subplots in each 10 x 10 m plot in 1986 and 1987 (16 m²); 1989 and 1994 survey values were from the entire 10 x 10 m plot (100 m²); and 1991 survey values were averages from four square 1.0 m² plots at four locations in each 10 x 10 m plot (16 m²). Values within columns may not add up to the value for Total Tree, Total Shrub, or Total Tree and Shrub due to rounding.

^b Present but <1.

most abundant species in 1991 with 28,000 stems per ha. By 1996, *Rosa* (7,000 stems per ha) and spicebush (6,000 stems per ha) were the most abundant shrubs in the fenced plot (Table 4).

The number of shrub seedling species recorded in the unfenced plot was one in 1986-87, five in 1989, six in 1991, eight in 1994, and four in 1996, indicating an increase in shrub species richness between 1986-87 and 1994, but then a decline in 1996 (Table 4). The density of shrub seedlings in the unfenced plot increased from 2,000 stems per ha in 1986-87 to 38,000 stems per ha in 1994, then decreased to 14,000 stems per ha in 1996 (Table 4). In 1986-87, smooth blackhaw was the only species recorded in the unfenced plot. By 1996, spicebush (9,000 stems per ha) was the most abundant shrub in the unfenced plot (Table 4).

The density of fenced tree seedlings <26 cm in height sharply decreased from 50,000 stems per ha in 1989 to 8,000 stems per ha in 1996 (Figure 4). Density of fenced tree seedlings ≥ 26 cm in height increased from 1989 (16,000 stems per ha) to 1994 (35,000 stems per ha), then decreased to 18,000 stems per ha in 1996. In the unfenced plot, density of tree seedlings <26 cm in height decreased from 61,000 to 4,000 stems per ha from 1989 to 1996. Density of unfenced tree seedlings ≥ 26 cm in height decreased from 12,000 to 1,000 stems per ha from 1989 to 1996, with no recorded stems ≥ 51 cm in height after the 1991 survey (Figure 4).

The density of fenced shrub seedlings <26 cm in height decreased from 13,000 stems per ha in 1989 to 4,000 stems per ha in 1996 (Figure 4). Density of fenced shrub seedlings ≥ 26 cm in height increased from 7,000 stems per ha in 1989 to 13,000 stems per ha in 1996. Density of unfenced shrub seedlings <26 cm in height increased from 1989 (8,000 stems per ha) to 1994 (26,000 stems per ha), then decreased in 1996 (7,000 stems per ha). Likewise, the density of unfenced shrub seedlings ≥ 26 cm in height increased from 1989 (4,000 stems per ha) to 1994 (12,000 stems per ha), then decreased in 1996 (7,000 stems per ha) (Figure 4).

In 1992, six herbaceous and vine species were found in the fenced subplot and 12 species were found in the unfenced subplot, based on the line-transect data and a complete search of the 1m² subplots sampled. Only three common species were found in both subplots. Four species were found along the line-transects in the fenced subplot and eight were found in the unfenced subplot. For the fenced subplot line-transect data, the Shannon Diversity and evenness indices were 0.565 and 0.938, respectively. The Shannon Diversity and Evenness indices were 0.829 and 0.918, respectively, for the unfenced subplot based on line-transect data.

Cobean Woodlot

The number of tree seedling species recorded in the fenced plot was six in 1986-87, seven in 1989, zero in 1991, seven in 1994, and five in 1996, indicating there was no consistent change in the species richness over the sampling period (Table 5). The density of tree seedlings was quite variable in the fenced plot over the 10-year sampling period. In 1989, tree seedling densities were maximized at 90,000 stems per ha; however, no tree seedlings were recorded in the next inventory in 1991. In 1996, 2,000 stems per ha were recorded in the fenced plot. In 1986-87, seedling densities were uniformly distributed among the six species present. In 1989, ash was

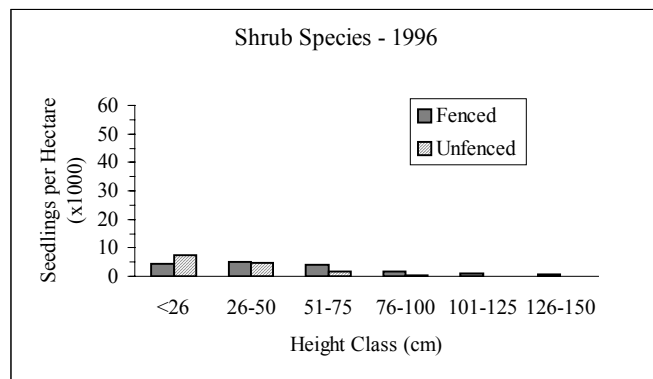
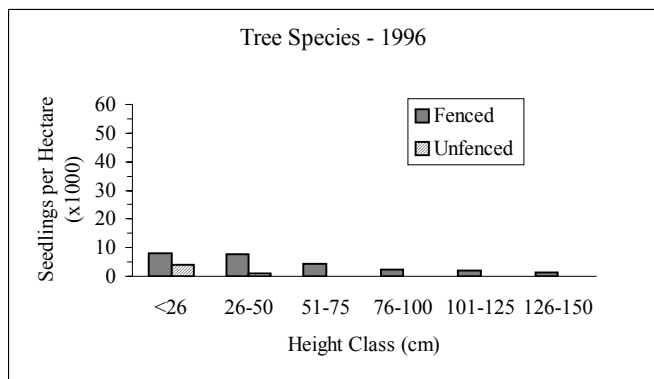
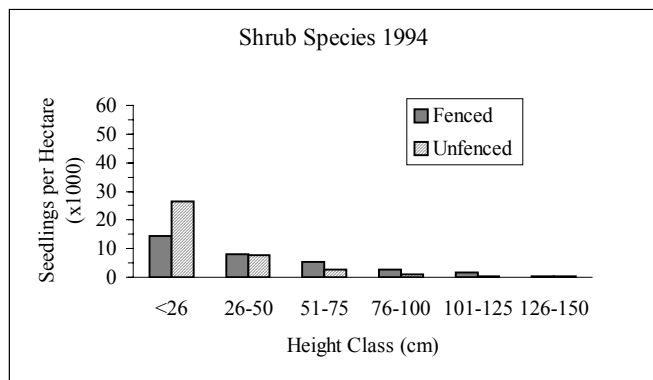
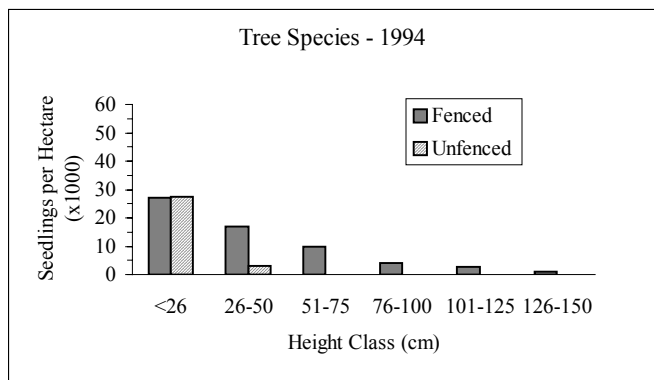
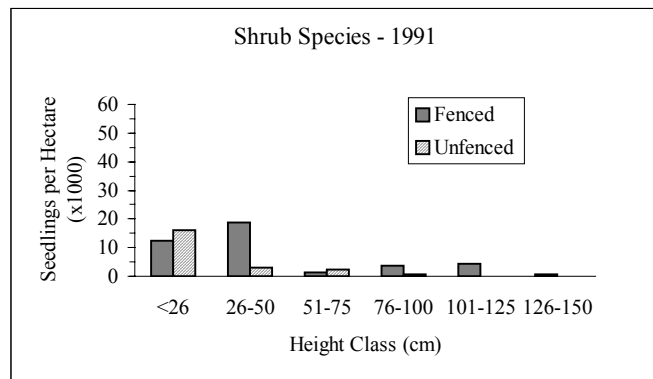
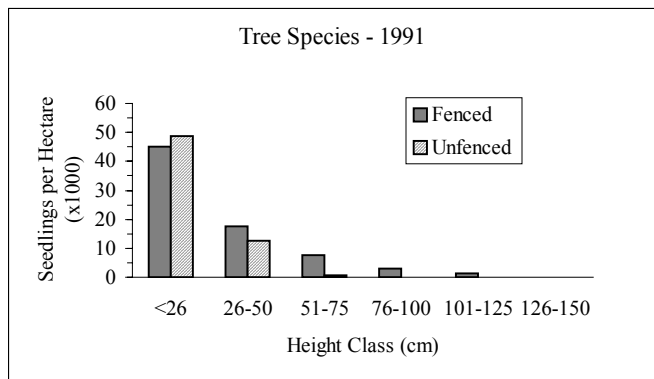
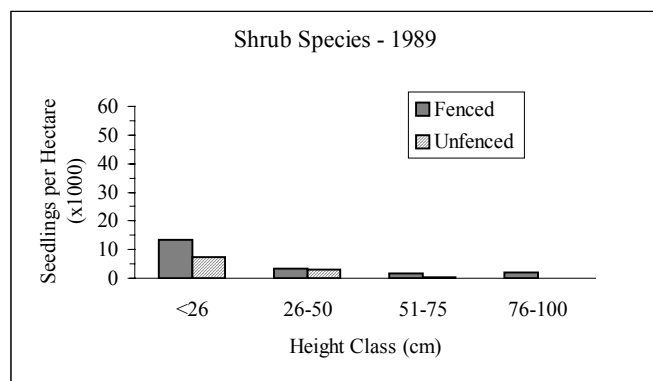
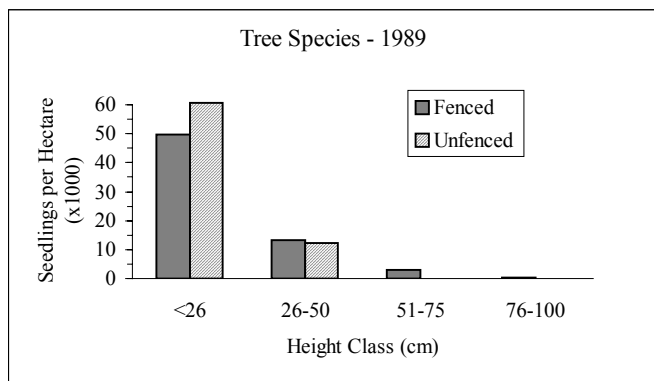


Figure 4. Density of tree and shrub seedlings (≤ 150 cm tall) by height class in the Fenced and Unfenced 10 x 10 m Demonstration Plots in Bushman Hill woodlot, Gettysburg National Military Park, in 1989, 1991, 1994, and 1996.

Table 5. Density of tree and shrub seedlings (≤ 150 cm tall) per hectare by species and survey year in the Fenced and Unfenced 10 x 10 m Demonstration Plots in Cobean woodlot, Gettysburg National Military Park, 1986-87 to 1996.^a

Species	Survey Year									
	1986-87		1989		1991		1994		1996	
	Fenced	Unfenced	Fenced	Unfenced	Fenced	Unfenced	Fenced	Unfenced	Fenced	Unfenced
	-----Seedlings (x1000) per hectare-----									
Ash	9	3	87	95			2	b	b	
Cherry, sweet									b	
Cherry, black	6		1	4					1	
Elm	1		b	1			b		b	
Hickory, mockernut							1		1	
Hickory, pignut	1	1								
Hickory, shagbark	3		1	b			2	2		
Locust, black							b			
Oak, black	2		b				b	b		
Oak, chestnut			b							
Oak, northern red			b				b			
Total Tree	21	3	90	100			6	2	2	
Barberry, Japanese			2							
Blackhaw, smooth			1	b						
Dogwood, flowering									b	
Honeysuckle, Tartarian						1	2	3	9	
Redbud, eastern				b			3	b		b
<i>Rosa</i>				16		5	2	22	15	
<i>Rubus</i>		1			1		14	3	14	7
Sassafras							1		1	
Total Shrub		1	3	b	17		24	9	40	31
Total Tree and Shrub	21	4	93	100	17		30	14	42	31

^a Values for the 1986-87 survey were averages from four circular 2.0 m² subplots in each 10 x 10 m plot in 1986 and 1987 (16 m²); 1989 and 1994 survey values were from the entire 10 x 10 m plot (100 m²); and 1991 survey values were averages from four square 1.0 m² plots at four locations in each 10 x 10 m plot (16 m²). Values within columns may not add up to the value for Total Tree, Total Shrub, or Total Tree and Shrub due to rounding.

^b Present but <1.

the most abundant species with 87,000 stems per ha. However, there were zero ash seedlings in 1991 (Table 5). By 1996, densities were again uniform among the five species recorded.

The number of tree seedling species recorded unfenced plot was two in 1986-87, four in 1989, zero in 1991, three in 1994, and zero in 1996, indicating there were slight variations in species richness during the sampling period (Table 5). The density of tree seedlings was quite variable in the unfenced plot over the 10-year sampling period. In 1989, tree seedling densities were maximized in the unfenced plot at 100,000 stems per ha; however, there were no tree seedlings recorded in 1991 or 1996. In 1986-87 and 1989, ash was the most abundant species with 3,000 and 87,000 stems per ha, respectively (Table 5). Shagbark hickory (*Carya ovata* (P. Mill.) K. Koch) was the most abundant species in 1994 with 2,000 stems per ha.

The number of shrub seedling species recorded in the fenced plot was zero in 1986-87, two in 1989, one in 1991, five in 1994, and five in 1996, indicating an increase in shrub species richness during the sampling period (Table 5). Although no shrub seedlings were recorded in the fenced plot in 1986-87, the total density increased steadily to 40,000 stems per ha in 1996 (Table 5). In 1994 and 1996, the density of *Rubus* increased to 14,000 stems per ha in the fenced plot. *Rosa* was the most abundant shrub in 1996, with a density of 15,000 stems per ha (Table 5).

The number of shrub seedling species recorded in the unfenced plot was one in 1986-87, three in 1989, two in 1991, five in 1994, and six in 1996, indicating an increase in shrub species richness during the sampling period (Table 5). The estimated density of shrub seedlings in the unfenced plot increased from 1,000 stems per ha in 1986-87 to 31,000 stems per ha in 1996. By 1989, the density of *Rosa* increased to 16,000 stems per ha, and remained the dominant species in 1991 and 1994 with 5,000 and 22,000 stems per ha, respectively. In 1986-87, *Rubus* was the only recorded shrub in the unfenced plot, averaging 1,000 stems per ha. It was also dominant in 1996 with 7,000 stems per ha (Table 5).

The density of fenced tree seedlings <26 cm in height sharply decreased from 1989 (88,000 stems per ha) to 1991 (0 stems per ha). By 1996, the density of fenced tree seedlings totaled <1,000 stems per ha for the <26 cm height class (Figure 5). Density of fenced tree seedlings $\geq$ 26 cm in height totaled 1,000 stems per ha in each of the 1989 and 1996 surveys. In 1989, the density of unfenced tree seedlings was 99,000 and <1,000 stems per ha for seedlings <26 and $\geq$ 26 cm in height, respectively. No unfenced tree seedlings were recorded in either the 1991 or the 1996 surveys (Figure 5).

The density of shrub seedlings <26 and $\geq$ 26 cm in height increased in both the fenced and unfenced plots over the 10-year sampling period. For fenced seedling shrubs <26 cm in height, density increased from <1,000 to 15,000 stems per ha from 1989 to 1996, respectively. For fenced seedling shrubs $\geq$ 26 cm in height, density increased from 2,000 to 25,000 stems per ha from 1989 to 1996, respectively. For unfenced seedling shrubs <26 cm in height, density increased from <1,000 to 11,000 stems per ha from 1989 to 1996, respectively. For unfenced seedling shrubs $\geq$ 26 cm in height, density increased from 0 to 20,000 stems per ha from 1989 to 1996, respectively (Figure 5).

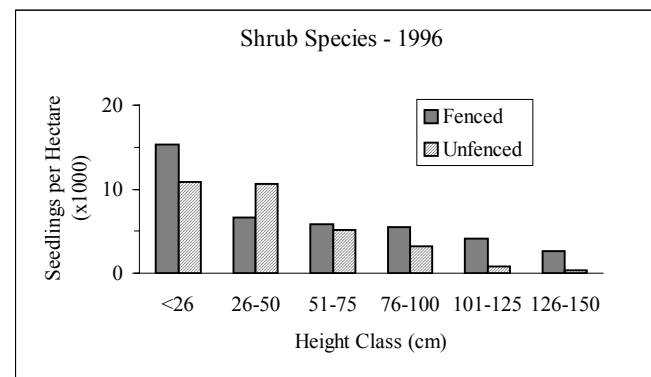
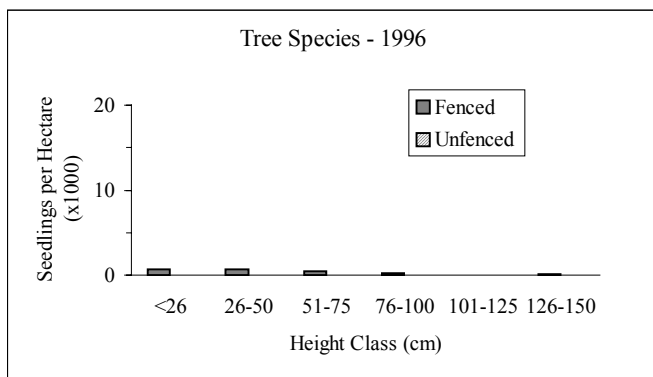
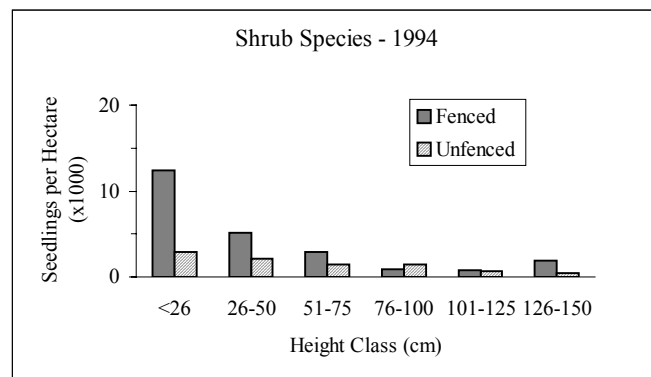
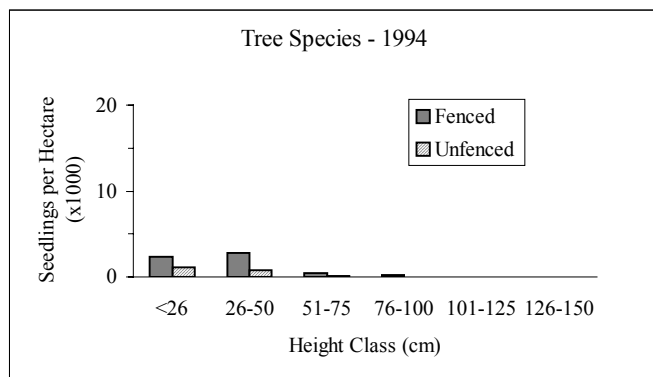
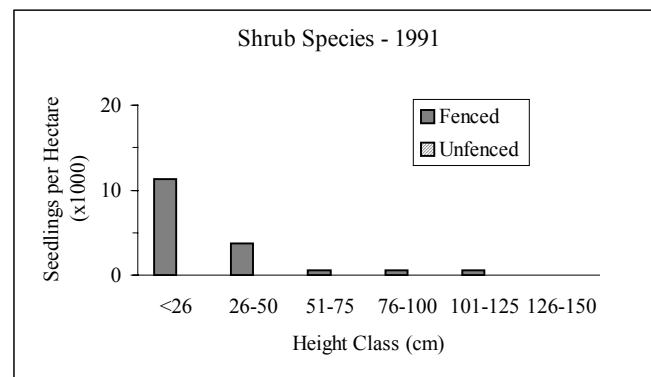
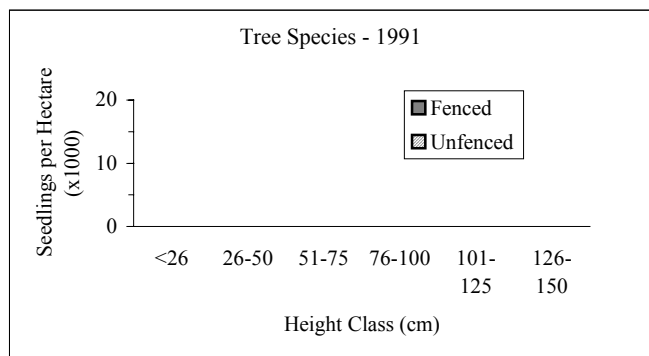
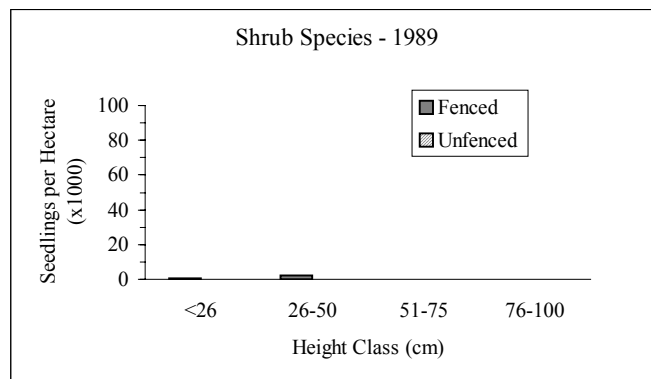
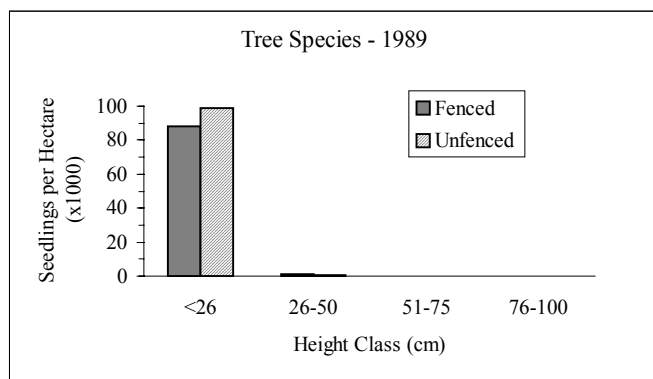


Figure 5. Density of tree and shrub seedlings (≤ 150 cm tall) by height class in the Fenced and Unfenced 10 x 10 m Demonstration Plots in Cobean woodlot, Gettysburg National Military Park, in 1989, 1991, 1994, and 1996.

Slyder (Granite Farm) Woodlot

The number of tree seedling species recorded in the fenced plot was two in 1986-87, three in 1989, three in 1991, seven in 1994, and four in 1996, indicating species richness was generally similar over the sampling period (Table 6). The density of tree seedlings did not change significantly in the fenced plot over the 10-year sampling period, it only ranged from 1,000 to 4,000 stems per ha. Maximum density occurred in 1994 with 4,000 stems per ha. From 1989 to 1996, northern red oak was the most abundant tree seedling species in the fenced plot (Table 6).

The number of tree seedling species recorded in the unfenced plot was three in 1986-87, three in 1989, one in 1991, two in 1994, and one in 1996, indicating species richness was generally similar over the sampling period (Table 6). In the unfenced plot, maximum tree seedling density occurred in 1991 with 34,000 stems per ha, but dropped to <1,000 stems per ha in 1996. Ash was the most abundant tree seedling species in the unfenced plot over time (Table 6).

The number of shrub seedling species recorded in the fenced plot was two in 1986-87, three in 1989, two in 1991, six in 1994, and six in 1996, indicating an overall increase in shrub species richness during the sampling period (Table 6). The estimated total number of shrub seedlings increased from 2,000 stems per ha in 1986-87 to 43,000 stems per ha in 1991, but then decreased to 21,000 stems per ha in 1996. From 1986-87 until 1989, shrub densities were uniform across the five species. *Rubus* was the most abundant species from 1991 (35,000 stems/ha) to 1994 (13,000 stems/ha), but by 1996 *Rosa* was dominant (14,000 stems/ha) (Table 6).

The number of shrub seedling species recorded in the unfenced plot was three in 1986-87, three in 1989, five in 1991, eight in 1994, and two in 1996, indicating an increase in shrub species richness until 1994, but then a decline in 1996 (Table 6). The estimated density of shrub seedlings in the unfenced plot increased from 4,000 stems per ha in 1986-87 to 23,000 stems per ha in 1991, but then decreased to 8,000 stems per ha in 1996. From 1989 to 1994, *Rosa* was the most abundant shrub species with densities ranging from 7,000 to 14,000 stems per ha, respectively. However, Japanese barberry was most abundant in 1996 with 5,000 stems per ha (Table 6).

The number of fenced tree seedlings <26 cm in height remained constant at 1,000 stems per ha from 1989 to 1996 (Figure 6). Likewise, the density of fenced tree seedlings ≥26 cm in height was 1,000 stems per ha in each of the 1989 and 1996 surveys. Density of unfenced tree seedlings <26 cm in height increased from 3,000 stems per ha in 1989 to 34,000 stems per ha in 1991, then decreased to <1,000 stems per ha in 1996. In 1991, *Rubus* totaled 17,000 stems/ha in the unfenced plot, but decreased to 1,000 stems/ha by 1996. The most abundant shrub in 1996 was Japanese barberry (5,000 stems/ha) (Table 6).

The density of fenced shrub seedlings <26 cm in height increased from <1,000 stems per ha in 1989 to 2,000 stems per ha in 1996 (Figure 6). Likewise, the density of fenced shrub seedlings ≥26 cm in height increased from 1,000 stems per ha in 1989 to 19,000 stems per ha in 1996. Density of unfenced shrub seedlings <26 cm in height increased from 4,000 stems per ha in 1989 to 16,000 stems per ha in 1991, then decreased to 1,000 stems per ha in 1996. In 1989, no

Table 6. Density of tree and shrub seedlings (≤ 150 cm tall) per hectare by species and survey year in the Fenced and Unfenced 10 x 10 m Demonstration Plots in Slyder woodlot, Gettysburg National Military Park, 1986-87 to 1996.^a

Species	Survey Year									
	1986-87		1989		1991		1994		1996	
	Fenced	Unfenced	Fenced	Unfenced	Fenced	Unfenced	Fenced	Unfenced	Fenced	Unfenced
	-----Seedlings (x1000) per hectare-----									
Ash		13		2		34		b		b
Blackgum								b		
Cedar, eastern red								b		
Cherry, black	1		b		b		b	1	b	
Hickory, mockernut					b		1		b	
Hickory, pignut		1	b	b						
Hickory, shagbark	1	1								
Maple, Norway							b		b	
Oak, northern red			1	b	2		2	b	1	
Total Tree	1	14	2	3	3	34	4	1	2	b
Barberry, Japanese								5		5
Blackhaw, smooth		1	b			5	1	b		
Dogwood, flowering			1	4					b	
Grape		1					3	b	1	
Greenbriar								3	b	b
Redbud, eastern	1	1		b		1		b		
<i>Rosa</i>					8		7	2	14	2
<i>Rubus</i>					35	17	13	3	5	1
Sassafras						1				
Serviceberry	1									
Spicebush			1	b			2	b	1	
Total Shrub	2	4	2	4	43	23	25	13	21	8
Total Tree and Shrub	3	16	4	6	46	56	29	14	23	9

^a Values for the 1986-87 survey were averages from four circular 2.0 m² subplots in each 10 x 10 m plot in 1986 and 1987 (16 m²); 1989 and 1994 survey values were from the entire 10 x 10 m plot (100 m²); and 1991 survey values were averages from four square 1.0 m² plots at four locations in each 10 x 10 m plot (16 m²). Values within columns may not add up to the value for Total Tree, Total Shrub, or Total Tree and Shrub due to rounding.

^b Present but <1.

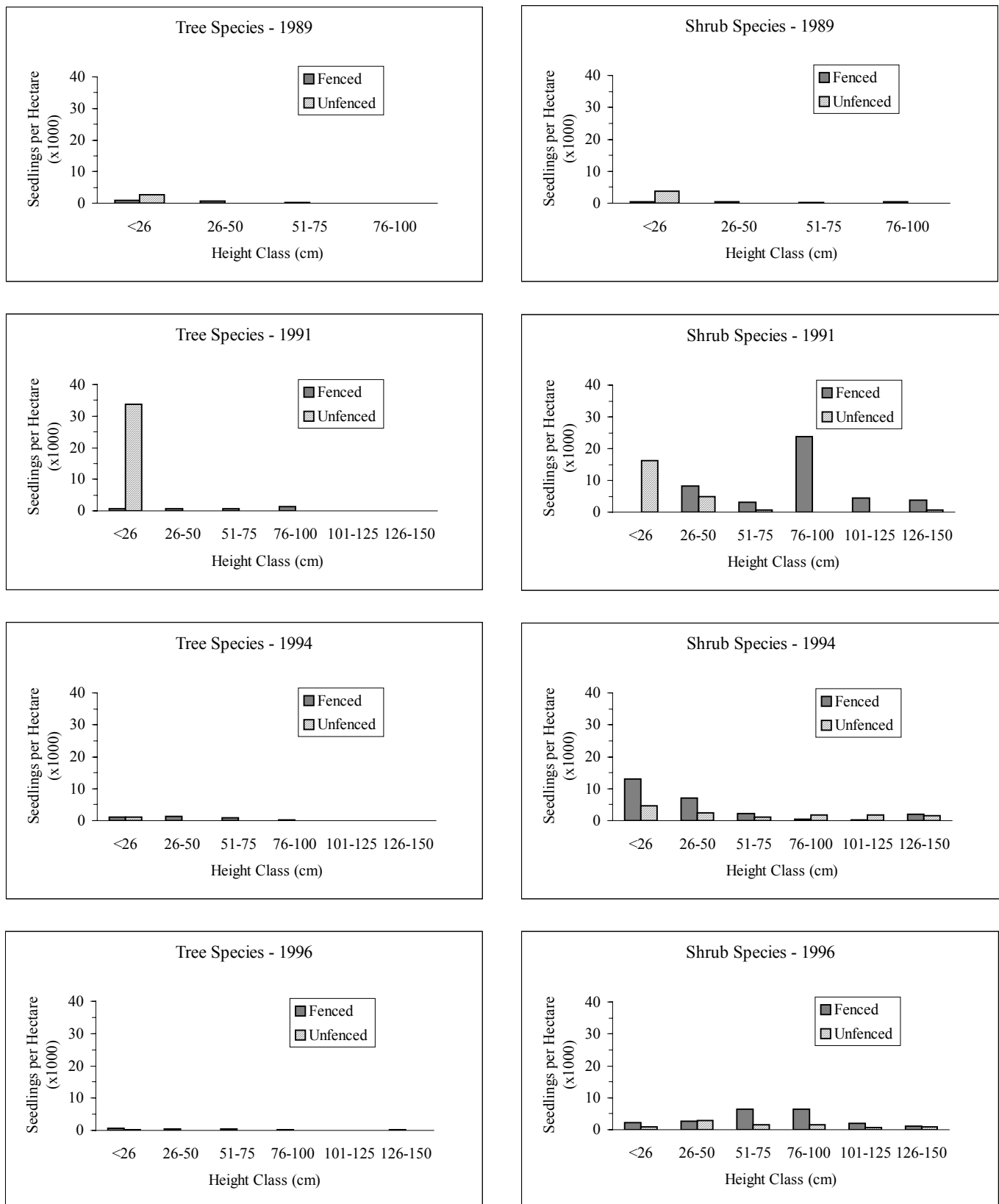


Figure 6. Density of tree and shrub seedlings (≤ 150 cm tall) by height class in the Fenced and Unfenced 10 x 10 m Demonstration Plots in Slyder woodlot, Gettysburg National Military Park, in 1989, 1991, 1994, and 1996.

unfenced shrub seedlings ≥ 26 cm in height were recorded, but in 1996, the density of unfenced shrubs ≥ 26 cm in height totaled 7,000 stems per ha (Figure 6).

Long Term Monitoring Plots

Biesecker Woodlot (Fenced and Unfenced Data Combined)

Overstory – Tree Species: Densities of overstory (>1.5 m in height and ≥ 12 cm dbh - diameter at 1.35 m above ground) trees by diameter classes are presented in Figure 7. In 1996, the density of overstory trees was estimated at 305 stems per ha, or 29% of all stems >1.5 m in height. The overstory trees averaged 27 cm in diameter and had a basal area of 25 m^2 per ha (Table 7). Hickory, white oak, and northern red oak were the most abundant species with 32, 26 and 16%, respectively, of the total tree overstory density. The remaining 11 species accounted for 26% of the overstory tree density. White oak, northern red oak, hickory, and black oak were the dominant tree species, accounting for 61, 14, 12, and 7%, respectively, of the total overstory tree basal area (Table 8). The remaining 10 tree species accounted for 6% of total basal area. The density and basal area values for the trees ≥ 12 cm in diameter would place the Biesecker woodlot in the 88% stocking level (Roach and Gingrich 1968). A list of scientific and common names of plants identified in the Long Term Monitoring plots is presented in Appendix B.

Overstory – Shrub Species: The densities of overstory shrubs by diameter classes are presented in Figure 8. Three percent of shrub species >1.5 m in height were ≥ 12 in diameter (Figure 8). Eastern redbud was the only overstory shrub species, with a density of three stems per ha, an average diameter of 14 cm, and a basal area of 0.05 m^2 per ha (Table 8).

Large Sapling – Tree Species: Large sapling (>1.5 m in height and 2-11.9 cm dbh) tree density was 747 stems per ha, with an average diameter of 6 cm, and a basal area of 2 m^2 per ha (Table 7). Hickory, black cherry, white oak, and sweet cherry (*Prunus avium* (L.) L.) accounted for 60, 12, 11, and 9% of the total large sapling density, respectively (Table 9). The remaining seven tree species accounted for 7% of total large sapling tree density.

Large Sapling – Shrub Species: Density of large sapling shrubs was 80 stems per ha. Average diameter was 5 cm and basal area was 0.17 m^2 per ha (Table 7). Smooth blackhaw, flowering dogwood, serviceberry (*Amelanchier arborea* (Michx.f.) Fern.), and eastern redbud accounted for 33, 31, 30, and 6%, respectively, of the total large sapling shrub density (Table 9).

Small Sapling – Tree Species: Small sapling (>1.5 m in height and <2 cm dbh) tree density was 11 stems per ha, with an average diameter of 0.9 cm, and basal area of 0.0008 m^2 per ha (Table 7). Black cherry, hickory, white oak, and northern red oak accounted for 36, 27, 27, and 9%, respectively, of the total small sapling tree density (Table 10).

Small Sapling – Shrub Species: Small sapling density for shrub species was 11 stems per ha, with an average diameter of 0.9 cm, and a basal area of 0.0008 m^2 per ha (Table 7). Smooth blackhaw, flowering dogwood, and serviceberry accounted for 62, 23, and 15%, respectively, of the total small sapling shrub density (Table 10).

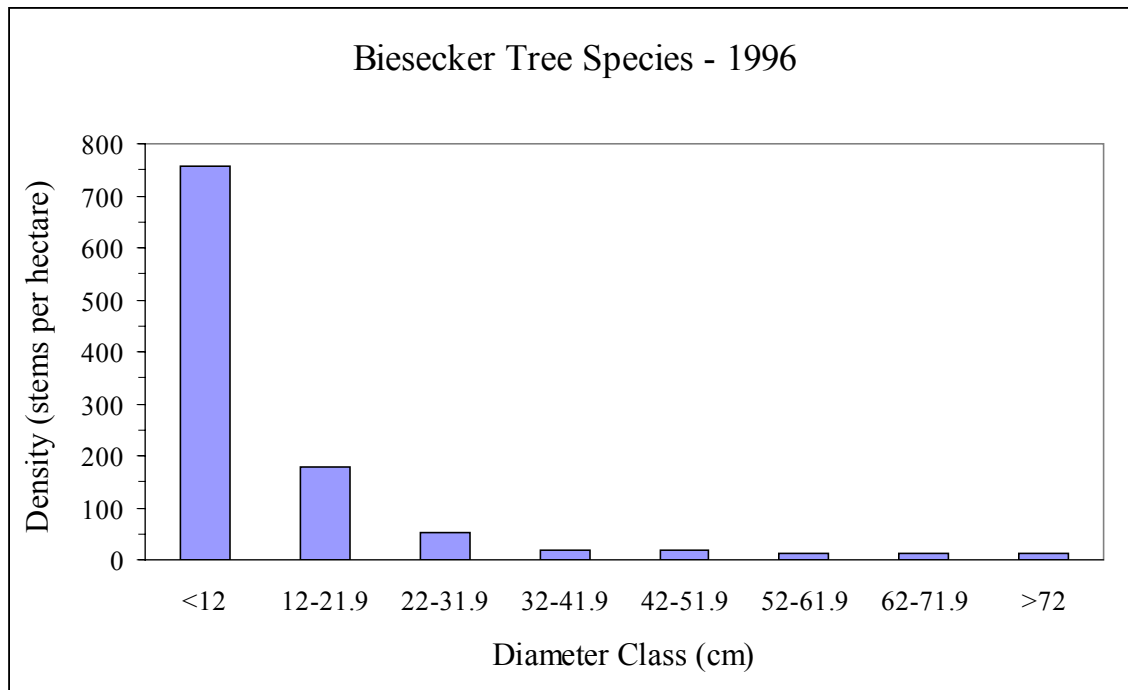


Figure 7. Density of small and large sapling (>1.5 m height and <12 cm dbh) and overstory (>1.5 m height and ≥ 12 cm dbh) trees by diameter class (cm) in thirty 20 x 20 m Long Term Monitoring Plots in Biesecker woodlot, Gettysburg National Military Park, 1996.

Table 7. Density, average diameter, and basal area of small sapling, large sapling, and overstory trees and shrubs in thirty 20 x 20 m Long Term Monitoring Plots in Biesecker woodlot, Gettysburg National Military Park, 1996.^a

	Small Sapling ^b	Large Sapling ^b	Overstory ^b
Tree			
Density (stems/ha)	11	747	305
Average Diameter (cm)	0.9	6	27
Basal Area (m ² /ha)	0.0008	2	25
Shrub			
Density (stems/ha)	11	80	3
Average Diameter (cm)	0.9	5	14
Basal Area (m ² /ha)	0.0008	0.17	0.05

^a Total area of 30 plots was 1.2 ha.

^b Small sapling stems were >1.5 m in height and <2 cm dbh; large saplings stems were >1.5 m in height and 2-11.9 cm dbh; and overstory stems were >1.5 m in height and ≥12 cm dbh.

Table 8. Density, average diameter, and basal area of overstory^a tree and shrub species in thirty 20 x 20 m Long Term Monitoring Plots in Biesecker woodlot, Gettysburg National Military Park, 1996.^b

	Density (stems/ha)	Average Diameter (cm)	Basal Area (m ² /ha)
Tree			
Ash	5	21	0.18
Cedar, eastern red	3	18	0.08
Cherry, sweet	20	14	0.32
Cherry, black	18	14	0.31
Elm, slippery	7	18	0.19
Hickory	98	18	3.06
Maple, red	2	15	0.03
Oak, black	18	31	1.77
Oak, northern red	50	27	3.51
Oak, scarlet	3	23	0.15
Oak, white	78	43	15.27
Pine, eastern white	1	24	0.04
Pine, Virginia	1	33	0.07
Walnut, black	1	15	0.01
Total	305	27	25.00
Shrub			
Redbud, eastern	3	14	0.05

^a Stems >1.5 m in height and ≥ 12 cm dbh.

^b Total area of 30 plots was 1.2 ha.

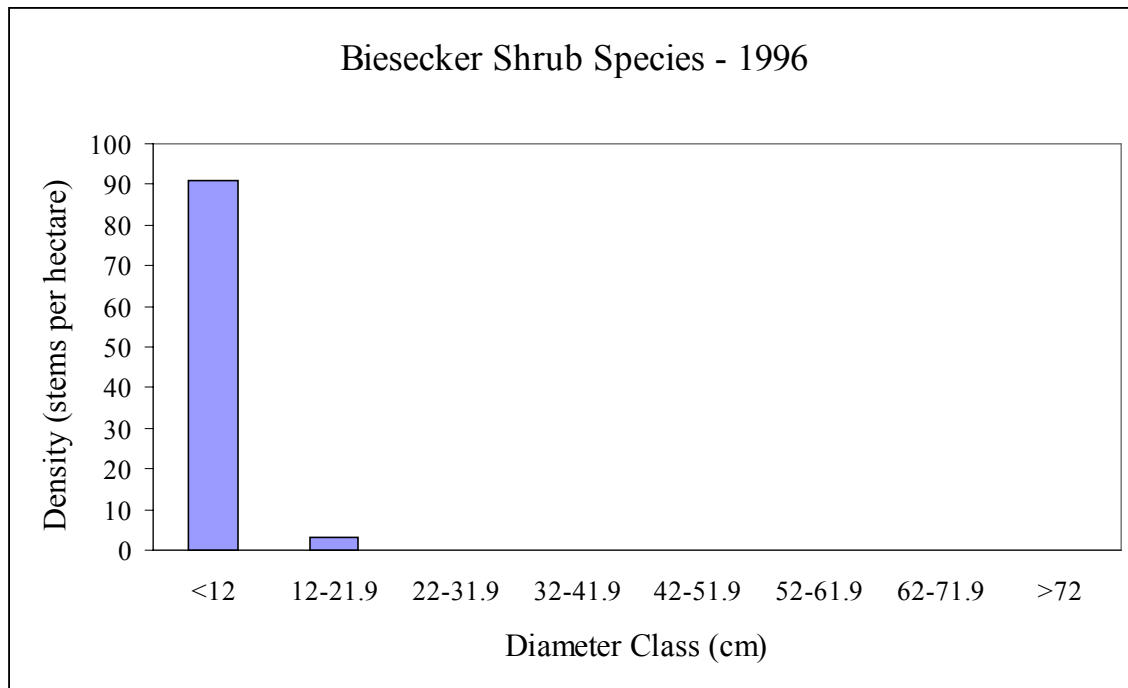


Figure 8. Density of small and large sapling (>1.5 m height and <12 cm dbh) and overstory (>1.5 m height and ≥ 12 cm dbh) shrubs by diameter class (cm) in thirty 20 x 20 m Long Term Monitoring Plots in Biesecker woodlot, Gettysburg National Military Park, 1996.

Table 9. Density, average diameter, and basal area of large sapling^a tree and shrub species in thirty 20 x 20 m Long Term Monitoring Plots in Biesecker woodlot, Gettysburg National Military Park, 1996.^b

	Density (stems/ha)	Average Diameter (cm)	Basal Area (m ² /ha)
Tree			
Ash	9	4	0.02
Blackgum	4	7	0.02
Cedar, eastern red	7	8	0.03
Cherry, sweet	68	8	0.33
Cherry, black	91	6	0.29
Elm, slippery	11	8	0.05
Hickory	448	5	1.27
Maple, red	3	9	0.02
Oak, black	11	7	0.04
Oak, northern red	11	8	0.07
Oak, white	85	6	0.31
Total	747	6	2.45
Shrub			
Blackhaw, smooth	26	3	0.03
Dogwood, flowering	25	5	0.05
Redbud, eastern	5	6	0.02
Serviceberry	24	6	0.08
Total	80	5	0.17

^a Stems >1.5 m in height and 2-11.9 cm dbh.

^b Total area of 30 plots was 1.2 ha.

Table 10. Density, average diameter, basal area of small sapling^a tree and shrub species in thirty 20 x 20 m Long Term Monitoring Plots in Biesecker woodlot, Gettysburg National Military Park, 1996.^b

	Density (stems/ha)	Average Diameter (cm)	Basal Area (m ² /ha)
Tree			
Cherry, black	4	0.8	0.0002
Hickory	3	1.2	0.0003
Oak, northern red	1	0.8	<0.0001
Oak, white	3	1.0	0.0002
Total	11	0.9	0.0008
Shrub			
Blackhaw, smooth	7	0.9	0.0004
Dogwood, flowering	3	1.0	0.0002
Serviceberry	2	1.0	0.0001
Total	11	0.9	0.0008

^a Stems >1.5 m in height and <2 cm dbh.

^b Total area of 30 plots was 1.2 ha.

Total Sapling – Tree Species: The density of small and large sapling trees combined was 758 stems per ha, of which 96% (725 stems per ha) was comprised of hickory, cherry, and oak species (Figure 9). Similarly, of the overstory trees (305 stems per ha), 93% (285 stems per ha) consisted of hickory, cherry, and oak species. For hickory and cherry species, densities of sapling stems were 4.6 and 4.3 times greater, respectively, than those of overstory stems. Conversely, the density of overstory oaks was 1.3 times greater than that of small and large sapling oaks.

Total Sapling – Shrub Species: The density of small and large sapling shrubs combined was 91 stems per ha. Smooth blackhaw, flowering dogwood, and serviceberry accounted for 36, 30, and 28%, respectively, of the total shrub sapling density, compared to only 5% for eastern redbud (Figure 10). Nevertheless, eastern redbud was the only overstory shrub present and had a density of three stems per ha.

Seedling – Tree Species: Seedlings (≤ 150 cm in height) of eight tree species had a density of 14,722 stems per ha (Table 11). Collectively, black cherry and oak accounted for 83% of the total tree seedling density. Hickory accounted for 8%, with the remaining three tree species accounting for 9% of the total.

Seedling – Shrub Species: Five shrub species had a density of 16,944 seedlings per ha (Table 11). Flowering dogwood and Japanese barberry were most abundant, collectively accounting for 78% of total shrub seedling density. Multiflora rose accounted for 15%, with the remaining two shrub species (eastern redbud and spicebush) accounting for 7% of the total.

Herbaceous Plants: Total herbaceous coverage averaged 24% (Table 12). Average forb coverage was greatest (11%), followed by grass and vine (7 and 6%, respectively).

Biesecker Woodlot (Fenced and Unfenced Treatments)

Overstory – Tree Species: In the overstory surrounding the fenced and unfenced treatments, there were 12 and 11 tree species, respectively (Table 13). Hickory, white oak, and northern red oak were the most abundant species in the fenced and unfenced treatments, accounting for 75 and 73%, respectively, of the total tree density. In the fenced treatment, there were nine other species making-up 25% of the total tree density. There were eight other species in the unfenced treatment that made up the remaining 27% of the total tree density. White oak was dominant for both fenced and unfenced treatments, accounting for 73 and 46% of total basal area, respectively. Hickory, black oak, and northern red oak collectively accounted for 22 and 48% of total basal area for fenced and unfenced treatments, respectively.

Overstory – Shrub Species: Eastern redbud was the only overstory shrub species recorded in the fenced treatments in 1996, with a basal area of 0.11 m² per ha (Table 13). No overstory shrub species were recorded in the unfenced treatments.

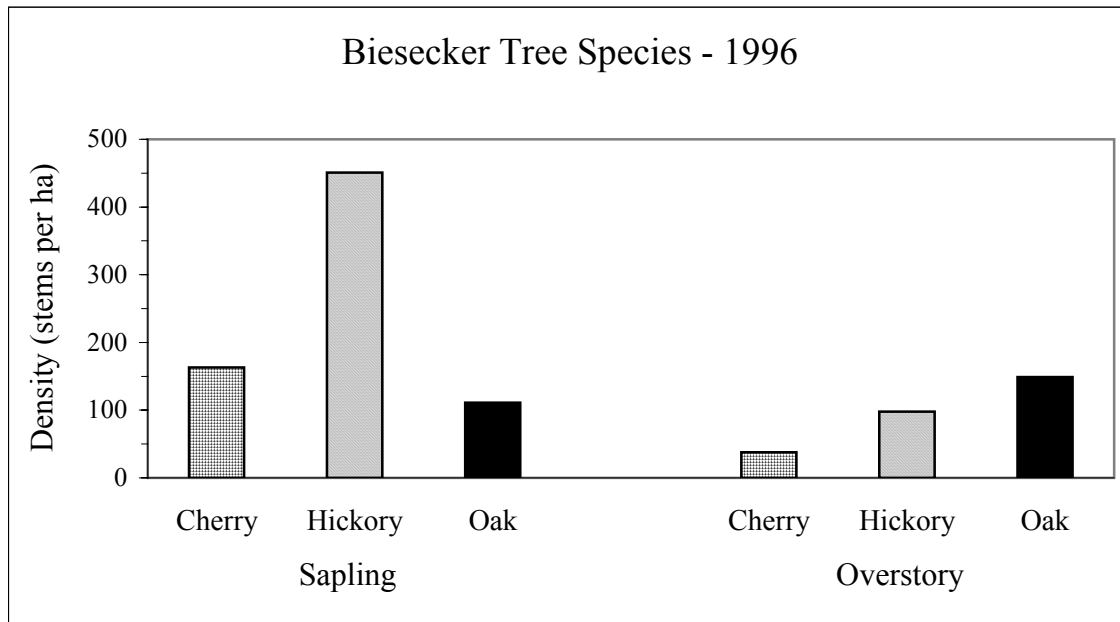


Figure 9. Density of small and large sapling (>1.5 m height and <12 cm dbh) and overstory (>1.5 m height and ≥ 12 cm dbh) selected tree species in thirty 20 x 20 m Long Term Monitoring Plots in Biesecker woodlot, Gettysburg National Military Park, 1996.

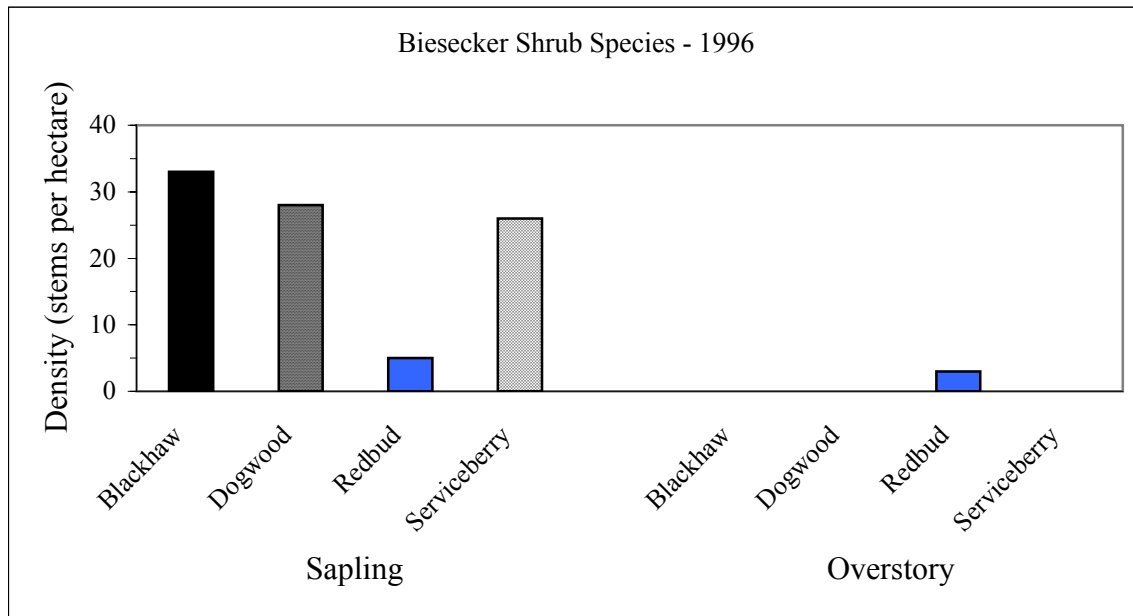


Figure 10. Density of small and large sapling (>1.5 m height and <12 cm dbh) and overstory (>1.5 m height and $\geq$ 12 cm dbh) shrub species in thirty 20 x 20 m Long Term Monitoring Plots in Biesecker woodlot, Gettysburg National Military Park, 1996.

Table 11. Density of seedling^a tree and shrub species in eighteen 2 x 2 m Long Term Monitoring subplots in Biesecker woodlot, Gettysburg National Military Park, 1996.^b

	Density (stems/ha)
Tree	
Ash	694
Blackgum	139
Cedar, eastern red	556
Cherry, black	6,667
Hickory	1,111
Oak, black	556
Oak, northern red	417
Oak, white	4,583
Total	14,722
Shrub	
Barberry, Japanese	6,528
Dogwood, flowering	6,667
Redbud, eastern	139
Rose, multiflora	2,500
Spicebush	1,111
Total	16,944

^a Stems ≤ 150 cm in height.

^b Total area of 18 subplots was 0.0072 ha.

Table 12. Average herbaceous coverage of grass, forb, vine and total species in thirty 2 x 2 m Long Term Monitoring subplots in Biesecker woodlot, Gettysburg National Military Park, 1996.^a

	Coverage (%)
Grass	7
Forb	11
Vine	6
Total	24

^a Total area of 30 subplots was 0.012 ha.

Table 13. Density, average diameter, and basal area of overstory^a tree and shrub species by fence treatment^b in thirty 20 x 20 m Long Term Monitoring Plots in Biesecker woodlot, Gettysburg National Military Park, 1996.^c

	<u>Fenced Treatment</u>			<u>Unfenced Treatment</u>		
	Density (stems/ha)	Diameter (cm)	Basal Area (m ² /ha)	Density (stems/ha)	Diameter (cm)	Basal Area (m ² /ha)
Tree						
Ash	10	21	0.36	0	0	0.00
Cedar, eastern red	5	18	0.12	2	17	0.04
Cherry, sweet	15	13	0.21	25	15	0.43
Cherry, black	20	15	0.34	17	14	0.28
Elm, slippery	5	19	0.16	8	18	0.23
Hickory	102	19	3.34	95	18	2.77
Maple, red	0	0	0.00	3	15	0.06
Oak, black	15	24	0.80	22	35	2.75
Oak, northern red	40	23	2.05	60	30	4.98
Oak, scarlet	3	25	0.16	3	22	0.14
Oak, white	88	49	20.36	67	36	10.19
Pine, eastern white	2	24	0.07	0	0	0.00
Pine, Virginia	0	0	0.00	2	33	0.14
Walnut, black	2	15	0.03	0	0	0.00
Total	307	28	28.00	303	25	22.00
Shrub						
Redbud, eastern	7	14	0.11	0	0	0.00

^a Stems >1.5 m in height and ≥12 cm dbh.

^b Fifteen plots contained a 3 x 3 m square and 1.8 m high fence, enclosing the 2 x 2 m subplot.

^c Total area of 30 plots was 1.2 ha.

Large Sapling – Tree Species: A total of 11 large sapling tree species were recorded in the fenced treatments, compared to 10 species in the unfenced treatments (Table 14). There were 820 large sapling trees per ha in the fenced treatments and 673 large sapling trees per ha in the unfenced treatments. Basal area of large sapling trees in the fenced and unfenced treatments was 2.54 and 2.37 m²/ha, respectively. Hickory was the most abundant species, accounting for 57% of total density in the fenced treatments and 64% of total density in the unfenced treatments. Sweet cherry, black cherry, and white oak collectively accounted for 36 and 29% of the total density in the fenced and unfenced treatments, respectively.

Large Sapling – Shrub Species: Four large sapling shrub species were recorded in the fenced treatments, compared to three species in the unfenced treatments (Table 14). Large sapling shrub density was 95 stems per ha in the fenced treatments and 65 stems per ha in the unfenced treatments. Smooth blackhaw was the most abundant species in the fenced treatment, accounting for 37% of total density. In the unfenced treatments, serviceberry was most abundant, accounting for 44% of the total density. Eastern redbud comprised 11% of shrub density in the fenced treatments but was not present in the unfenced treatments.

Small Sapling – Tree Species: Small sapling tree density was 20 stems per ha in the fenced treatments and two stems per ha in the unfenced treatments. In the fenced treatments, black cherry, white oak, hickory, and northern red oak, comprised 42, 33, 17, and 8%, respectively, of the total density (Table 15). Hickory was the only tree species recorded in the unfenced treatments, totaling two stems per ha.

Small Sapling – Shrub Species: Small sapling shrub density was 18 stems per ha in the fenced treatments and three stems per ha in the unfenced treatments. Smooth blackhaw, serviceberry, and flowering dogwood were the small sapling shrub species in the fenced treatments, accounting for 73, 18, and 9%, respectively, of the total density (Table 15). In the unfenced treatments, flowering dogwood (3 stems per ha) was the only recorded shrub species.

Seedling – Tree Species: Eight seedling tree species were recorded in the fenced treatments, compared to three species in the unfenced treatment (Table 16). Ash, blackgum (*Nyssa sylvatica* Marshall), eastern red cedar (*Juniperus virginiana* L.), black oak, and white oak were recorded in the fenced treatments but were not present in the unfenced treatments. In the fenced and unfenced treatments, total tree seedling densities were 20,833 and 2,500 stems per ha, respectively. Black cherry and white oak were the most abundant species in the fenced treatments, accounting for 44 and 33%, respectively, of the total density. In the unfenced treatments, black cherry was the most abundant species, accounting for 67% of the total density.

Seedling – Shrub Species: In the fenced and unfenced treatments, four and five species of shrub seedlings, respectively, were recorded in 1996 (Table 16). Eastern redbud was present in the unfenced treatments but was absent in the fenced treatments. Total shrub seedling densities were 16,458 stems per ha in the fenced treatments and 17,917 stems per ha in the unfenced treatments. Flowering dogwood was the most abundant species in the fenced treatments, comprising 52% of the total density. In the unfenced treatments, Japanese barberry was the most abundant species, comprising 77% of the total density.

Table 14. Density, average diameter, and basal area of large sapling^a tree and shrub species by fence treatment^b in thirty 20 x 20 m Long Term Monitoring Plots in Biesecker woodlot, Gettysburg National Military Park, 1996.^c

	<u>Fenced Treatment</u>			<u>Unfenced Treatment</u>		
	Density (stems/ha)	Diameter (cm)	Basal Area (m ² /ha)	Density (stems/ha)	Diameter (cm)	Basal Area (m ² /ha)
Tree						
Ash	13	4	0.02	5	7	0.02
Blackgum	8	7	0.04	0	0	0.00
Cedar, eastern red	8	8	0.05	5	7	0.02
Cherry, sweet	47	7	0.22	88	8	0.45
Cherry, black	125	5	0.36	57	7	0.23
Elm, slippery	7	6	0.02	15	8	0.08
Hickory	467	5	1.36	430	5	1.17
Maple, red	2	8	0.01	3	10	0.02
Oak, black	8	8	0.04	13	6	0.04
Oak, northern red	15	7	0.08	7	10	0.05
Oak, white	120	5	0.34	50	8	0.29
Total	820	6	2.54	673	6	2.37
Shrub						
Blackhaw, smooth	35	3	0.03	17	4	0.02
Dogwood, flowering	30	4	0.05	20	5	0.04
Redbud, eastern	10	6	0.03	0	0	0.00
Serviceberry	20	5	0.05	28	6	0.10
Total	95	4	0.17	65	5	0.16

^a Stems >1.5 m in height and 2-11.9 cm dbh.

^b Fifteen plots contained a 3 x 3 m square and 1.8 m high fence, enclosing the 2 x 2 m subplot.

^c Total area of 30 plots was 1.2 ha.

Table 15. Density, average diameter, and basal area of small sapling^a tree and shrub species by fence treatment^b in thirty 20 x 20 m Long Term Monitoring Plots in Biesecker woodlot, Gettysburg National Military Park, 1996.^c

	<u>Fenced Treatment</u>			<u>Unfenced Treatment</u>		
	Density (stems/ha)	Diameter (cm)	Basal Area (m ² /ha)	Density (stems/ha)	Diameter (cm)	Basal Area (m ² /ha)
Tree						
Cherry, black	8	0.8	0.0005	0	0.0	0.0000
Hickory	3	1.3	0.0004	2	1.0	0.0003
Oak, northern red	2	0.8	0.0001	0	0.0	0.0000
Oak, white	7	1.0	0.0005	0	0.0	0.0000
Total	20	0.9	0.0015	2	1.0	0.0003
Shrub						
Blackhaw, smooth	13	0.9	0.0008	0	0.0	0.0000
Dogwood, flowering	2	1.0	0.0001	3	1.0	0.0001
Serviceberry	3	1.0	0.0003	0	0.0	0.0000
Total	18	0.9	0.0012	3	1.0	0.0001

^a Stems >1.5 m in height and <2 cm dbh.

^b Fifteen plots contained a 3 x 3 m square and 1.8 m high fence, enclosing the 2 x 2 m subplot.

^c Total area of 30 plots was 1.2 ha.

Table 16. Density of seedling^a tree and shrub species by fence treatment^b in eighteen 2 x 2 m Long Term Monitoring subplots in Biesecker woodlot, Gettysburg National Military Park, 1996.^c

	<u>Fenced Treatment</u>	<u>Unfenced Treatment</u>
	Density (stems/ha)	Density (stems/ha)
Tree		
Ash	1,042	0
Blackgum	208	0
Cedar, eastern red	833	0
Cherry, black	9,167	1,667
Hickory	1,458	417
Oak, black	833	0
Oak, northern red	417	417
Oak, white	6,875	0
Total	20,833	2,500
Shrub		
Barberry, Japanese	2,917	13,750
Dogwood, flowering	8,542	2,917
Redbud, eastern	0	417
Rose, multiflora	3,542	417
Spicebush	1,458	417
Total	16,458	17,917

^a Stems ≤ 150 cm in height.

^b Twelve plots contained a 3 x 3 m square and 1.8 m high fence, enclosing the 2 x 2 m subplot.

^c Total area of 18 subplots was 0.0072 ha.

Herbaceous Plants: Total herbaceous coverage averaged 27% in the fenced treatments, compared to 22% in the unfenced treatments (Table 17). Average forb and vine coverages in the fenced treatments (13 and 10%, respectively) were greater than those in the unfenced treatments (9 and 3%, respectively). Conversely, average grass coverage was greater in the unfenced treatments (10%) than in the fenced treatments (4%).

Pitzer Woodlot (Fenced and Unfenced Data Combined)

Overstory – Densities of overstory (>1.5 m in height and ≥ 12 cm dbh) trees by diameter class are presented in Figure 11. Overstory tree density was estimated at 291 stems per ha or 28% of all stems >1.5 m in height (Table 18). The overstory trees average 28 cm in diameter and 25 m² per ha in basal area (Table 19). Hickory and white oak were the most abundant species with 23 and 21%, respectively, of the total tree overstory density. White oak, black oak, hickory, and northern red oak were the dominant tree species, accounting for 56, 11, 11, and 8%, respectively, of the total overstory tree basal area (Table 19). The remaining 11 tree species accounted for 14% of the total basal area. The density and basal area values for trees ≥ 12 cm dbh would place the Pitzer woodlot in the 88% stocking level (Roach and Gingrich 1968).

Overstory – Shrub Species: The densities of overstory shrubs by diameter class are presented in Figure 12. Three percent of shrub species >1.5 m in height were overstory shrubs (Figure 12). Overstory shrub density was eight stems per ha, with an average diameter of 13 cm, and a basal area of 0.11 m² per ha (Table 18). Sassafras (*Sassafras albidum* (Nutt.) Nees), flowering dogwood, and serviceberry comprised 55, 35, and 10%, respectively, of the total overstory shrub basal area (Table 19).

Large Sapling – Tree Species: The density of large sapling (>1.5 m in height and 2-11.9 cm dbh) trees was estimated at 744 stems per ha, with an average diameter of 6 cm, and a basal area of 2 m² per ha (Table 18). Hickory, red maple (*Acer rubrum* L.), ash, and black cherry accounted for 39, 16, 14, and 12%, respectively, of the total large sapling tree density (Table 20). The remaining eight tree species accounted for 19% of the total density.

Large Sapling – Shrub Species: The density of large sapling shrubs was 214 stems per ha, with an average diameter of 4 cm, and a basal area of 0.37 m² per ha (Table 18). Smooth blackhaw, flowering dogwood, serviceberry, and sassafras comprised 51, 32, 11, and 7%, respectively, of the total large sapling shrub density (Table 20).

Small Sapling – Tree Species: The density of small sapling (>1.5 m in height and <2 cm dbh) trees was 23 stems per ha, with an average diameter of 1.1 cm, and a basal area of 0.0021 m² per ha (Table 18). Ash, black cherry, hickory, red maple, and white oak accounted for 63, 15, 7, 7, and 7%, respectively, of the total small sapling tree density (Table 21).

Small Sapling – Shrub Species: The density of small sapling shrubs was 45 stems per ha, with an average diameter of 0.9 cm, and a basal area of 0.0033 m² per ha (Table 18). Smooth blackhaw, flowering dogwood, and serviceberry comprised 94, 4, and 2%, respectively, of the total small sapling shrub density (Table 21).

Table 17. Average herbaceous coverage of grass, forb, vine, and total species by fence treatment^a in thirty 2 x 2 m Long Term Monitoring subplots in Biesecker woodlot, Gettysburg National Military Park, 1996.^b

	<u>Fenced Treatment</u>	<u>Unfenced Treatment</u>
	Coverage (%)	Coverage (%)
Grass	4	10
Forb	13	9
Vine	10	3
Total	27	22

^a Fifteen plots contained a 3 x 3 m square and 1.8 m high fence, enclosing the 2 x 2 m subplot.

^b Total area of 30 subplots was 0.012 ha.

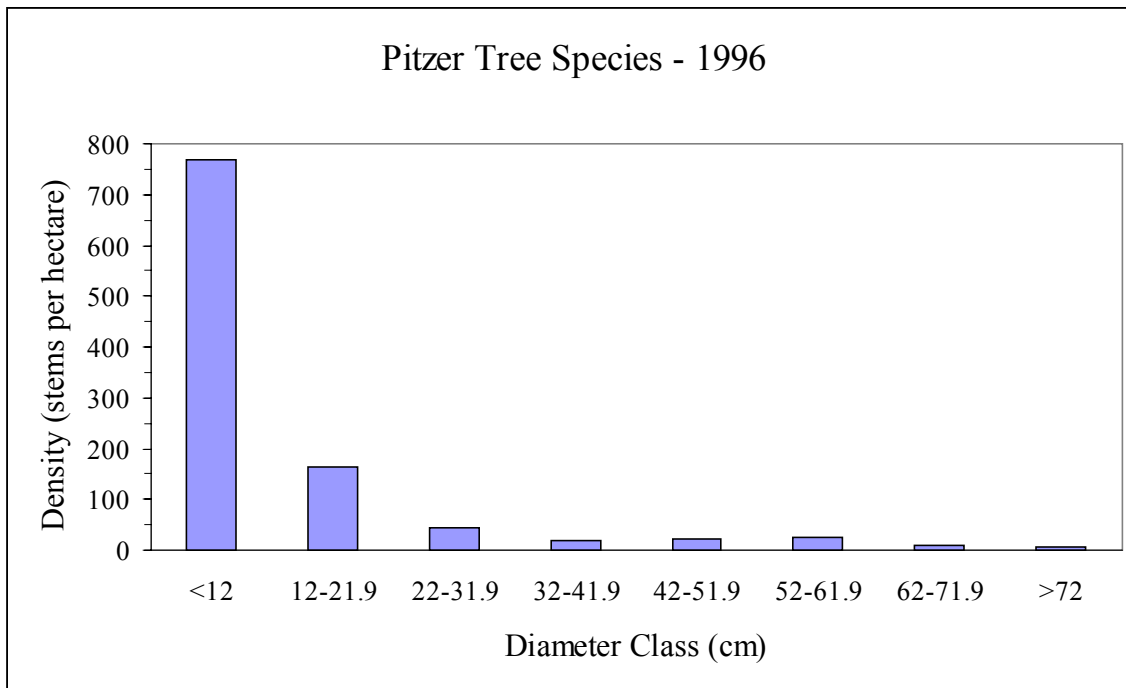


Figure 11. Density of small and large sapling (>1.5 m in height and <12 cm dbh) and overstory (>1.5 m height and ≥ 12 cm dbh) trees by diameter class in thirty 20 x 20 m Long Term Monitoring Plots in Pitzer woodlot, Gettysburg National Military Park, 1996.

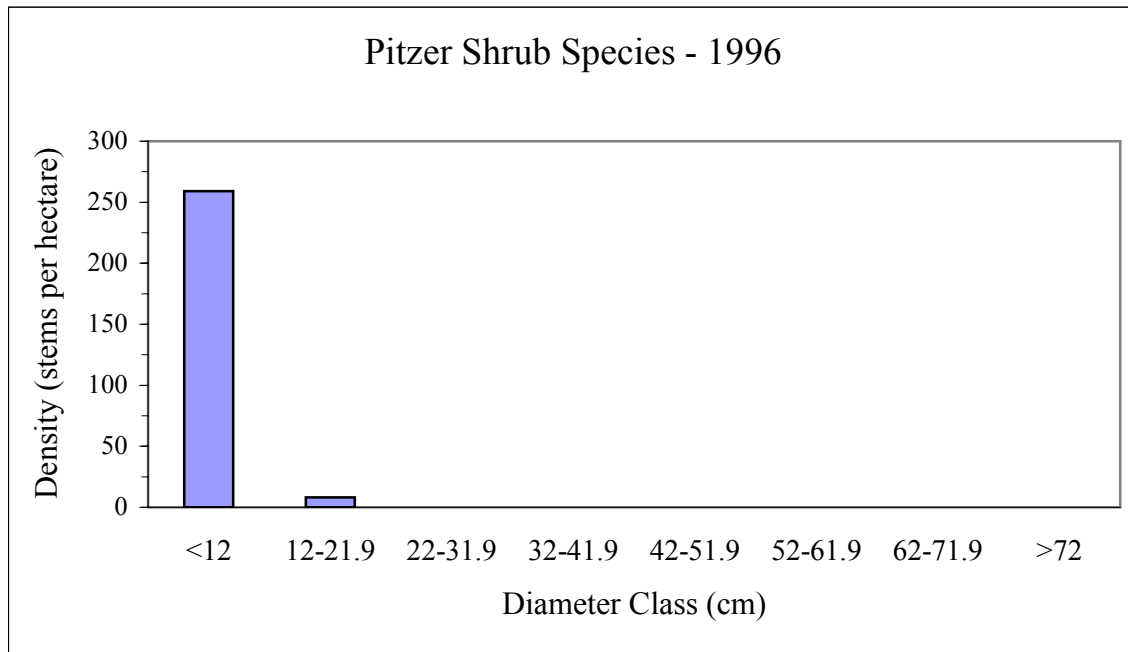


Figure 12. Density of small and large sapling (>1.5 m in height and <12 cm dbh) and overstory (>1.5 m height and ≥ 12 cm dbh) shrubs by diameter class in thirty 20 x 20 m Long Term Monitoring Plots in Pitzer woodlot, Gettysburg National Military Park, 1996.

Table 18. Density, average diameter, and basal area of small sapling, large sapling, and overstory trees and shrubs in thirty 20 x 20 m Long Term Monitoring Plots in Pitzer woodlot, Gettysburg National Military Park, 1996.^a

	Small Sapling ^b	Large Sapling ^b	Overstory ^b
Tree			
Density			
(stems/ha)	23	744	291
(stems/ac)	9	301	118
Average Diameter			
(cm)	1.1	6	28
(in)	0.4	2	11
Basal Area			
(m ² /ha)	0.0021	2	25
(ft ² /ac)	0.0092	10	109
Shrub			
Density			
(stems/ha)	45	214	8
(stems/ac)	18	87	3
Average Diameter			
(cm)	0.9	4	13
(in)	0.4	2	5
Basal Area			
(m ² /ha)	0.0033	0.37	0.11
(ft ² /ac)	0.0143	1.61	0.46

^a Total area of 30 plots was 1.2 ha.

^b Small saplings were stems >1.5 m in height and <2 cm dbh; large saplings were stems >1.5 m in height and 2-11.9 cm dbh; overstory were stems >1.5 m in height and ≥12 cm dbh.

Table 19. Density, average diameter, and basal area of overstory^a tree and shrub species in thirty 20 x 20 m Long Term Monitoring Plots in Pitzer woodlot, Gettysburg National Military Park, 1996.^b

	Density (stems/ha)	Average Diameter (cm)	Basal Area (m ² /ha)
Tree			
Ash	6	17	0.14
Blackgum	27	22	1.15
Cedar, eastern red	1	13	0.01
Cherry, sweet	15	15	0.27
Cherry, black	13	15	0.23
Elm, slippery	4	17	0.11
Hickory	68	20	2.74
Maple, red	38	16	0.88
Oak, black	15	42	2.75
Oak, northern red	34	25	2.01
Oak, scarlet	3	29	0.26
Oak, white	61	51	13.98
Pine, Virginia	2	28	0.11
Sycamore, American	1	37	0.09
Walnut, black	5	22	0.22
Total	291	28	24.94
Shrub			
Dogwood, flowering	3	14	0.04
Sassafras	4	13	0.06
Serviceberry	1	13	0.01
Total	8	13	0.11

^a Stems >1.5 m in height and >12 cm dbh.

^b Total area of 30 plots was 1.2 ha.

Table 20. Density, average diameter, and basal area of large sapling^a tree and shrub species in thirty 20 x 20 m Long Term Monitoring Plots in Pitzer woodlot, Gettysburg National Military Park, 1996.^b

	Density (stems/ha)	Average Diameter (cm)	Basal Area (m ² /ha)
Tree			
Ash	102	4	0.15
Blackgum	53	6	0.19
Cedar, eastern red	5	6	0.02
Cherry, sweet	32	7	0.14
Cherry, black	91	6	0.27
Elm, slippery	8	5	0.02
Hickory	292	5	0.78
Maple, red	118	6	0.44
Mulberry spp.	1	6	<0.01
Oak, black	13	8	0.07
Oak, northern red	18	9	0.11
Oak, white	14	6	0.05
Total	744	6	2.23
Shrub			
Blackhaw, smooth	110	3	0.08
Dogwood, flowering	68	5	0.17
Sassafras	14	8	0.07
Serviceberry	23	5	0.05
Total	214	4	0.3

^a Stems >1.5 m in height and 2-11.9 cm dbh.

^b Total area of 30 plots was 1.2 ha.

Table 21. Density, average diameter, and basal area of small sapling^a tree and shrub species in thirty 20 x 20 m Long Term Monitoring Plots in Pitzer woodlot, Gettysburg National Military Park, 1996.^b

	Density (stems/ha)	Average Diameter (cm)	Basal Area (m ² /ha)
Tree			
Ash	14	1.1	0.0013
Cherry, black	3	1.1	0.0003
Hickory	2	1.3	0.0002
Maple, red	2	1.1	0.0002
Oak, white	2	0.6	0.0001
Total	23	1.1	0.0021
Shrub			
Blackhaw, smooth	43	0.9	0.0030
Dogwood, flowering	2	1.1	0.0002
Serviceberry	1	1.3	0.0001
Total	45	0.9	0.0033

^a Stems >1.5 m in height and <2 cm dbh.

^b Total area of 30 plots was 1.2 ha.

Total Sapling – Tree Species: For tree species, the density of small and large saplings combined was 767 stems per ha, of which 91% (700 stems per ha) was comprised of ash, cherry, hickory, maple, and oak species (Figure 13). Similarly, of the overstory trees (291 stems per ha), 87% (253 stems per ha) consisted of ash, cherry, hickory, maple, and oak species. For ash, cherry, hickory, and maple species, densities of sapling stems were 19.3, 4.5, 4.3, and 3.1 times greater, respectively, than those of overstory stems. Conversely, the density of overstory oak was 2.5 times greater than that of sapling oak.

Total Sapling – Shrub species: The density of small and large sapling shrubs combined was 259 stems per ha. Smooth blackhaw, flowering dogwood, serviceberry, and sassafras accounted for 59, 27, 9, and 5%, respectively, of the total shrub sapling density (Figure 14). For flowering dogwood, serviceberry, and sassafras, densities of sapling stems were 23, 23, and 3.5 times greater, respectively, than those of overstory stems. The density of small and large sapling smooth blackhaw was 153 stems per ha. Nevertheless, no smooth blackhaw was recorded in the overstory in 1996.

Seedling – Tree Species: Six species of tree seedlings had a density of 6,711 stems per ha (Table 22). Collectively, hickory and red maple comprised 86% of the total tree seedling density. Ash, slippery elm (*Ulmus rubra* Muhl.), and black oak each accounted for 4%, while black walnut (*Juglans nigra* L.) accounted for 2% of the total tree seedling density.

Seedling – Shrub Species: Four species of shrub seedlings were recorded, with a density of 7,237 stems per ha (Table 22). Flowering dogwood and spicebush were the most abundant species, collectively accounting for 93% of total shrub seedling density. Multiflora rose and sassafras each accounted for 4% of the total.

Herbaceous Plants: Average herbaceous coverage totaled 19% in the Pitzer woodlot (Table 23). Forb coverage was greatest (15%), followed by vine (4%) and grass (1%).

Pitzer Woodlot (Fenced and Unfenced Treatments)

Overstory – Tree Species: In the fenced and unfenced treatments, 14 and 13 overstory tree species, respectively, were recorded in 1996 (Table 24). Hickory, white oak, red maple, and blackgum were the most abundant species in the fenced treatments, accounting for 23, 23, 14, and 12%, respectively, of the total overstory tree density. Hickory, white oak, northern red oak, and red maple were the most abundant species in the unfenced treatments, accounting for 23, 19, 15, and 12%, respectively, of the total overstory tree density. In the fenced treatments, there were 10 other species making up 31% of the density. There were nine other species in the unfenced treatments that contributed to the remaining 28% of the total overstory tree density. White oak was dominant in both the fenced and unfenced treatments, accounting for 51 and 61% of total basal area, respectively. Hickory, black oak, and northern red oak collectively accounted for 32 and 28% of the total basal area in the fenced and unfenced treatments, respectively.

Overstory – Shrub Species: Three overstory shrub species were recorded in the fenced treatments, compared to two species in the unfenced treatments (Table 24). In the fenced and unfenced treatments, overstory shrub densities were 12 and 3 stems per ha, respectively (Table 24). Sassafras, flowering dogwood, and serviceberry comprised 59, 29, and 12%, respectively, of the total basal area in the fenced treatments, whereas sassafras and flowering dogwood each accounted for 50% of the total basal area in the unfenced treatments.

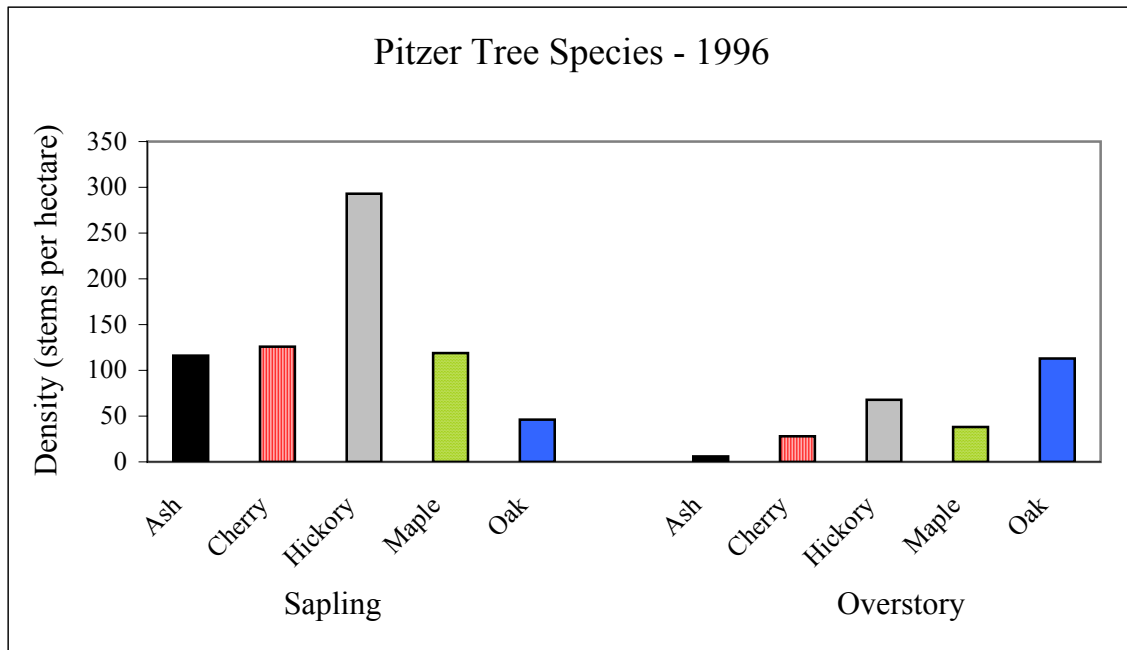


Figure 13. Density of small and large sapling (>1.5 m in height and <12 cm dbh) and overstory (>1.5 m height and ≥ 12 cm dbh) selected tree species in thirty 20 x 20 m Long Term Monitoring Plots in Pitzer woodlot, Gettysburg National Military Park, 1996.

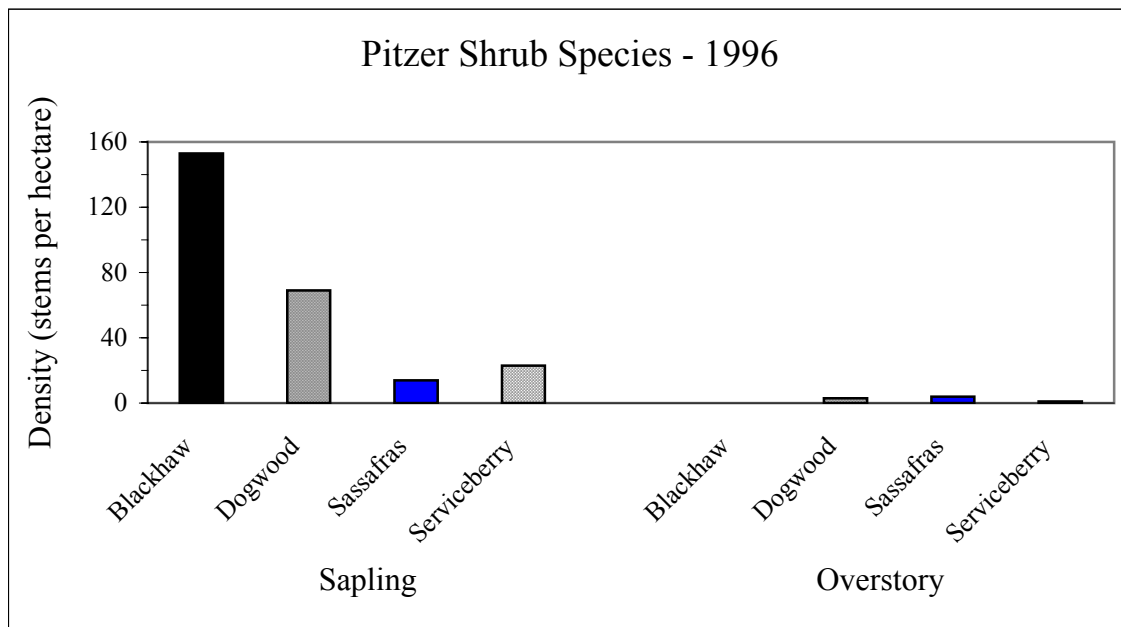


Figure 14. Density of small and large sapling (>1.5 m in height and <12 cm dbh) and overstory (>1.5 m height and ≥ 12 cm dbh) shrub species in thirty 20 x 20 m Long Term Monitoring Plots in Pitzer woodlot, Gettysburg National Military Park, 1996.

Table 22. Density of seedling^a tree and shrub species in nineteen 2 x 2 m Long Term Monitoring subplots in Pitzer woodlot, Gettysburg National Military Park, 1996.^b

	Density (stems/ha)
Tree	
Ash	263
Elm, slippery	263
Hickory	4,342
Maple, red	1,447
Oak, black	263
Walnut, black	132
Total	6,711
Shrub	
Dogwood, flowering	5,263
Rose, multiflora	263
Sassafras	263
Spicebush	1,447
Total	7,237

^a Stems ≤ 150 cm in height.

^b Total area of 19 subplots was 0.0076 ha.

Table 23. Average herbaceous coverage for grass, forb, vine, and total species in thirty 2 x 2 m Long Term Monitoring subplots in Pitzer woodlot, Gettysburg National Military Park, 1996.^a

	Coverage (%)
Grass	1
Forb	15
Vine	4
Total	19

^a Total area of 30 subplots was 0.012 ha.

Table 24. Density, average diameter, and basal area of overstory^a tree and shrub species by fence treatment^b in thirty 20 x 20 m Long Term Monitoring Plots in Pitzer woodlot, Gettysburg National Military Park, 1996.^c

	<u>Fenced Treatment</u>			<u>Unfenced Treatment</u>		
	Density (stems/ha)	Diameter (cm)	Basal Area (m ² /ha)	Density (stems/ha)	Diameter (cm)	Basal Area (m ² /ha)
Tree						
Ash	10	17	0.25	2	16	0.03
Blackgum	35	24	1.83	18	17	0.46
Cedar, eastern red	2	13	0.02	0	0	0.00
Cherry, sweet	12	16	0.25	18	14	0.29
Cherry, black	12	16	0.23	13	14	0.22
Elm, slippery	2	29	0.11	7	14	0.11
Hickory	70	21	3.05	65	20	2.43
Maple, red	42	16	0.92	33	17	0.83
Oak, black	13	51	3.42	17	35	2.08
Oak, northern red	27	24	1.54	42	25	2.49
Oak, scarlet	2	51	0.34	5	21	0.18
Oak, white	68	46	12.81	53	58	15.14
Pine, Virginia	0	0	0.00	3	28	0.22
Sycamore, American	2	37	0.18	0	0	0.00
Walnut, black	5	25	0.28	5	19	0.16
Total	300	28	25.22	282	28	24.66
Shrub						
Dogwood, flowering	3	14	0.05	2	14	0.02
Sassafras	7	14	0.10	2	12	0.02
Serviceberry	2	13	0.02	0	0	0.00
Total	12	14	0.17	3	13	0.04

^a Stems >1.5 m in height and ≥12 cm dbh.

^b Fifteen plots contained a 3 x 3 m square and 1.8 m high fence, enclosing the 2 x 2 m subplot.

^c Total area of 30 plots was 1.2 ha.

Large Sapling – Tree Species: Eleven large sapling tree species were recorded in the fenced treatments, compared to twelve species in the unfenced treatments (Table 25). There were 717 large sapling trees per ha in the fenced treatments and 772 large sapling trees per ha in the unfenced treatments. Hickory was the most abundant species accounting for 27% of the total large sapling tree density in the fenced treatments and 51% of the total large sapling tree density in the unfenced treatments. Ash, black cherry, and red maple collectively accounted for 50 and 34% of the total density in the fenced and unfenced treatments, respectively.

Large Sapling – Shrub Species: Four large sapling shrub species were recorded in each of the fenced and unfenced treatments (Table 25). The density of large sapling shrubs was 237 stems per ha in the fenced treatments and 192 stems per ha in the unfenced treatments. Ash, smooth blackhaw, and flowering dogwood were the most abundant species, collectively accounting for 81 and 85% of the total density in the fenced and unfenced treatments, respectively. Serviceberry and sassafras accounted for 10 and 9%, respectively, of the total large sapling shrub density in the fenced treatments and 11 and 4%, respectively, of the total large sapling shrub density in the unfenced treatments.

Small Sapling – Tree Species: Five small sapling tree species were recorded in the fenced treatments, compared to four species in the unfenced treatments (Table 26). Ash was dominant in both the fenced and unfenced treatments, accounting for 63 and 64%, respectively, of the total small sapling tree density. White oak comprised 12% of the total density in the fenced treatments but was not recorded in the unfenced treatments in the 1996 survey.

Small Sapling – Shrub Species: Smooth blackhaw and serviceberry were the only small sapling shrub species recorded in the fenced treatments, accounting for 96 and 4%, respectively, of the total density (Table 26). In the unfenced treatments, smooth blackhaw and flowering dogwood accounted for 93 and 7%, respectively, of the total small sapling shrub density.

Seedling – Tree Species: Three tree species were recorded in the fenced treatments, compared to four species in the unfenced treatments (Table 27). In the fenced and unfenced treatments, the total tree seedling densities were 5,833 and 7,500 stems per ha, respectively. Red maple comprised 52% of the total density in the fenced treatments, but was not recorded in the unfenced treatments. Hickory and black oak comprised 38 and 10%, respectively, of the total seedling tree density in the fenced treatments. In the unfenced treatments, hickory was dominant, accounting for 83% of the total tree seedling density. Ash and slippery elm each accounted for 7%, while black walnut accounted for 3% of the total.

Seedling – Shrub Species: In the fenced and unfenced treatments there were two and four shrub species, respectively, recorded as seedlings (Table 27). Multiflora rose and sassafras were present in the unfenced treatments but were absent in the fenced treatments. Total shrub seedling densities in the fenced and unfenced treatments were 11,389 and 3,500 stems per ha, respectively. Flowering dogwood and spicebush comprised 80 and 20%, respectively, of the total seedling shrub density in the fenced treatments. In the unfenced treatments, flowering dogwood and spicebush comprised 50 and 21% of the total seedling shrub density, respectively, while multiflora rose and sassafras each accounted for 14% of the total.

Herbaceous Plants: Average herbaceous coverage was 10% in the fenced treatments, compared to 28% in the unfenced treatments (Table 28). Forb and vine coverage values in the unfenced

Table 25. Density, average diameter, and basal area of large sapling^a tree and shrub species by fence treatment^b in thirty 20 x 20 m Long Term Monitoring Plots in Pitzer woodlot, Gettysburg National Military Park, 1996.^c

	<u>Fenced Treatment</u>			<u>Unfenced Treatment</u>		
	Density (stems/ha)	Diameter (cm)	Basal Area (m ² /ha)	Density (stems/ha)	Diameter (cm)	Basal Area (m ² /ha)
Tree						
Ash	147	4	0.19	57	5	0.12
Blackgum	75	6	0.27	30	7	0.11
Cedar, eastern red	5	6	0.02	5	5	0.01
Cherry, sweet	30	6	0.10	33	8	0.18
Cherry, black	100	6	0.31	82	5	0.23
Elm, slippery	15	5	0.04	2	4	<0.01
Hickory	193	6	0.59	390	5	0.97
Maple, red	113	6	0.40	122	6	0.47
Mulberry spp.	0	0	0.00	2	6	0.01
Oak, black	7	8	0.03	18	8	0.10
Oak, northern red	18	8	0.11	17	9	0.11
Oak, white	13	6	0.05	15	7	0.06
Total	717	5	2.10	772	6	2.36
Shrub						
Blackhaw, smooth	118	3	0.08	102	3	0.09
Dogwood, flowering	73	5	0.17	62	5	0.16
Sassafras	22	8	0.13	7	5	0.02
Serviceberry	23	5	0.05	22	4	0.04
Total	237	4	0.43	192	4	0.31

^a Stems >1.5 m in height and 2-11.9 cm in dbh.

^b Fifteen plots contained a 3 x 3 m square and 1.8 m high fence, enclosing the 2 x 2 m subplot.

^c Total area of 30 plots was 1.2 ha.

Table 26. Density, average diameter, and basal area of small sapling^a tree and shrub species by fence treatment^b in thirty 20 x 20 m Long Term Monitoring Plots in Pitzer woodlot, Gettysburg National Military Park, 1996.^c

	<u>Fenced Treatment</u>			<u>Unfenced Treatment</u>		
	Density (stems/ha)	Diameter (cm)	Basal Area (m ² /ha)	Density (stems/ha)	Diameter (cm)	Basal Area (m ² /ha)
Tree						
Ash	17	1.1	0.0017	12	1.0	0.0009
Cherry, black	3	1.1	0.0003	3	1.1	0.0003
Hickory	2	1.3	0.0002	2	1.3	0.0002
Maple, red	2	1.3	0.0002	2	1.0	0.0001
Oak, white	3	0.6	0.0001	0	0.0	0.0000
Total	27	1.1	0.0026	18	1.0	0.0016
Shrub						
Blackhaw, smooth	38	1.0	0.0030	47	0.9	0.0030
Dogwood, flowering	0	0.0	0.0000	3	1.1	0.0003
Serviceberry	2	1.3	0.0002	0	0.0	0.0000
Total	40	1.0	0.0032	50	0.9	0.0033

^a Stems >1.5 m in height and <2 cm dbh.

^b Fifteen plots contained a 3 x 3 m square and 1.8 m high fence, enclosing the 2 x 2 m subplot.

^c Total area of 30 plots was 1.2 ha.

Table 27. Density of seedling^a tree and shrub species by fence treatment^b in nineteen 2 x 2 m Long Term Monitoring subplots in Pitzer woodlot, Gettysburg National Military Park, 1996.^c

	<u>Fenced Treatment</u>	<u>Unfenced Treatment</u>
	Density (stems/ha)	Density (stems/ha)
Tree		
Ash	0	500
Elm, slippery	0	500
Hickory	2,222	6,250
Maple, red	3,056	0
Oak, black	556	0
Walnut, black	0	250
Total	5,833	7,500
Shrub		
Dogwood, flowering	9,167	1,750
Rose, multiflora	0	500
Sassafras	0	500
Spicebush	2,222	750
Total	11,389	3,500

^a Stems ≤ 150 cm in height.

^b Nine plots contained a 3 x 3 m square and 1.8 m high fence, enclosing the 2 x 2 m subplot.

^c Total area of 19 subplots was 0.0076 ha.

Table 28. Average herbaceous coverage for grass, forb, vine, and total species by fence treatment^a in thirty 2 x 2 m Long Term Monitoring subplots in Pitzer woodlot, Gettysburg National Military Park, 1996.^b

	<u>Fenced Treatment</u>	<u>Unfenced Treatment</u>
	Coverage (%)	Coverage (%)
Grass	1	1
Forb	7	22
Vine	2	5
Total	10	28

^a Fifteen plots contained a 3 x 3 m square and 1.8 m high fence, enclosing the 2 x 2 m subplot.

^b Total area of 30 subplots was 0.012 ha.

treatments (22 and 5%, respectively) were greater than those in the fenced treatments (7 and 2%, respectively). Grass coverage was 1% for each of the fenced and unfenced treatments.

Herr Ridge Woodlot

Overstory – Tree Species: Densities of overstory (>1.5 m in height and ≥ 12 cm dbh) trees are presented in Figure 15. Total overstory tree density was estimated at 222 stems per ha or 16% of all stems >1.5 m in height. The overstory trees averaged 28 cm dbh and had a basal area of 18 m² per ha (Table 29). Hickory, white oak, and ash were the most abundant species with 36, 19, and 13%, respectively, of the total tree overstory density. White oak, black oak, hickory, and northern red oak were the dominant tree species, accounting for 39, 23, 14, and 14%, respectively, of the total overstory tree basal area (Table 30). The remaining five tree species accounted for 9% of total basal area. The overstory density and basal area would place the Herr Ridge woodlot in the 63% stocking level (Roach and Gingrich 1968).

Overstory – Shrub Species: No overstory shrub species were recorded in the Herr Ridge woodlot in the 1996 survey (Table 29).

Large Sapling – Tree Species: Large sapling tree density was 837 stems per ha, with an average diameter of 5 cm, and a basal area of 2 m² per ha (Table 29). Hickory and black cherry accounted for 53 and 35%, respectively, of the total large sapling density (Table 31). The remaining nine tree species accounted for 12% of total density.

Large Sapling – Shrub Species: Large sapling shrub density was 317 stems per ha, with an average diameter of 3 cm, and a basal area of 0.33 m² per ha (Table 29). Smooth blackhaw, eastern redbud, serviceberry, and flowering dogwood accounted for 45, 35, 12, and 8%, respectively, of the total density (Table 31).

Small Sapling – Tree Species: Small sapling tree density was 315 stems per ha, with an average diameter of 0.8 cm, and a basal area of 0.0178 m² per ha (Table 29). Black cherry was dominant, comprising 77% of the total small sapling tree density (Table 32). Ash, hickory, black oak, and white oak collectively accounted for 21% of total density, with the remaining four tree species comprising 2% of the total.

Small Sapling – Shrub Species: Small sapling shrub density was 183 stems per ha, with an average diameter of 0.8 cm, and a basal area of 0.0117 m² per ha (Table 29). Smooth blackhaw was dominant, accounting for 83% of the total small sapling shrub density (Table 32). Flowering dogwood and eastern redbud collectively accounted for 14% of the total density, with the remaining two shrub species comprising 4% of the total.

Total Sapling – Tree Species: The density of small and large sapling trees combined was 1,152 stems per ha, of which 97% (1,120 stems per ha) was comprised of cherry, hickory, oak, and ash species (Figure 17). Similarly, of the overstory trees (222 stems per ha), 95% (212 stems per ha) consisted of cherry, hickory, oak, and ash species. Cherry and hickory species sapling densities were 32.8 and 5.9 times greater, respectively, than those of overstory stems. Conversely, the density of overstory oak was 1.3 times greater than that of sapling oak. For ash species, sapling and overstory stems each totaled 28 stems per ha.

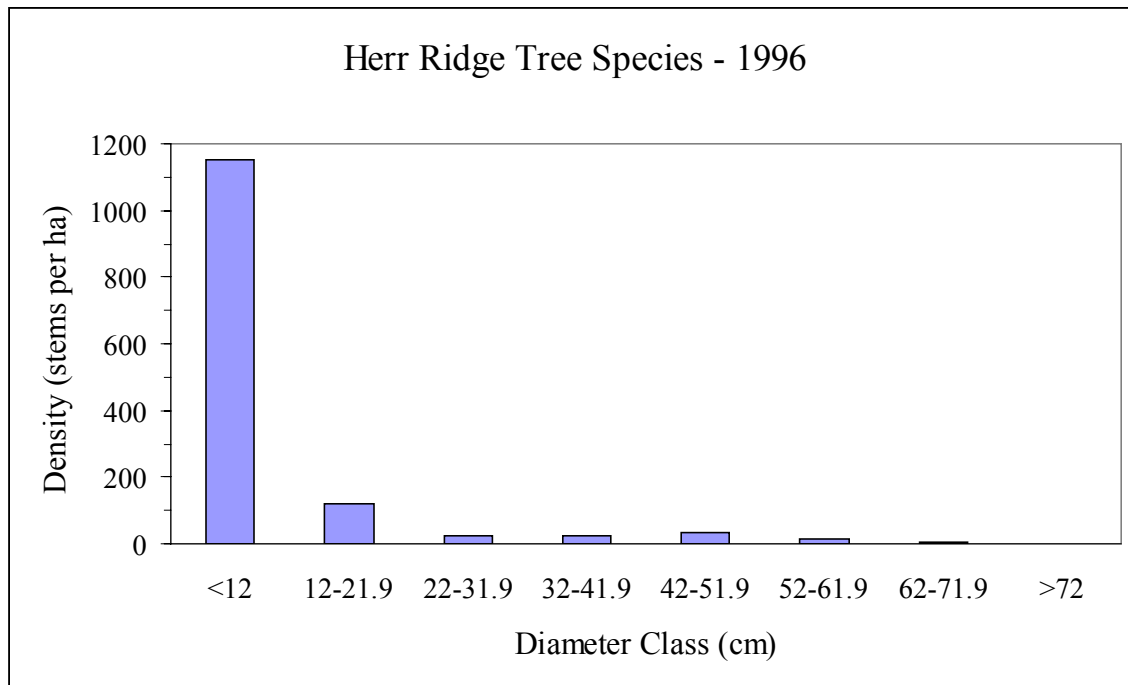


Figure 15. Density of small and large sapling (>1.5 m in height and <12 cm dbh) and overstory (>1.5 m in height and ≥ 12 cm dbh) trees by diameter class in fifteen 20 x 20 m Long Term Monitoring Plots in Herr Ridge woodlot, Gettysburg National Military Park, 1996.

Table 29. Density, average diameter, and basal area of small sapling, large sapling, and overstory trees and shrubs in fifteen 20 x 20 m Long Term Monitoring Plots in Herr Ridge woodlot, Gettysburg National Military Park, 1996.^a

	Small Sapling ^b	Large Sapling ^b	Overstory ^b
Tree			
Density			
(stems/ha)	315	837	222
(stems/ac)	128	339	90
Average Diameter			
(cm)	0.8	5	28
(in)	0.3	2	11
Basal Area			
(m ² /ha)	0.0178	2	18
(ft ² /ac)	0.0774	8	77
Shrub			
Density			
(stems/ha)	183	317	0
(stems/ac)	74	128	0
Average Diameter			
(cm)	0.8	3	0
(in)	0.3	1	0
Basal Area			
(m ² /ha)	0.0117	0.33	0.00
(ft ² /ac)	0.0508	1.42	0.00

^a Total area of 15 plots was 0.6 ha.

^b Small saplings were stems >1.5 m in height and <2 cm dbh; large saplings were stems >1.5 m in height and 2-11.9 cm dbh; overstory were stems >1.5 m in height and ≥12 cm dbh.

Table 30. Density, average diameter, and basal area of overstory^a tree species in fifteen 20 x 20 m Long Term Monitoring Plots in Herr Ridge woodlot, Gettysburg National Military Park, 1996.^b

	Density (stems/ha)	Average Diameter (cm)	Basal Area (m ² /ha)
Tree			
Ash	28	18	0.89
Blackgum	8	21	0.31
Cherry, sweet	10	15	0.18
Cherry, black	7	16	0.13
Hickory	80	19	2.53
Maple, Norway	2	27	0.10
Oak, black	22	47	4.15
Oak, northern red	22	36	2.46
Oak, white	43	43	6.98
Total	222	28	17.73

^a Stems >1.5 m in height and ≥ 12 cm dbh.

^b Total area of 15 plots was 0.6 ha.

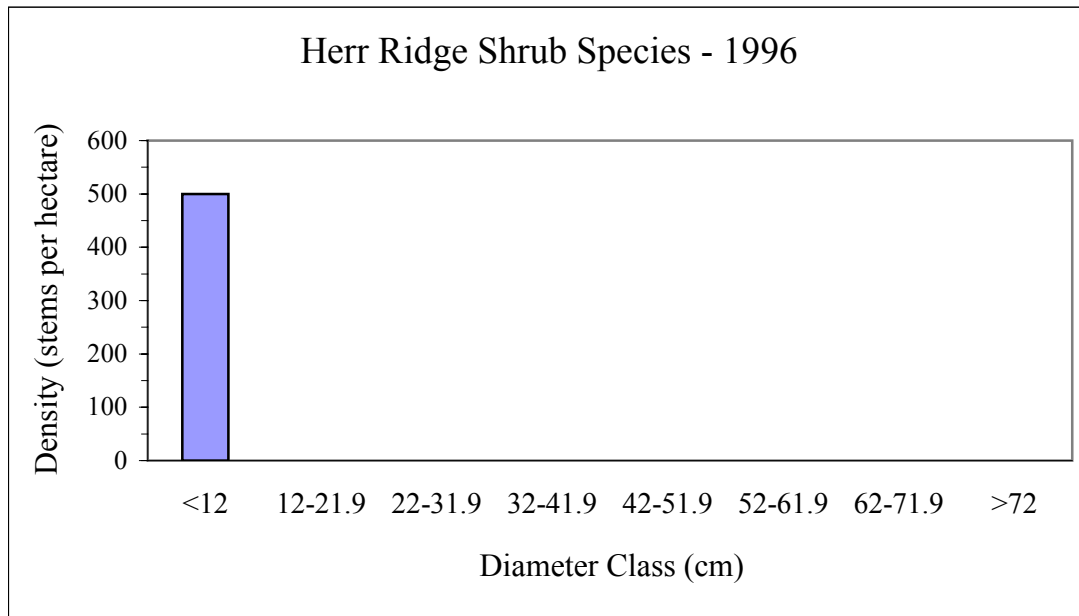


Figure 16. Density of small and large sapling (>1.5 in height and <12 cm dbh) and overstory (>1.5 m in height and ≥ 12 cm dbh) shrubs by diameter class in fifteen 20 x 20 m Long Term Monitoring Plots in Herr Ridge woodlot, Gettysburg National Military Park, 1996.

Table 31. Density, average diameter, and basal area of large sapling^a tree and shrub species in fifteen 20 x 20 m Long Term Monitoring Plots in Herr Ridge woodlot, Gettysburg National Military Park, 1996.^b

	Density (stems/ha)	Average Diameter (cm)	Basal Area (m ² /ha)
Tree			
Ash	15	6	0.04
Blackgum	12	6	0.04
Cherry, sweet	22	6	0.08
Cherry, black	292	4	0.49
Elm, slippery	5	8	0.03
Hickory	443	5	1.12
Maple, Norway	7	7	0.03
Maple, red	5	6	0.02
Oak, black	15	5	0.04
Oak, northern red	5	7	0.03
Oak, white	17	4	0.02
Total	837	5	1.94
Shrub			
Blackhaw, smooth	142	3	0.12
Dogwood, flowering	27	3	0.02
Redbud, eastern	110	4	0.14
Serviceberry	38	4	0.05
Total	317	3	0.33

^a Stems >1.5 m in height and 2-11.9 cm dbh.

^b Total area of 15 plots was 0.6 ha.

Table 32. Density, average diameter, and basal area of small sapling^a tree and shrub species in fifteen 20 x 20 m Long Term Monitoring Plots in Herr Ridge woodlot, Gettysburg National Military Park, 1996.^b

	Density (stems/ha)	Average Diameter (cm)	Basal Area (m ² /ha)
Tree			
Ash	13	0.6	0.0005
Cherry, sweet	2	1.0	0.0001
Cherry, black	242	0.7	0.0126
Elm, slippery	2	1.3	0.0002
Hickory	27	1.1	0.0025
Maple, red	2	1.0	0.0001
Oak, black	12	0.7	0.0005
Oak, northern red	2	1.3	0.0002
Oak, white	15	0.8	0.0009
Total	315	0.8	0.0178
Shrub			
Blackhaw, smooth	152	0.8	0.0094
Dogwood, flowering	13	0.9	0.0009
Hawthorn	2	0.8	0.0001
Redbud, eastern	12	0.9	0.0009
Serviceberry	5	0.9	0.0004
Total	183	0.8	0.0117

^a Stems >1.5 m in height and <2 cm dbh.

^b Total area of 15 plots was 0.6 ha.

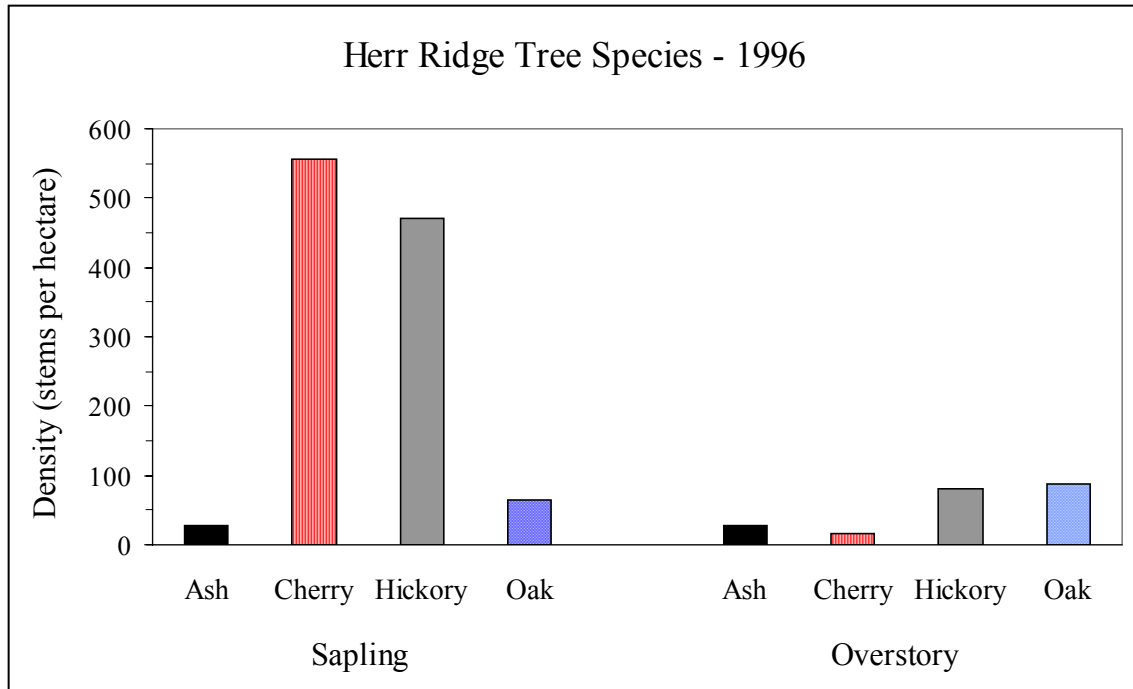


Figure 17. Density of small and large sapling (>1.5 m in height and <12 cm dbh) and overstory (>1.5 m in height and ≥ 12 cm dbh) selected tree species in fifteen 20 x 20 m Long Term Monitoring Plots in Herr Ridge woodlot, Gettysburg National Military Park, 1996.

Total Sapling – Shrub species: The density of small and large sapling shrubs combined was 500 stems per ha. Smooth blackhaw, eastern redbud, serviceberry, flowering dogwood, and hawthorn (*Crataegus spp.*) accounted for 59, 24, 9, 8, and <1%, respectively, of the total shrub sapling density (Figure 18). Nevertheless, none of these shrub species were recorded in the overstory.

Seedling – Tree Species: Eight species of tree seedlings were recorded with a density of 18,654 stems per ha (Table 33). Collectively, ash and black cherry accounted for 74% of total tree seedling density. Hickory and sweet cherry accounted for 11 and 7%, respectively, with the remaining four species accounting for 7% of the total.

Seedling – Shrub Species: Five species of shrub seedlings had a density of 15,962 stems per ha (Table 33). *Rubus* was the most abundant species, comprising 46% of total shrub seedling density. Flowering dogwood and multiflora rose collectively accounted for 42%, with the remaining two species accounting for 12% of the total.

Herbaceous Plants: Average herbaceous coverage totaled 27% in 1996 (Table 34). Forb coverage was greatest (14%), followed by vine and grass (13 and <1%, respectively).

Spangler Woodlot

Overstory – Densities of overstory (>1.5 m in height and ≥ 12 cm dbh) trees by diameter class are presented in Figure 19. Overstory tree density was estimated at 302 stems per ha or 36% of all stems >1.5 m in height (Figure 19). The overstory trees averaged 26 cm dbh with a basal area of 23 m² per ha (Table 35). White oak, black cherry, sweet cherry, and hickory oak were the most abundant species with 19, 18, 15, and 14%, respectively, of the total overstory tree density. White oak and hickory were the dominant tree species, accounting for 54 and 18%, respectively, of the total overstory tree basal area (Table 36). The remaining nine tree species accounted for 28% of total basal area. The density and basal area values for overstory trees would place the Spangler woodlot in the 82% stocking level (Roach and Gingrich 1968).

Overstory – Shrub Species: Three percent of the shrubs >1.5 m in height were overstory shrubs (Figure 20). Overstory shrub density was 5 stems per ha, with an average diameter of 14 cm, and a basal area of 0.08 m² per ha (Table 35). Sassafras and serviceberry comprised 63 and 37%, respectively, of the total overstory shrub basal area (Table 36).

Large Sapling – Tree Species: Large sapling tree density was 532 stems per ha, with an average diameter of 6 cm, and a basal area of 2 m² per ha (Table 35). Hickory, black cherry, sweet cherry, and ash accounted for 34, 20, 14, and 14%, respectively, of the total large sapling density (Table 37). The remaining seven tree species accounted for 17% of the total density.

Large Sapling – Shrub Species: The density of large sapling shrubs was 173 stems per ha, with an average diameter of 4 cm, and a basal area of 0.34 m² per ha (Table 35). Smooth blackhaw, flowering dogwood, and serviceberry collectively accounted for 93% of the total shrub density, with the remaining two species accounting for 7% of the total (Table 37).

Small Sapling – Tree Species: Ash was the only small sapling tree species recorded, with a density of 13 stems per ha, an average diameter of 1.2 cm, and a basal area of 0.0016 m² per ha (Table 38).

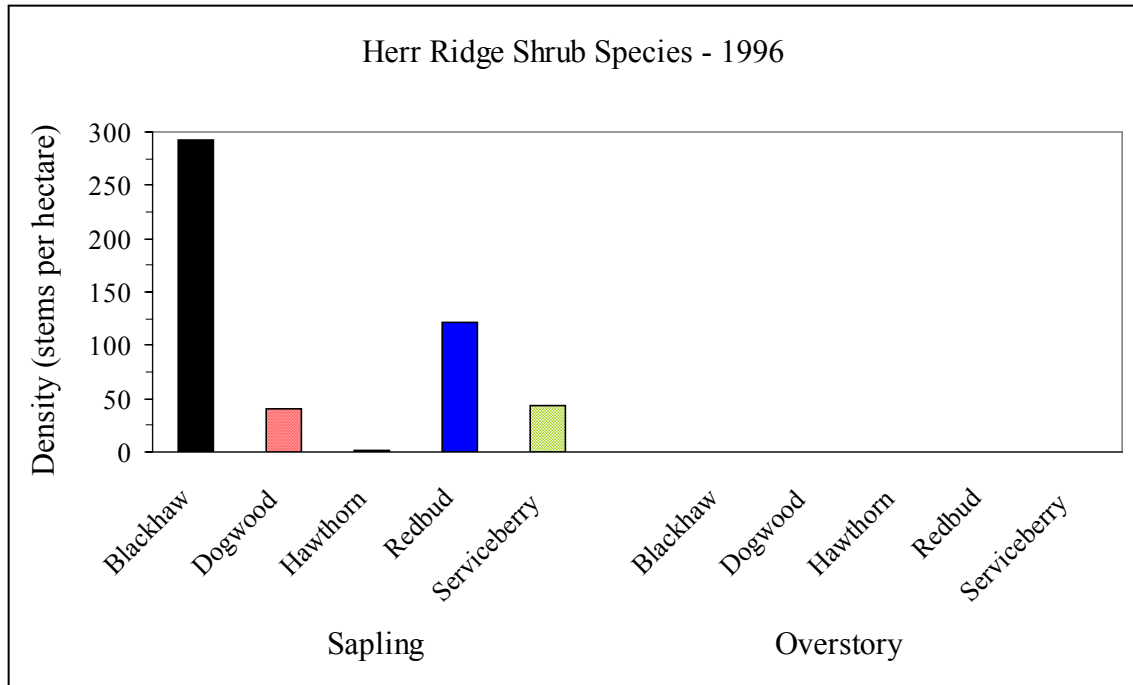


Figure 18. Density of small and large sapling (>1.5 m in height and <12 cm dbh) and overstory (>1.5 m in height and $\geq$ 12 cm dbh) shrub species in fifteen 20 x 20 m Long Term Monitoring Plots in Herr Ridge woodlot, Gettysburg National Military Park, 1996.

Table 33. Density of seedling^a tree and shrub species in thirteen 2 x 2 m Long Term Monitoring subplots in Herr Ridge woodlot, Gettysburg National Military Park, 1996.^b

	Density (stems/ha)
Tree	
Ash	7,115
Blackgum	385
Cherry, sweet	1,346
Cherry, black	6,731
Elm, slippery	192
Hickory	2,115
Maple, red	192
Oak, northern red	577
Total	18,654
Shrub	
Dogwood, flowering	3,462
Redbud, eastern	1,731
Rose, multiflora	3,269
<i>Rubus</i>	7,308
Sassafras	192
Total	15,962

^a Stems ≤ 150 cm in height.

^b Total area of 13 subplots was 0.0052 ha.

Table 34. Average herbaceous coverage for grass, forb, vine, and total species in fifteen 2 x 2 m Long Term Monitoring subplots in Herr Ridge woodlot, Gettysburg National Military Park, 1996.^a

	Coverage (%)
Grass	<1
Forb	14
Vine	13
Total	27

^a Total area of 15 subplots was 0.006 ha.

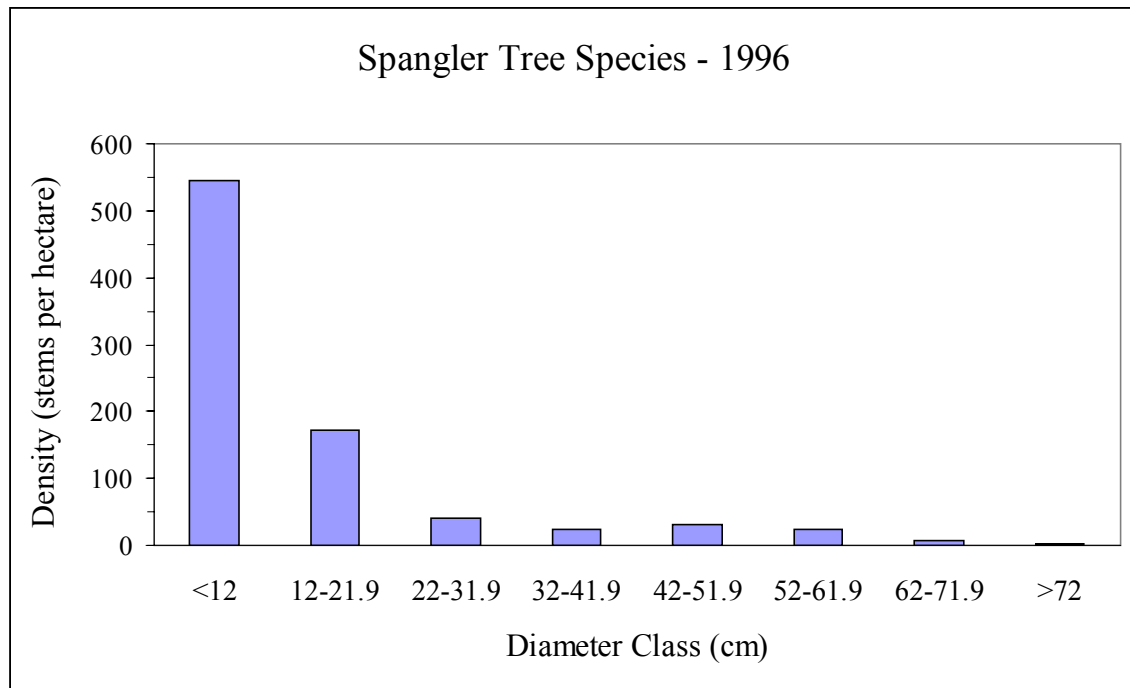


Figure 19. Density of small and large sapling (>1.5 m in height and <12 cm dbh) and overstory (>1.5 m in height and ≥ 12 cm dbh) trees by diameter class in fifteen 20 x 20 m Long Term Monitoring Plots in Spangler woodlot, Gettysburg National Military Park, 1996.

Table 35. Density, average diameter, and basal area of small sapling, large sapling, and overstory trees and shrubs in fifteen 20 x 20 m Long Term Monitoring Plots in Spangler woodlot, Gettysburg National Military Park, 1996.^a

	Small Sapling ^b	Large Sapling ^b	Overstory ^b
Tree			
Density			
(stems/ha)	13	532	302
(stems/ac)	5	215	122
Average Diameter			
(cm)	1.2	6	26
(in)	0.5	2	10
Basal Area			
(m ² /ha)	0.0016	2	23
(ft ² /ac)	0.0070	8	99
Shrub			
Density			
(stems/ha)	13	173	5
(stems/ac)	5	70	2
Average Diameter			
(cm)	1.2	4	14
(in)	0.5	2	6
Basal Area			
(m ² /ha)	0.0015	0.34	0.08
(ft ² /ac)	0.0064	1.48	0.35

^a Total area of 15 plots was 0.6 ha.

^b Small saplings were stems >1.5 m in height and <2 cm dbh; large saplings were stems >1.5 m in height and 2-11.9 cm dbh; overstory were stems >1.5 m in height and ≥12 cm dbh.

Table 36. Density, average diameter, and basal area of overstory^a tree and shrub species in fifteen 20 x 20 m Long Term Monitoring Plots in Spangler woodlot, Gettysburg National Military Park, 1996.^b

	Density (stems/ha)	Average Diameter (cm)	Basal Area (m ² /ha)
Tree			
Ash	22	16	0.47
Blackgum	7	25	0.35
Cherry, sweet	45	15	0.81
Cherry, black	53	16	1.11
Elm, slippery	8	16	0.17
Hickory	43	31	4.09
Maple, red	8	14	0.14
Oak, black	25	29	1.89
Oak, northern red	30	22	1.25
Oak, scarlet	2	30	0.12
Oak, white	58	49	12.23
Total	302	26	22.63
Shrub			
Sassafras	3	14	0.05
Serviceberry	2	15	0.03
Total	5	14	0.08

^a Stems >1.5 m in height and ≥12 cm dbh.

^b Total area of 15 plots was 0.6 ha.

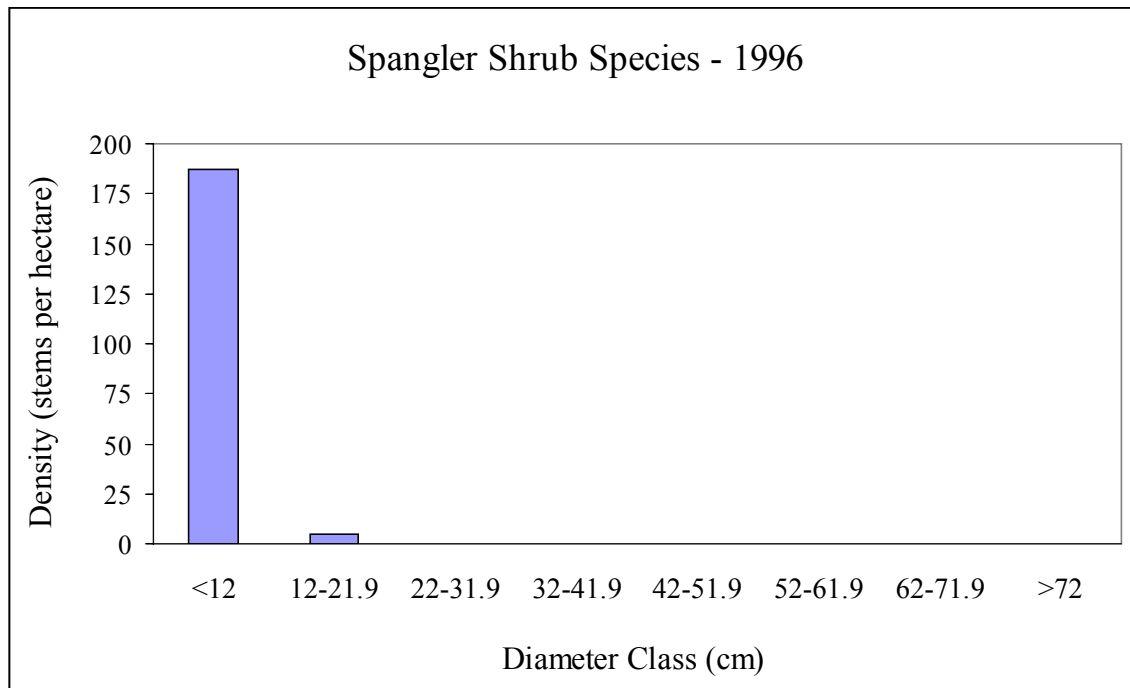


Figure 20. Density of small and large sapling (>1.5 m in height and <12 cm dbh) and overstory (>1.5 m in height and ≥ 12 cm dbh) shrubs by diameter class in fifteen 20 x 20 m Long Term Monitoring Plots in Spangler woodlot, Gettysburg National Military Park, 1996.

Table 37. Density, average diameter, and basal area of large sapling^a tree and shrub species in fifteen 20 x 20 m Long Term Monitoring Plots in Spangler woodlot, Gettysburg National Military Park, 1996.^b

	Density (stems/ha)	Average Diameter (cm)	Basal Area (m ² /ha)
Tree			
Ash	73	6	0.23
Blackgum	20	7	0.08
Cherry, sweet	75	7	0.36
Cherry, black	108	6	0.40
Elm, slippery	22	6	0.06
Hackberry	2	7	0.01
Hickory	183	5	0.52
Maple, red	23	7	0.10
Oak, black	12	7	0.05
Oak, northern red	10	8	0.06
Oak, white	3	8	0.02
Total	532	6	1.89
Shrub			
Blackhaw, smooth	40	2	0.02
Dogwood, flowering	83	5	0.19
Redbud, eastern	2	5	<0.01
Sassafras	10	8	0.05
Serviceberry	38	5	0.08
Total	173	4	0.34

^a Stems >1.5 m in height and 2-11.9 cm dbh.

^b Total area of 15 plots was 0.6 ha.

Table 38. Density, average diameter, and basal area of small sapling^a tree and shrub species in fifteen 20 x 20 m Long Term Monitoring Plots in Spangler woodlot, Gettysburg National Military Park, 1996.^b

	Density (stems/ha)	Average Diameter (cm)	Basal Area (m ² /ha)
Tree			
Ash	13	1.2	0.0016
Shrub			
Blackhaw, smooth	7	1.2	0.0008
Dogwood, flowering	5	1.1	0.0005
Serviceberry	2	1.3	0.0002
Total	13	1.2	0.0015

^a Stems >1.5 m in height and <2 cm dbh.

^b Total area of 15 plots was 0.6 ha.

Small Sapling – Shrub Species: Density of small sapling shrubs was 13 stems per ha, with an average diameter of 1.2 cm, and a basal area of 0.0015 m² per ha (Table 35). Smooth blackhaw, flowering dogwood and serviceberry comprised 50, 38, and 13%, respectively, of the total small sapling shrub density (Table 38).

Total Sapling – Tree species: The density of small and large saplings combined was 545 stems per ha, of which 88% (478 stems per ha) was comprised of ash, cherry, hickory, and oak species (Figure 21). Similarly, 92% (278 stems per ha) of the overstory trees consisted of ash, cherry, hickory, and oak species. Densities of ash, cherry, and hickory saplings were 4.0, 1.9, and 4.3 times greater, respectively, than those of overstory stems. Conversely, the density of overstory oaks was 4.6 times greater than that of sapling oaks.

Total Sapling – Shrub species: The density of small and large sapling shrubs combined was 186 stems per ha. Flowering dogwood, smooth blackhaw, serviceberry, sassafras, and eastern redbud accounted for 47, 25, 21, 5, and 1%, respectively, of the total sapling shrub density (Figure 22). Densities of serviceberry and sassafras saplings were 20.0 and 3.3 times greater, respectively, than those of overstory stems. No flowering dogwood, smooth blackhaw, or eastern redbud were recorded in the overstory in 1996.

Seedling – Tree Species: Eight species of tree seedlings had a density of 9,333 stems per ha (Table 39). Hickory, black cherry, and ash comprised 52, 16, and 13%, respectively, of the total tree seedling density, with the remaining five species accounting for 20% of the total.

Seedling – Shrub Species: Flowering dogwood and sassafras were the only recorded shrub seedlings with a density of 1,667 stems per ha (Table 39). Flowering dogwood and sassafras comprised 70 and 30% of total seedling shrub density, respectively.

Herbaceous Plants: Average herbaceous coverage totaled 11% in 1996 (Table 40). Forb coverage was greatest (8%), followed by grass and vine (2 and 1%, respectively).

Bushman Hill Woodlot

Overstory and sapling data were not collected in the 1996 inventory.

Seedling – Tree Species: Eight species of tree seedlings had a density of 26,500 stems per ha (Table 41). Black oak, hickory, and ash comprised 38, 23, and 22%, respectively, of the total tree seedling density, with the remaining five species accounting for 17% of the total.

Seedling – Shrub Species: Seven species of shrub seedlings had a density of 20,833 stems per ha (Table 41). Eastern redbud, spicebush, *Rubus*, and flowering dogwood comprised 40, 30, 12, and 10%, respectively, of the total shrub seedling density. The remaining three shrub species accounted for 7% of the total density.

Herbaceous Plants: Average herbaceous coverage totaled 40% in 1996 (Table 42). Forb coverage was greatest (18%), followed by vine and grass (13 and 9%, respectively).

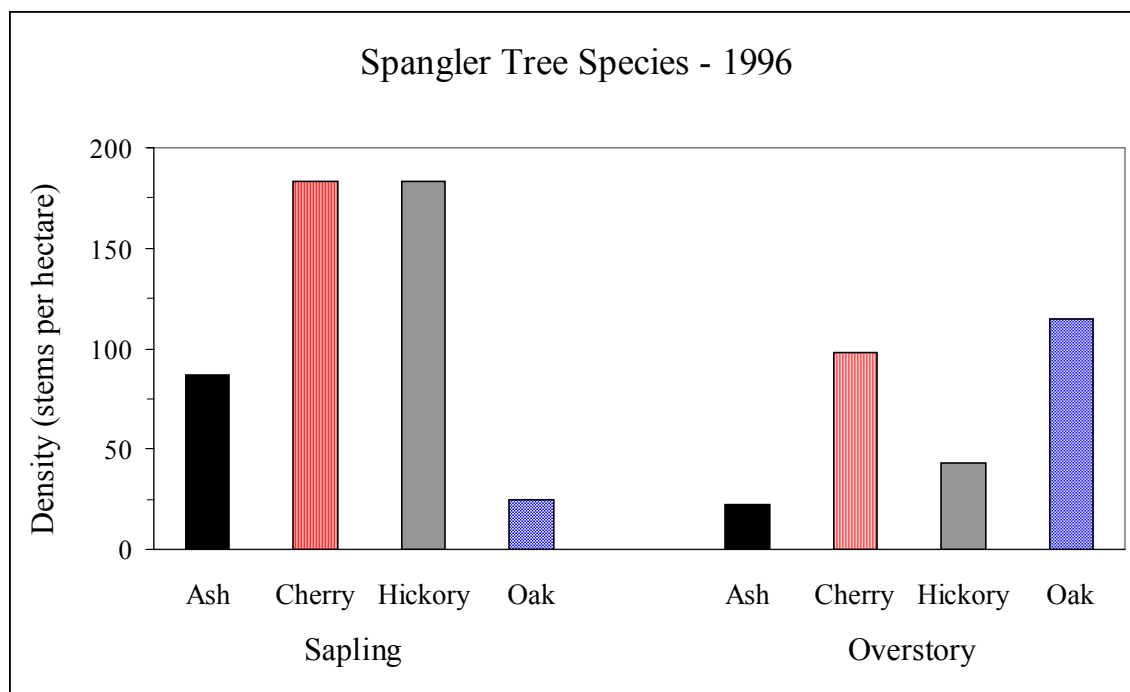


Figure 21. Density of small and large sapling (>1.5 m in height and <12 cm dbh) and overstory (>1.5 m in height and ≥ 12 cm dbh) selected tree species present in fifteen 20 x 20 m Long Term Monitoring Plots in Spangler woodlot, Gettysburg National Military Park, 1996.

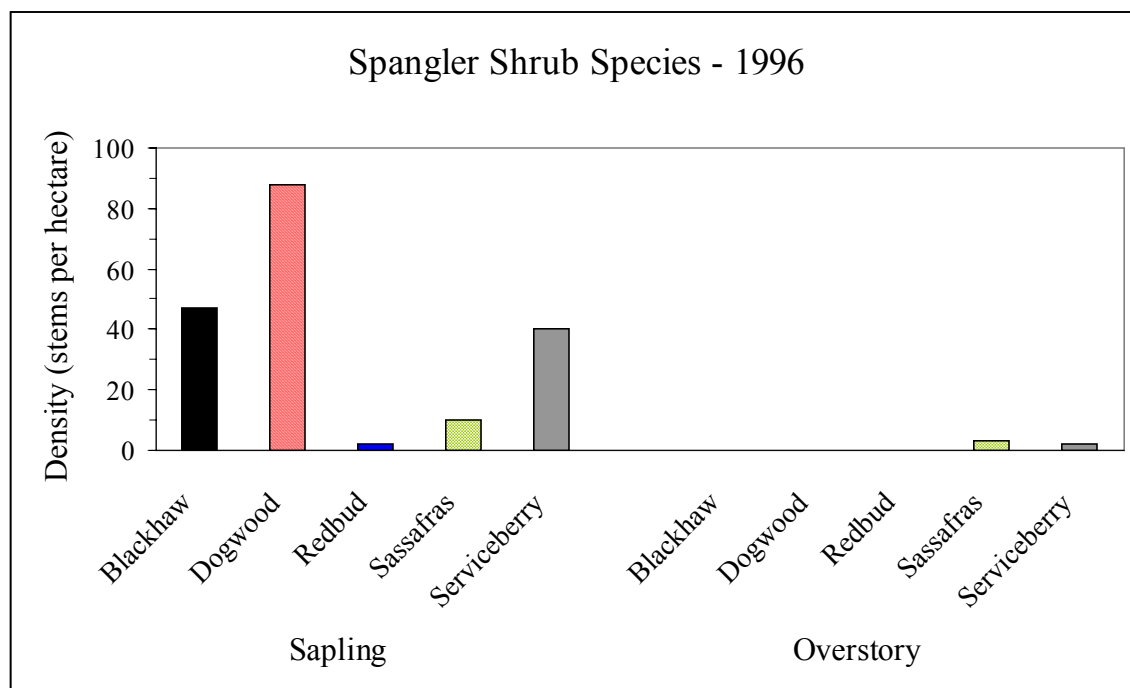


Figure 22. Density of small and large sapling (>1.5 m in height and <12 cm dbh) and overstory (>1.5 m in height and ≥ 12 cm dbh) shrub species in fifteen 20 x 20 m Long Term Monitoring Plots in Spangler woodlot, Gettysburg National Military Park, 1996.

Table 39. Density of seedling^a tree and shrub species in fifteen 2 x 2 m Long Term Monitoring subplots in Spangler woodlot, Gettysburg National Military Park, 1996.^b

	Density (stems/ha)
Tree	
Ash	1,167
Cedar, eastern red	333
Cherry, black	1,500
Hickory	4,833
Maple, red	667
Oak, black	333
Oak, northern red	167
Oak, white	333
Total	9,333
Shrub	
Dogwood, flowering	1,167
Sassafras	500
Total	1,667

^a Stems ≤ 150 cm in height.

^b Total area of 15 subplots was 0.006 ha.

Table 40. Average herbaceous coverage for grass, forb, vine, and total species in fifteen 2 x 2 m Long Term Monitoring subplots in Spangler woodlot, Gettysburg National Military Park, 1996.^a

	Coverage (%)
Grass	2
Forb	8
Vine	1
Total	11

^a Total area of 15 subplots was 0.006 ha.

Table 41. Density of seedling^a tree and shrub species in fifteen 2 x 2 m Long Term Monitoring subplots in Bushman Hill woodlot, Gettysburg National Military Park, 1996.^b

	Density (stems/ha)
Tree	
Ash	5,833
Cherry, black	1,833
Elm, slippery	1,000
Hickory	6,167
Oak, black	10,000
Oak, chestnut	333
Oak, northern red	500
Oak, white	833
Total	26,500
Shrub	
Barberry, Japanese	333
Dogwood, flowering	2,167
Redbud, eastern	8,333
Rose, multiflora	833
<i>Rubus</i>	2,500
Serviceberry	333
Spicebush	6,333
Total	20,833

^a Stems ≤ 150 cm in height.

^b Total area of 15 subplots was 0.006 ha.

Table 42. Average herbaceous coverage for grass, forb, vine, and total species in fifteen 2 x 2 m Long Term Monitoring subplots in Bushman Hill woodlot, Gettysburg National Military Park, 1996.^a

	Coverage (%)
Grass	9
Forb	18
Vine	13
Total	40

^a Total area of 15 subplots was 0.006 ha.

Powers Hill Woodlot

Overstory and sapling data were not collected in the 1996 inventory.

Seedling – Tree Species: Eight species of tree seedlings had a density of 23,500 stems per ha (Table 43). Ash, black cherry, and hickory were the most abundant species, collectively accounting for 77% of the total tree seedling density, with the remaining five tree species accounting for 23% of the total.

Seedling – Shrub Species: Seven species of shrub seedlings had a density of 63,167 stems per ha (Table 43). Japanese barberry and spicebush were the most abundant species, collectively accounting for 84% of the total shrub seedling density, with the remaining five shrub species accounting for 16% of the total.

Herbaceous Plants: Average herbaceous coverage totaled 42% in 1996 (Table 44). Forb coverage was greatest (19%), followed by grass and vine (12 and 11%, respectively).

Canopy Treatment Plots

Overstory Stems

Overstory trees and shrubs were not inventoried in 1994. In 1996 (four years after canopy treatment), a total of 16 overstory (>1.5 m in height and ≥ 11 cm dbh) tree and three overstory shrub species were recorded in the Canopy Treatment plots in Bushman Hill, Herr Ridge, and Powers Hill woodlots (Table 45). All species recorded in the survey are listed in Appendix C. Overstory tree and shrub densities were 158 and one stem per ha, respectively. White oak (37 stems per ha) was the most abundant tree species, followed by mockernut hickory (*Carya tomentosa* (Lam. Ex Poir.) Nutt.) (26 stems per ha). For the three shrub species, flowering dogwood density was one stem per ha, while the densities of boxelder (*Acer negundo* L.) and eastern redbud were each less than one stem per ha.

Canopy treatment and diameter class were significant predictors of average number of overstory tree species four years after canopy treatment in 1996 (Table 46). The closed canopy treatments averaged 1.96 tree species per 0.2 ha plot, compared to 1.41 species per 0.2 ha plot in the partially open canopy treatments. Greatest numbers of tree species occurred in the 11-20.9 and 21-30.9 cm diameter classes (an average of 4.72 and 3.83 species per 0.2 ha plot, respectively). Lowest average numbers of tree species occurred in the 71-80.9, 81-90.9, 91-100.9, and >100 cm diameter classes (0.50, 0.28, 0.17, and 0.00 species per 0.2 ha plot, respectively).

In 1996, significant predictors of overstory tree density were canopy treatment and diameter class (Table 46). The tree density in the partially open canopy treatments (115 stems per ha) was 60% of that in the closed canopy (202 stems per ha) treatments. The 11-20.9 cm diameter class had the greatest density (60 stems per ha), followed by the 21-30.9 cm diameter class (34 stems per ha). Lowest densities occurred in the 71-80.9 (three stems per ha), 81-90.9 (one stem per ha), 91-100.9 (one stem per ha), and >100 (zero stems per ha) cm diameter classes.

Table 43. Density of seedling^a tree and shrub species in fifteen 2 x 2 m Long Term Monitoring subplots in Powers Hill woodlot, Gettysburg National Military Park, 1996.^b

	Density (stems/ha)
Tree	
Ash	8,667
Blackgum	333
Cherry, black	6,167
Elm, slippery	1,833
Hickory	3,333
Maple, red	1,833
Oak, black	1,167
Oak, chestnut	167
Total	23,500
Shrub	
Barberry, Japanese	34,500
Dogwood, flowering	1,500
Redbud, eastern	6,167
Rose, multiflora	500
<i>Rubus</i>	1,167
Sassafras	667
Spicebush	18,667
Total	63,167

^a Stems ≤ 150 cm in height.

^b Total area of 15 subplots was 0.006 ha.

Table 44. Average herbaceous coverage for grass, forb, vine, and total species in fifteen 2 x 2 m Long Term Monitoring subplots in Powers Hill woodlot, Gettysburg National Military Park, 1996.^a

	Coverage (%)
Grass	12
Forb	19
Vine	11
Total	42

^a Total area of 15 subplots was 0.006 ha.

Table 45. Density of seedling (≤ 150 cm in height), sapling (> 150 cm in height and < 11 cm dbh), and overstory (> 1.5 m in height and ≥ 11 cm dbh) tree and shrub species in the Bushman Hill, Herr Ridge, and Powers Hill Canopy Treatment Plots four years after canopy treatment, Gettysburg National Military Park, 1996.

	Seedling ^a	Sapling ^b	Overstory ^c
Tree	(-----stems per ha-----)		
Ash	9,537	27	11
Blackgum	0	5	12
Cedar, eastern red	0	1	0
Cherry, sweet	0	7	1
Cherry, black	1,481	128	2
Elm	278	6	4
Hickory, mockernut	2,315	220	26
Hickory, pignut	0	3	6
Hickory, shagbark	0	0	16
Maple, Norway	0	2	<1
Maple, red	0	6	2
Oak, black	1,574	0	16
Oak, chestnut	0	0	1
Oak, northern red	185	7	14
Oak, white	463	0	37
Walnut, black	0	0	1
Yellow poplar	463	4	10
Total	16,296	416	158
Shrub			
Barberry, Japanese	5,741	0	0
Blackhaw, smooth	2,315	35	0
Boxelder	0	0	<1
Dogwood, flowering	370	108	1
Grape	6,019	0	0
Greenbriar	278	0	0
Honeysuckle, Tartarian	741	0	0
Olive, autumn	0	4	0
Redbud, eastern	4,722	56	<1
Rose, multiflora	1,204	0	0
<i>Rubus</i>	19,815	0	0
Sassafras	93	1	0
Serviceberry	0	6	0
Spicebush	15,370	25	0
Witch hazel	0	23	0
Total	56,667	258	1

^a Based on 108 – 0.0001 ha subplots.

^b Based on 108 – 0.01 ha subplots.

^c Based on 18 – 0.2 ha plots.

Table 46. Average^a number of species and density of overstory (>1.5 m in height and ≥11 cm dbh) tree, shrub, and total species by woodlot, canopy treatment, and diameter class in Bushman Hill, Herr Ridge, and Powers Hill Canopy Treatment Plots four years after canopy treatment, Gettysburg National Military Park, 1996.

	Tree	Shrub	Total
Woodlot	(-----species per 0.2 ha plot-----)		
Bushman Hill	1.53a	0.00a	1.53b
Herr Ridge	1.58a	0.02a	1.60ab
Powers Hill	1.93a	0.05a	1.98a
Canopy Treatment			
Closed	1.96a	0.01a	1.97a
Partially Open	1.41b	0.03a	1.44b
Diameter Class (cm)			
11-20.9	4.72a	0.11a	4.83a
21-30.9	3.83a	0.06a	3.89a
31-40.9	2.17b	0.06a	2.22b
41-50.9	2.17b	0.00a	2.17b
51-60.9	2.00bc	0.00a	2.00bc
61-70.9	1.00cd	0.00a	1.00cd
71-80.9	0.50d	0.00a	0.50d
81-90.9	0.28d	0.00a	0.28d
91-100.9	0.17d	0.00a	0.17d
>100	0.00d	0.00a	0.00d
Woodlot	(-----stems per ha-----)		
Bushman Hill	133a	0a	133a
Herr Ridge	179a	1a	180a
Powers Hill	163a	3a	166a
Canopy Treatment			
Closed	202a	1a	211a
Partially Open	115b	2a	117b
Diameter Class (cm)			
11-20.9	60a	1a	61a
21-30.9	34b	<1a	34b
31-40.9	15cd	<1a	15cd
41-50.9	17cd	0a	17cd
51-60.9	21c	0a	21c
61-70.9	7de	0a	7de
71-80.9	3e	0a	3e
81-90.9	1e	0a	1e
91-100.9	1e	0a	1e
>100	0e	0a	0e

^a For each variable (woodlot, canopy treatment, and diameter class) values within the same species group (tree, shrub, and total) with the same letter were not significantly different at the 0.05 probability level.

There were no significant predictors of average number of overstory shrub species at four years after canopy treatment (Table 46). Over all woodlots, the average number of overstory shrub species was 0.02 species per 0.2 ha plot. In 1996, there were no significant predictors of overstory shrub density (Table 46). Over all woodlots, the overstory shrub density was one stems per ha.

Analyses of total (tree and shrub) overstory species and density reflected those of overstory tree species and density, with one exception: woodlot was a significant predictor of average total overstory species (Table 46). Powers Hill had the greatest average number of total overstory species (1.98 species per 0.2 ha plot), while the lowest number of total species occurred in Bushman Hill (1.53 species per 0.2 ha plot). Average number of total species in Herr Ridge (1.60 species per 0.2 ha plot) was not significantly different from either Powers Hill or Bushman Hill.

Sapling Stems

1994 Saplings

In 1994, among the three woodlots a total of 15 tree and 11 shrub species were recorded in the canopy treatments (Table 47). Tree and shrub sapling (>1.5 m in height and <11 cm dbh) densities were 543 and 408 stems per ha, respectively. Mockernut hickory (239 stems per ha) and black cherry (182 stems per ha) were the most abundant tree species. The most abundant shrub species were spicebush (109 stems per ha) and flowering dogwood (95 stems per ha).

1994 Tree Saplings

Woodlot, canopy treatment, and diameter class were significant predictors of the number of sapling tree species two years after treatment (Table 48). Herr Ridge had the greatest average number of tree species (0.55 species per 0.01 ha subplot). There was no significant difference in average number of tree species between Bushman Hill (0.13 species per subplot) and Powers Hill (0.08 species per subplot). Average numbers of sapling tree species were greater in the closed and partially open canopy treatments (0.36 and 0.29 species per subplot, respectively), compared to 0.11 species per subplot in the open canopy treatments. The one cm diameter class contained the greatest average number of tree species (0.78 species per subplot), followed by the two cm diameter class (0.35 species per subplot). Lowest average numbers of tree species occurred in the five, nine, and 10 cm diameter classes (0.15, 0.12, and 0.10 species per subplot, respectively).

In 1994, significant predictors of sapling tree density were woodlot and diameter class (Table 48). Density was greatest in Herr Ridge (1,339 stems per ha), with no significant difference in density between Powers Hill (153 stems per ha) and Bushman Hill (136 stems per ha). Sapling tree density was greatest in the one cm diameter class (311 stems per ha), with no significant differences in density among the other nine diameter classes.

Table 47. Density of seedling (≤ 150 cm in height) and sapling (> 150 cm in height and < 11 cm dbh) tree and shrub species in Bushman Hill, Herr Ridge, and Powers Hill Canopy Treatment Plots two years after canopy treatment, Gettysburg National Military Park, 1994.

	Seedling ^a	Sapling ^b
Tree	(-----stems per ha-----)	
Ash	21,204	74
Blackgum	2,593	7
Cedar, eastern red	93	1
Cherry, sweet	93	4
Cherry, black	3,056	182
Elm	2,593	7
Hackberry	0	4
Hickory, mockernut	3,148	239
Hickory, pignut	185	5
Maple, Norway	0	1
Maple, red	1,481	6
Oak, black	278	2
Oak, chestnut	93	0
Oak, northern red	463	7
Oak, white	7,685	1
Yellow poplar	14,259	3
Total	57,222	543
Shrub		
Barberry, Japanese	93	8
Blackhaw, smooth	2,037	58
Blueberry	278	0
Dogwood, flowering	3,611	95
Honeysuckle, Tartarian	0	38
Olive, autumn	185	2
Redbud, eastern	9,444	56
Rose, multiflora	556	0
<i>Rubus</i>	18,889	0
Sassafras	93	2
Serviceberry	463	9
Spicebush	18,704	109
Sumac	93	2
Witch hazel	93	28
Total	54,722	408

^a Based on 108 – 0.0001 ha subplots.

^b Based on 108 – 0.01 ha subplots.

Table 48. Average^a number of species and density of sapling (>1.5 m in height and <11 cm dbh) tree, shrub, and total species by woodlot, canopy treatment, and diameter class in Bushman Hill, Herr Ridge, and Powers Hill Canopy Treatment Plots two years after canopy treatment, Gettysburg National Military Park, 1994.

	Tree	Shrub	Total
Woodlot	(-----species per 0.01 ha subplot-----)		
Bushman Hill	0.13b	0.19b	0.32b
Herr Ridge	0.55a	0.16b	0.72a
Powers Hill	0.08b	0.28a	0.36b
Canopy Treatment			
Closed	0.36a	0.34a	0.70a
Partially Open	0.29a	0.21b	0.50b
Open	0.11b	0.09c	0.19c
Diameter Class (cm)			
1	0.78a	0.81a	1.59a
2	0.35b	0.25bc	0.60b
3	0.19bc	0.30b	0.48bc
4	0.21bc	0.26b	0.47bc
5	0.15c	0.17bcd	0.31cd
6	0.19bc	0.16bcd	0.34cd
7	0.19bc	0.07cd	0.26cd
8	0.26bc	0.07cd	0.33cd
9	0.12c	0.03d	0.15d
10	0.10c	0.01d	0.11d
Woodlot	(-----stems per ha-----)		
Bushman Hill	136b	250b	386c
Herr Ridge	1,339a	367b	1,706a
Powers Hill	153b	608a	761b
Canopy Treatment			
Closed	606a	597a	1,203a
Partially Open	419a	358b	778b
Open	603a	269b	872b
Diameter Class (cm)			
1	311a	240a	551a
2	55b	42b	96b
3	28b	38b	66bc
4	30b	29b	58bc
5	19b	21b	40bc
6	20b	19b	39bc
7	23b	10b	33bc
8	28b	9b	37bc
9	14b	4b	18c
10	12b	1b	13c

^a For each variable (woodlot, canopy treatment, and diameter class) values within the same species group (tree, shrub, and total) with the same letter were not significantly different at the 0.05 probability level.

1994 Shrub Saplings

At two years after canopy treatment, significant predictors of average number of sapling shrub species were woodlot, canopy treatment, and diameter class (Table 48). Powers Hill averaged 0.28 species per 0.01 ha subplot, compared to 0.19 and 0.16 species per subplot in Bushman Hill and Herr Ridge, respectively. Average number of sapling shrub species decreased with increasing amount of canopy removal. In the closed, partially open, and open canopy treatments, the average number of shrub species were 0.34, 0.21, and 0.09 species per 0.01 ha subplot, respectively. The one cm diameter class averaged 0.81 shrub species per 0.01 ha subplot, followed by the three and four cm diameter classes (0.30 and 0.26 species per 0.01 ha subplot, respectively). The nine and 10 cm diameter classes contained the lowest average numbers of shrub species (0.03 and 0.01 species per 0.01 ha subplot, respectively).

In 1994, woodlot, canopy treatment, and diameter class were significant predictors of sapling shrub density (Table 48). The density in Powers Hill was 608 stems per ha, compared to 367 stems per ha in Herr Ridge, and 250 stems per ha in Bushman Hill. Sapling shrub density was greatest in the closed canopy treatments (597 stems per ha), compared to the partially open and open canopy treatments (358 and 269 stems per ha, respectively). Density was greatest in the one cm diameter class (240 stems per ha), with no significant difference in density among the other diameter classes.

1994 Total (Tree and Shrub) Saplings

Woodlot, canopy treatment, and diameter class were significant predictors of total sapling species two years after canopy treatment (Table 48). Average number of total species in Herr Ridge (0.72 species per 0.01 ha subplot) was significantly different than in Powers Hill (0.36 species per 0.01 ha subplot) and in Bushman Hill (0.32 species per 0.01 ha subplot). The closed, partially open, and open canopy treatments averaged 0.70, 0.50, and 0.19 species per 0.01 ha subplot, respectively. The one cm diameter class had significantly different average number of species (1.59 species per 0.01 ha subplot) than the remaining nine diameter classes.

Two years after canopy treatment significant predictors of total sapling density were woodlot, canopy treatment, and diameter class (Table 48). Total sapling densities in Herr Ridge, Powers Hill and Bushman Hill were 1,706, 761, and 386 stems per ha, respectively, with significant differences among the density values for each woodlot. The closed canopy treatment density (1,203 stems per ha) was significantly different than in both the open canopy (872 stems per ha) and partially open canopy (778 stems per ha) treatments, which were not significantly different from each other. Total sapling density was greatest in the one cm diameter class (551 stems per ha), followed by the two cm diameter class (96 stems per ha). Densities were lowest in the nine and 10 cm diameter classes (18 and 13 stems per ha, respectively).

1996 Saplings

Four years after the canopy treatments were installed, the number of sapling-sized tree species had decreased to 12 and the sapling-sized shrubs had decreased to eight species over all woodlots (Table 45). Tree and shrub sapling densities decreased to 416 and 258 stems per ha, respectively. Mockernut hickory (220 stems per ha) and black cherry (128 stems per ha) were still the most abundant tree species, but densities for both species had decreased slightly by the four-year survey. Flowering dogwood (108 stems per ha) was the most abundant shrub species. Spicebush had been the most abundant shrub in 1994, but decreased to 25 stems per ha in 1996.

1996 Tree Saplings

Woodlot and diameter class still had significant effects on the average number of sapling tree species, but canopy treatment was no longer significant four years after treatment (Table 49). Herr Ridge continued to have significantly different average number of tree species (0.54 species per 0.01 ha subplot) compared to Bushman Hill and Powers Hill (0.13 and 0.07 species per 0.01 ha subplot, respectively), which were not significantly different from each other. The one cm diameter class had 0.44 tree species per 0.01 ha subplot, 1.8 times less than the 0.78 tree species per 0.01 ha subplot recorded in 1994. Conversely, the two cm diameter class averaged 0.49 tree species per 0.01 ha subplot in 1996, 1.4 times greater than the 0.35 tree species per 0.01 ha subplot recorded in 1994. In 1996, lowest average number of tree species occurred in the 10 cm diameter class, which remained at 0.10 tree species per 0.01 ha subplot (Table 49).

In 1996, woodlot, canopy treatment, and diameter class were significant predictors of sapling tree density (Table 49). Herr Ridge continued to have significantly different density (953 stems per ha) than Bushman Hill (156 stems per ha) and Powers Hill (139 stems per ha). Sapling tree density in the open canopy treatments was significantly different (564 stems per ha) than in the closed and partially open canopy treatments (375 and 308 stems per ha, respectively). The one cm diameter class had 112 tree saplings per ha, 2.8 times less than the 311 stems per ha in 1994. Conversely, the two cm diameter class had 106 stems per ha in 1996, 1.9 times greater than the 55 stems per ha in 1994. Lowest density occurred in the 10 cm diameter class, which remained at 12 stems per ha.

1996 Shrub Saplings

Significant predictors of four-year average number of sapling shrub species were woodlot, canopy treatment, and diameter class (Table 49). Powers Hill continued to have the greatest average number of shrub species (0.25 species per subplot). Lowest average number of shrub species occurred in Herr Ridge (0.13 species per subplot). The average number of shrub species in Bushman Hill (0.19 species per subplot) was not significantly different from either Powers Hill or Herr Ridge. As in 1994, the number of shrub species in 1996 decreased with increasing light levels. For the closed, partially open, and open canopy treatments the average number of shrub species were 0.29, 0.20, and 0.08 species per 0.01 ha subplot, respectively. In 1996, the one cm diameter class averaged 0.37 sapling shrub species per 0.01 ha subplot, 2.2 times less than the 0.81 species per 0.01 ha subplot in 1994. Conversely, the average number of species in the two cm diameter class increased to 0.34 species per 0.01 ha subplot, 1.4 times the 1994 value. Lowest numbers of shrub species occurred in the nine and 10 cm diameter classes (0.05 and 0.01 species per 0.01 ha subplot, respectively).

Woodlot, canopy treatment, and diameter class were significant predictors of shrub sapling density in 1996 (Table 49). The sapling shrub density in Powers Hill (381 stems per ha) was significantly different than in Bushman Hill and Herr Ridge (219 and 175 stems per ha, respectively), which were not significantly different from each other. Shrub density decreased with increasing light levels. The closed, partially open, and open canopy treatments had 417, 236, and 122 stems per ha, respectively. The density decreased in the one cm diameter class to 60 stems per ha, four times less than in 1994. Whereas the two cm diameter class density increased slightly to 49 stems per ha in 1996. The nine (five stems per ha) and 10 (one stem per ha) cm diameter classes had the lowest four-year shrub sapling densities.

Table 49. Average^a number of species and density of sapling (>1.5 m in height and <11 cm dbh) tree, shrub, and total species by woodlot, canopy treatment, and diameter class in Bushman Hill, Herr Ridge, and Powers Hill Canopy Treatment Plots four years after canopy treatment, Gettysburg National Military Park, 1996.

	Tree	Shrub	Total
Woodlot	(-----species per 0.01 ha subplot-----)		
Bushman Hill	0.13b	0.19ab	0.32b
Herr Ridge	0.54a	0.13b	0.66a
Powers Hill	0.07b	0.25a	0.32b
Canopy Treatment			
Closed	0.27a	0.29a	0.56a
Partially Open	0.23a	0.20b	0.43b
Open	0.24a	0.08c	0.31c
Diameter Class (cm)			
1	0.44a	0.37a	0.82a
2	0.49a	0.34a	0.83a
3	0.33ab	0.30ab	0.63ab
4	0.22bc	0.27abc	0.49bc
5	0.19bc	0.23abcd	0.42bcd
6	0.13c	0.16bcde	0.29cde
7	0.18bc	0.11cde	0.29cde
8	0.19bc	0.07de	0.26cde
9	0.17bc	0.05e	0.21de
10	0.10c	0.01e	0.11e
Woodlot	(-----stems per ha-----)		
Bushman Hill	156b	219b	375b
Herr Ridge	953a	175b	1,128a
Powers Hill	139b	381a	519b
Canopy Treatment			
Closed	375b	417a	792a
Partially Open	308b	236b	544b
Open	564a	122c	686ab
Diameter Class (cm)			
1	112a	60a	172a
2	106a	49ab	156a
3	53b	46ab	99b
4	34bc	33bc	68bc
5	21bc	27bcd	48cd
6	14c	19cd	32cd
7	23bc	11cd	34cd
8	22bc	7cd	30cd
9	18bc	5d	22cd
10	12c	1d	13d

^a For each variable (woodlot, canopy treatment, and diameter class) values within the same species group (tree, shrub, and total) with the same letter were not significantly different at the 0.05 probability level.

1996 Total (Tree and Shrub) Saplings

In 1996, woodlot, canopy treatment, and diameter class were significant predictors of total number of sapling species (Table 49). Herr Ridge still had the greatest average number of total species (0.66 species per 0.01 ha subplot), compared to 0.32 species per 0.01 ha subplot for each of the Bushman Hill and Powers Hill woodlots. Average number of total species decreased with increasing amount of canopy removal. Total species in the closed, partially open, and open canopy treatments averaged 0.56, 0.43, and 0.31 species per 0.01 ha subplot, respectively. By 1996, the one cm diameter class averaged 0.82 total species per 0.01 ha subplot, 1.9 times less than the 1.59 total species per 0.01 ha subplot in 1994. Conversely, the two cm diameter class averaged 0.83 total species per 0.01 ha subplot in 1996, 1.4 times greater than the 0.60 total species per 0.01 ha subplot in 1994. The 10 cm diameter class had the lowest average number of total species (0.11 species per 0.01 ha subplot).

Significant predictors of total sapling density four years after canopy treatment were woodlot, canopy treatment, and diameter class (Table 49). Herr Ridge continued to have the greatest density (1,128 stems per ha). There was no significant difference in total sapling density between Powers Hill (519 stems per ha) and Bushman Hill (375 stems per ha). The closed canopy treatments had significantly different total sapling density (792 stems per ha), than the partially open canopy treatments (544 stems per ha). The density in the open canopy treatments (686 stems per ha) was not significantly different from the other two canopy treatments. Total sapling density decreased in the one cm diameter class to 172 stems per ha, 3.2 times less than the 551 stems per ha in 1994. Conversely, density in the two cm diameter class increased to 156 stems per ha in 1996, 1.6 times greater than in 1994. In 1996, the lowest density occurred in the 10 cm diameter class (13 stems per ha), which was unchanged from the 1994 results.

Seedling Stems

1994 Seedlings

In 1994, a total of 14 tree and 14 shrub species were recorded as seedlings (≤ 150 cm in height) among the three woodlots (Table 47). Tree and shrub seedling densities averaged 57,222 and 54,722 stems per ha, respectively. Ash (21,204 stems per ha) and yellow poplar (*Liriodendron tulipifera* L.) (14,259 stems per ha) were the most abundant tree species, while *Rubus* (18,889 stems per ha) and spicebush (18,704 stems per ha) were the dominant shrubs.

1994 Tree Seedlings

Woodlot and height class were significant predictors of average number of seedling tree species two years after canopy treatment in 1994 (Table 50). Bushman Hill, Powers Hill, and Herr Ridge averaged 0.57, 0.43, and 0.19 tree species per 0.0001 ha subplot, respectively. All woodlot averages were significantly different from one another. The <26 cm height class had the greatest average number of tree species (1.81 species per 0.0001 ha subplot), followed by the 26-50.9 cm height class (0.44 species per 0.0001 ha subplot). The average number of tree species in the 51-75.9, 76-100.9, 101-125.9, and 126-150 cm height classes were not significantly different from one another.

In 1994, significant predictors of tree seedling density were woodlot, canopy treatment, and height class (Table 50). Bushman Hill (80,000 stems per ha) and Powers Hill (75,000 stem per ha) had significantly different tree seedling densities compared to Herr Ridge (16,667 stems per ha). The partially open canopy treatment (77,500 stems per ha) had significantly different tree seedling density than the closed and open canopy treatments (47,500 and 46,667 stems per ha,

Table 50. Average^a number of species and density of seedling (≤ 150 cm in height) tree, shrub, and total species by woodlot, canopy treatment, and diameter class in Bushman Hill, Herr Ridge, and Powers Hill Canopy Treatment Plots two years after canopy treatment, Gettysburg National Military Park, 1994.

	Tree	Shrub	Total
Woodlot	(-----species per 0.0001 ha subplot-----)		
Bushman Hill	0.57a	0.35b	0.92a
Herr Ridge	0.19c	0.31b	0.49b
Powers Hill	0.43b	0.54a	0.97a
Canopy Treatment			
Closed	0.42a	0.38a	0.80a
Partially Open	0.43a	0.36a	0.78a
Open	0.34a	0.46a	0.80a
Height Class (cm)			
<26	1.81a	1.32a	3.13a
26-50.9	0.44b	0.64b	1.08b
51-75.9	0.06c	0.31c	0.37c
76-100.9	0.06c	0.07d	0.13cd
101-125.9	0.01c	0.02d	0.03d
126-150	0.01c	0.02d	0.03d
Woodlot	(-----stems per ha-----)		
Bushman Hill	80,000a	45,556b	125,556a
Herr Ridge	16,667b	43,889b	60,556b
Powers Hill	75,000a	74,722a	149,722a
Canopy Treatment			
Closed	47,500b	51,667a	99,167b
Partially Open	77,500a	53,889a	131,389a
Open	46,667b	58,611a	105,278ab
Height Class (cm)			
<26	50,000a	33,981a	83,981a
26-50.9	5,648b	13,241b	18,889b
51-75.9	648b	5,463c	6,111c
76-100.9	741b	1,019c	1,759c
101-125.9	93b	370c	463c
126-150	93b	648c	741c

^a For each variable (woodlot, canopy treatment, and diameter class) values within the same species group (tree, shrub, and total) with the same letter were not significantly different at the 0.05 probability level.

respectively). The <26 cm height class had 50,000 stems per ha, which was significantly different than the other five height classes, which ranged 93 to 5,648 stems per ha.

1994 Shrub Seedlings

At two years after canopy treatment, significant predictors of average number of seedling shrub species were woodlot and height class (Table 50). Powers Hill had significantly different average number of shrub species (0.54 species per 0.0001 ha subplot) compared to Bushman Hill (0.35 species per subplot) and Herr Ridge (0.31 species per subplot), which were not different from one another. The <26 cm height class contained an average of 1.32 shrub species per 0.0001 ha subplot, followed by the 26-50.9 and 51-75.9 cm height classes (0.64 and 0.31 species per subplot, respectively). Average numbers of shrub species in the remaining three height classes were not significantly different from one another.

In 1994, significant predictors of shrub seedling density were woodlot and height class (Table 50). Seedling shrub density was significantly different in Powers Hill (74,722 stems per ha) than in Bushman Hill and Herr Ridge (45,556 and 43,889 stems per ha, respectively). The <26 cm height class had 33,981 stems per ha, followed by 13,241 stems per ha in the 26-50.9 cm height class. Shrub densities in the remaining four height classes were not significantly different from one another.

1994 Total (Tree and Shrub) Seedlings

Woodlot and height class were significant predictors of average total seedling species two years after canopy treatment (Table 50). Powers Hill (0.97 species per 0.0001 ha subplot) and Bushman Hill (0.92 species per 0.0001 ha subplot) had significantly different average total seedling species compared to Herr Ridge (0.49 species per 0.0001 ha subplot). The <26 cm height class averaged 3.13 total species per 0.0001 ha subplot, followed by 1.08 total species per 0.0001 ha subplot for the 26-50.9 cm height class. Lowest average number of total species occurred in the 101-125.9 and 126-150 cm height classes, each containing an average of 0.03 species per subplot.

Woodlot, canopy treatment and height class were significant predictors of total seedling density in 1994 (Table 50). Powers Hill and Bushman Hill total seedling densities (149,722 and 125,556 stems per ha, respectively) were significantly different from Herr Ridge (60,556 stems per ha). Total seedling density in the partially open canopy treatments (131,389 stems per ha) was significantly different than in the closed canopy treatments (99,167 stems per ha). The density of seedlings in the open canopy treatments (105,278 stems per ha) was not significantly different from the other canopy treatments. Total seedling density was greatest in the <26 cm height class (83,981 stems per ha), followed by the 26-50.9 cm height class (18,889 stems per ha). There were no significant differences in total seedling density among the remaining height classes.

1996 Seedlings

By four years after canopy treatment, the number of tree and shrub seedling species decreased. There were eight tree seedling species, compared to 11 shrub seedling species (Table 45). Total tree seedling density sharply decreased to 16,296 stems per ha, whereas shrub seedling density increased slightly to 56,667 stems per ha. Ash was again the most abundant seedling tree species, but the density of ash had decreased to 9,537 stems per ha. Yellow poplar was the second most abundant tree seedling species in 1994, but decreased to only 463 seedling stems

per ha in 1996. *Rubus* and spicebush were still the dominant shrub species at the four-year survey. Density of *Rubus* increased slightly to 19,815 stems per ha, whereas spicebush decreased to 15,370 stems per ha.

1996 Tree Seedlings

Woodlot no longer had a significant effect on the average number of seedling tree species, whereas canopy treatment was now significant (Table 51). Height class was again significant in 1996. The average number of seedling tree species decreased with increasing light levels. The closed, partially open, and open canopy treatments averaged 0.30, 0.16, and 0.06 species per 0.0001 ha subplot, respectively. The <26 cm height class averaged 0.60 tree species per 0.0001 ha subplot in 1996, three times less than the 1.81 tree species per 0.0001 ha subplot in 1994. The 26-50.9 cm height class averaged 0.27 tree species per 0.0001 ha subplot in 1996. There were no significant differences in the number of tree species among the other height classes.

By the four-year survey, woodlot was no longer a significant predictor of tree seedling density, whereas canopy treatment and height class still had significant effects (Table 51). Tree density decreased with increasing amount of canopy removed. The closed canopy treatments had significantly different tree seedling density (28,611 stems per ha) than the partially open treatments (15,278 stems per ha), which was also significantly different than the density in the open canopy treatments (5,000 stems per ha). The <26 cm height class had 10,556 stems per ha in 1996, nearly five times less than the 50,000 stems per ha in 1994. Conversely, the 126-150 cm height class had 833 tree stems per ha in 1996, compared to 93 stems per ha in 1994.

1996 Shrub Seedlings

Woodlot and height class were significant predictors of average number of seedling shrub species four years after canopy treatment (Table 51). Bushman Hill and Powers Hill had significantly different average number of shrub species (0.66 and 0.63 species per 0.0001 ha subplot, respectively) than Herr Ridge (0.21 species per 0.0001 ha subplot). The <26 cm height class had the greatest average number of shrub species (1.11 species per 0.0001 ha subplot), followed by the 26-50.9 cm height class (0.80 species per 0.0001 ha subplot). Lowest average number of shrub species occurred in the 101-125.9 cm and 126-150 cm height classes (0.16 and 0.14 species per 0.001 ha subplot, respectively). Nevertheless, there were eight times more shrub species per subplot in the 101-125.9 cm height class and seven times more shrub species per subplot in the 126-150 cm height class in 1996 than in 1994.

Woodlot, canopy treatment, and height class were significant predictors of shrub seedling density (Table 51). Shrub seedling densities were significantly different in Bushman Hill (76,111 stems per ha) and Powers Hill (67,222 stems per ha) than in Herr Ridge (26,667 stems per ha). Shrub seedling density increased with increasing light levels. The open canopy treatments had significantly different shrub seedling density (70,000 stems per ha) than the closed canopy treatments (47,500 stems per ha). The partially open treatments density (52,500 stems per ha) was not significantly different from the other two treatments. The <26 cm height class had 22,870 stems per ha in 1996, which was 1.5 times less than the 33,981 stems per ha in 1994. Lowest density occurred in the 126-150 cm height class, but the 3,333 stems per ha in 1996 was 5.1 times greater than the 648 stems per ha in 1994.

Table 51. Average^a number of species and density of seedling (≤ 150 cm in height) tree, shrub, and total species by woodlot, canopy treatment, and diameter class in Bushman Hill, Herr Ridge, and Powers Hill Canopy Treatment Plots four years after canopy treatment, Gettysburg National Military Park, 1996.

	Tree	Shrub	Total
Woodlot	(-----species per 0.0001 ha subplot-----)		
Bushman Hill	0.22a	0.66a	0.88a
Herr Ridge	0.17a	0.21b	0.38b
Powers Hill	0.13a	0.63a	0.77b
Canopy Treatment			
Closed	0.30a	0.48a	0.78a
Partially Open	0.16b	0.46a	0.62a
Open	0.06c	0.56a	0.63a
Height Class (cm)			
<26	0.60a	1.11a	1.71a
26-50.9	0.27b	0.80b	1.06b
51-75.9	0.09c	0.49c	0.58c
76-100.9	0.01c	0.31cd	0.31cd
101-125.9	0.03c	0.16d	0.19d
126-150	0.05c	0.14d	0.19d
Woodlot	(-----stems per ha-----)		
Bushman Hill	20,278a	76,111a	96,389a
Herr Ridge	13,056a	26,667b	39,722b
Powers Hill	15,556a	67,222a	82,778a
Canopy Treatment			
Closed	28,611a	47,500b	76,111a
Partially Open	15,278b	52,500ab	67,778a
Open	5,000c	70,000a	75,000a
Height Class (cm)			
<26	10,556a	22,870a	33,426a
26-50.9	3,611b	13,056b	16,667b
51-75.9	926c	8,796bc	9,722c
76-100.9	93c	5,093cd	5,185c
101-125.9	278c	3,519cd	3,796c
126-150	833c	3,333d	4,167c

^a For each variable (woodlot, canopy treatment, and diameter class) values within the same species group (tree, shrub, and total) with the same letter were not significantly different at the 0.05 probability level.

1996 Total (Tree and Shrub) Seedlings

At four years after canopy treatment, woodlot and height class were significant predictors of average number of total seedling species (Table 51). Average number of total species was significantly different in Bushman Hill (0.88 species per 0.0001 ha subplot) than in Powers Hill and Herr Ridge (0.77 and 0.38 species per 0.0001 ha subplot, respectively). The <26 cm height class averaged 1.71 total species per 0.0001 ha subplot in 1996, nearly two times less than the total of 3.13 species per 0.0001 ha subplot in 1994. Conversely, in 1996, the average 0.19 total species per 0.0001 ha subplot for each of the 101-125.9 and 126-150 cm height classes was six times greater than the 0.03 total species per 0.0001 ha subplot in 1994.

Woodlot and height class were significant predictors of total seedling density in 1996 (Table 51). Bushman Hill (96,389 stems per ha) and Powers Hill (82,778 stems per ha) had significantly different densities than Herr Ridge (39,722 stems per ha). The 1996 total seedling density of 33,426 stems per ha in the <26 cm height class was 2.5 times less than the 83,981 stems per ha in 1994. Lowest total seedling density occurred in the 51-75.9 cm (9,722 stems per ha), 76-100.9 cm (5,185 stems per ha), 101-125.9 cm (3,796 stems per ha), and 126-150 (4,167 stems per ha) cm height classes. Nevertheless, the 1996 total seedling density in the 51-75.9, 76-100.9, 101-125.9, and 126-150 cm height classes were 1.6, 2.9, 8.2, and 5.6 times greater, respectively, than those in 1994.

Herbaceous Plants

In 1994, the herbaceous coverage averaged 11% for grass, 19% for forb, 19% for vine, and 49% for total species among the three woodlots. Canopy treatment was a significant predictor of average grass, forb, vine, and total coverage (Table 52). The open canopy treatments had significantly different average forb (35%), vine (46%), and total (101%) coverage values than the closed (6, 4, and 11%, respectively) and partially open (15, 8, and 34%, respectively) canopy treatments. Average grass coverage in the open canopy (20%) was not significantly different than in the partially open canopy (11%), but was different than in the closed canopy (0%). Lowest average grass (0%) and total herbaceous (11%) coverage occurred in the closed canopy treatments. Forb and vine coverage values in the closed canopy treatments (6 and 4%, respectively) were not significantly different from those in the partially open treatments (15 and 8%, respectively).

In 1996, the average grass, forb and total herbaceous coverage values had increased to 26, 27, and 65%, respectively, whereas average vine coverage had decreased to 13% (Table 53). Woodlot was a significant predictor of average grass, forb, and total coverage, with Powers Hill having significantly different average grass (58%) and total herbaceous (80%) coverage but the lowest forb coverage (12%). Average grass and forb coverages in Bushman Hill (6 and 30%, respectively) were not significantly different from those in Herr Ridge (13 and 38%, respectively). However, Herr Ridge had significantly different total herbaceous coverage (65%) than Bushman Hill (50%). In 1996, canopy treatment was again significant for each of the four vegetation groups, with the open canopy treatments having significantly different average grass (45%), forb (38%), vine (18%), and total (101%) coverages. Lowest average grass (3%), forb (16%), and total (29%) herbaceous coverage occurred in the closed canopy treatments, while vine coverage was not significantly different between the closed canopy (11%) and the partially open canopy (9%) treatments.

Table 52. Average^a herbaceous coverage of grass, forb, vine, and total species by woodlot and canopy treatment in Bushman Hill, Herr Ridge, and Powers Hill Canopy Treatment Plots two years after canopy treatment, Gettysburg National Military Park, 1994.

	Grass	Forb	Vine	Total
Woodlot	(-----% coverage-----)			
Bushman Hill	9a	18a	20a	47a
Herr Ridge	6a	19a	17a	43a
Powers Hill	17a	19a	20a	56a
Canopy Treatment				
Closed	0b	6b	4b	11c
Partially Open	11a	15b	8b	34b
Open	20a	35a	46a	101a

^a For each variable (woodlot and canopy treatment) values within the same species group (grass, forb, vine, and total) with the same letter were not significantly different at the 0.05 probability level.

Table 53. Average^a herbaceous coverage of grass, forb, vine, and total species by woodlot and canopy treatment in Bushman Hill, Herr Ridge, and Powers Hill Canopy Treatment Plots four years after canopy treatment, Gettysburg National Military Park, 1996.

	Grass	Forb	Vine	Total
Woodlot	(-----% coverage-----)			
Bushman Hill	6b	30a	13a	50c
Herr Ridge	13b	38a	14a	65b
Powers Hill	58a	12b	11a	80a
Canopy Treatment				
Closed	3c	16c	11b	29c
Partially Open	30b	26b	9b	65b
Open	45a	38a	18a	101a

^a For each variable (woodlot and canopy treatment) values within the same species group (grass, forb, vine, and total) with the same letter were not significantly different at the 0.05 probability level.

Discussion

Demonstration Plots

Eighteen tree seedling species were recorded at least once among the fenced and unfenced plots in the six woodlots during the 1986-87, 1989, 1991, 1994 and 1996 surveys. Ash, black cherry, black oak, eastern red cedar, elm, mockernut hickory, pignut hickory (*Carya glabra* (P. Mill.) Sweet), red maple, shagbark hickory, sweet cherry, and white oak were tree species recorded in all surveys. Black locust (*Robinia pseudoacacia* L.) was recorded in 1989 and 1994. Chestnut oak (*Quercus prinus* L.) was recorded in the 1986-87 and 1989 surveys but was not present from 1991 to 1996. Northern red oak was recorded in all inventories, except 1986-87. Blackgum and Norway maple (*Acer platanoides* L.) were recorded in the 1994 and 1996 surveys, while *Ailanthus* and yellow poplar were recorded only in 1994.

Ash, black cherry, and white oak consistently dominated, accounting for 66 to 92% of all tree seedlings recorded in each of the surveys. In 1986-87, white oak was the most abundant species, comprising 41% of all tree seedlings, followed by ash (28%) and black cherry (21%). By 1996, white oak had decreased to 16% of all tree seedlings. Ash was the most abundant species in 1996, accounting for 26% of the total tree seedling density, followed by black cherry (23%).

The density of tree seedlings decreased from 1986-87 to 1996 in both the fenced and unfenced plots and the rate of decrease was the same for the fenced and unfenced plots (Figure 23). The density of tree seedlings decreased from 56,000 per ha in 1986-87 to 11,000 per ha in 1996 in the fenced plots and from 39,000 per ha in 1986-87 to 1,000 per ha in 1996 in the unfenced plots. In 1986-87, the greater density of tree seedlings in the fenced plots compared to the unfenced plots was due to the selection of plots to be fenced and remain unfenced, and was not due to the one to two years of protection from white-tailed deer browsing. Therefore, to properly evaluate the effect of fencing on the seedlings, it is necessary to account for these initial differences or to examine the changes that occurred in the fenced and unfenced plots over time and not the actual differences between the fenced and unfenced plots in any particular survey.

The density of tree seedlings <26 cm in height decreased from 1989 to 1996 in both the fenced and unfenced plots (Figure 24). In 1989, there were 44,000 tree stems per ha <26 cm in height in the fenced plots, compared to 4,000 stems per ha in 1996. In the unfenced plots, the density of tree seedlings <26 cm in height was 36,000 and 1,000 stems per ha in 1989 and 1996, respectively.

Fencing had a greater effect on the density of tree seedlings ≥ 26 cm in height (Figure 24). In the fenced plots, the density of tree seedlings ≥ 26 cm in height was 7,000 stems per ha in each of the 1989 and 1996 surveys, whereas seedling density in the same height class decreased from 3,000 stems per ha in 1989 to <1,000 stems per ha in 1996 in the unfenced plots.

This suggests that white-tailed deer were influencing the height growth of tree seedlings over the survey period. Likewise, selective feeding by deer in the unfenced plots may account for the significant reduction of white oak seedlings that started with 17,500 stems per ha 1986-87 and ended with <1,000 per ha in 1996. Conversely, the decline in the density of tree seedlings <26 cm in height in both the fenced and unfenced plots suggest that other factors, possibly competition from the overstory trees, shrubs, and herbaceous plants, were influencing the establishment of new recruits and/or the survival of existing seedlings.

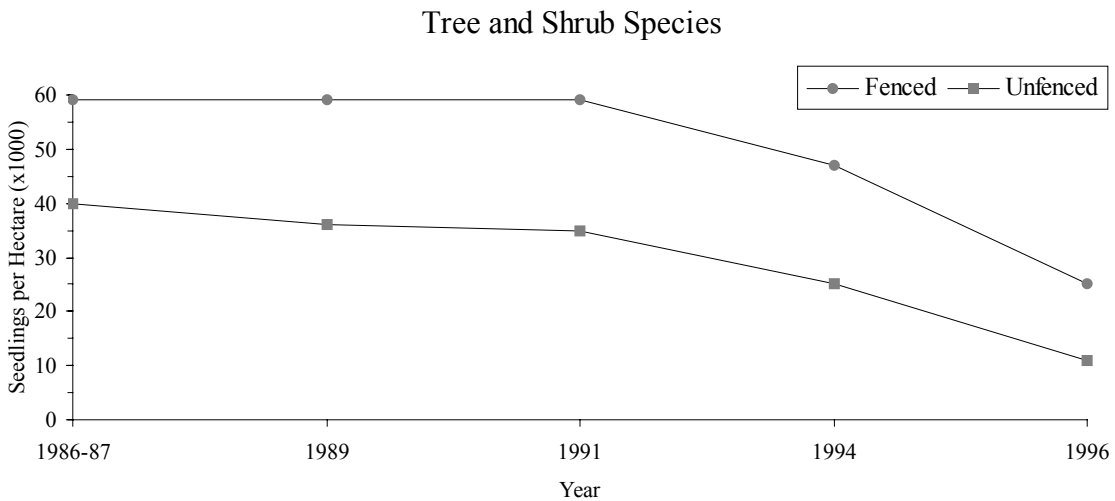
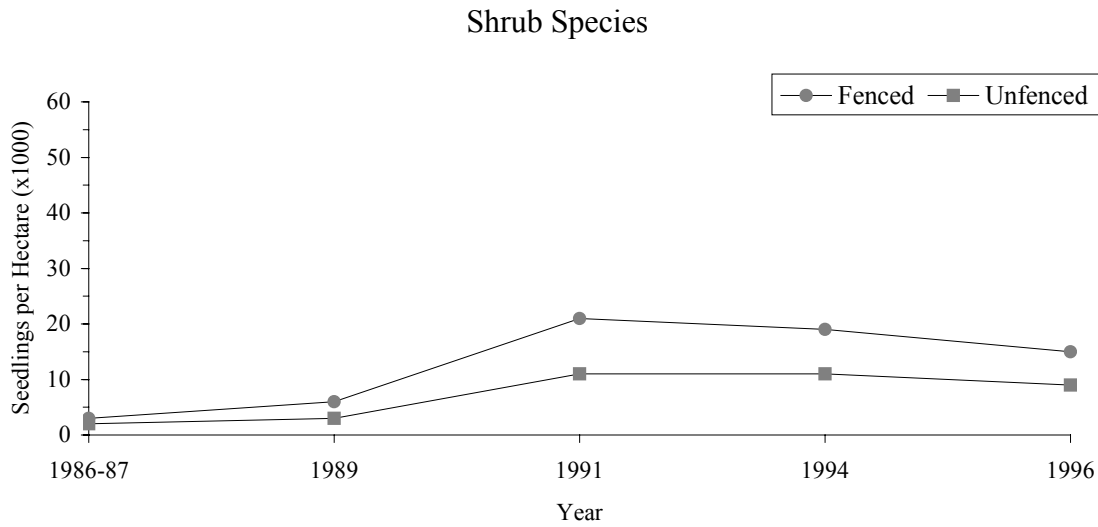
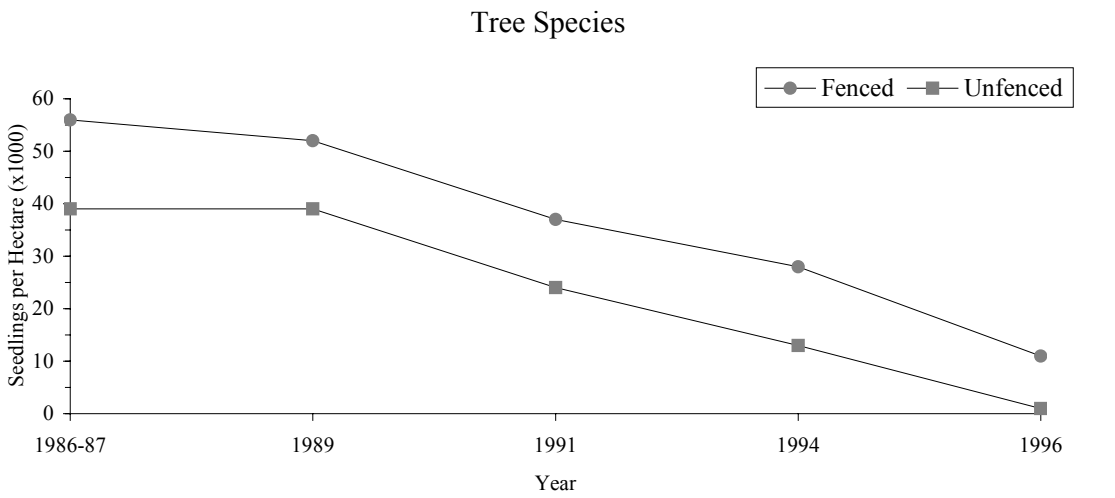
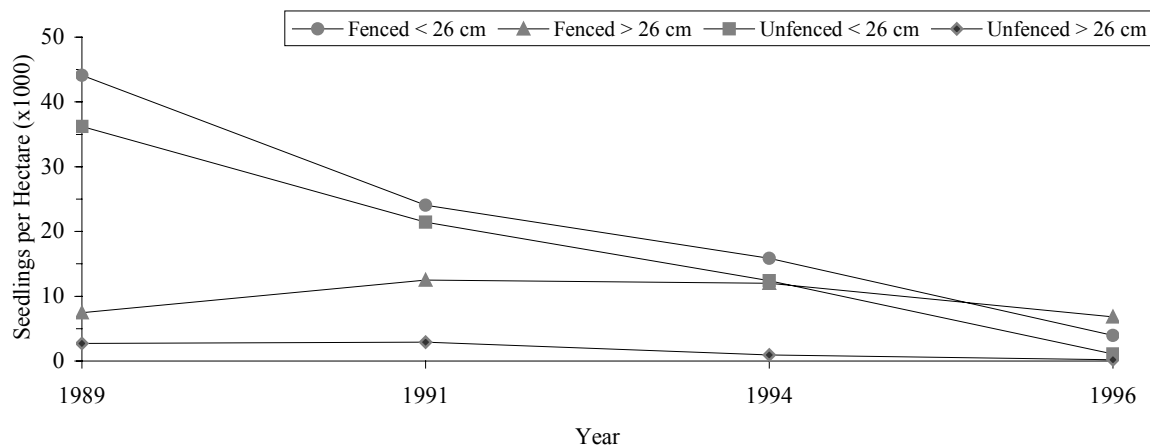
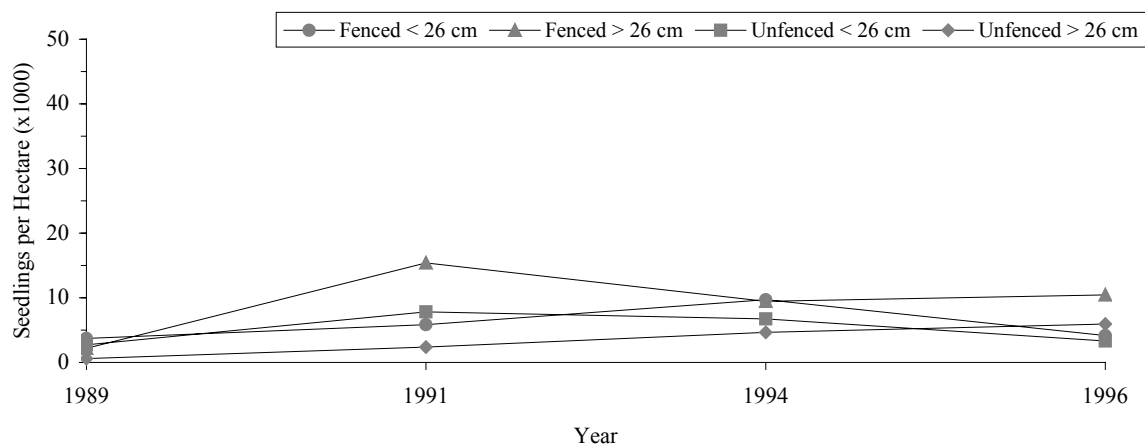


Figure 23. Average number of seedlings per hectare of tree, shrub, and total (tree and shrub) species in the Fenced and Unfenced 10 x 10 m Demonstration Plots in Biesecker, Bushman Hill, Cobean, Pitzer, Slyder, and Spangler woodlots, Gettysburg National Military Park, during the 1986-87 to 1996 surveys.

Tree Species



Shrub Species



Tree and Shrub Species

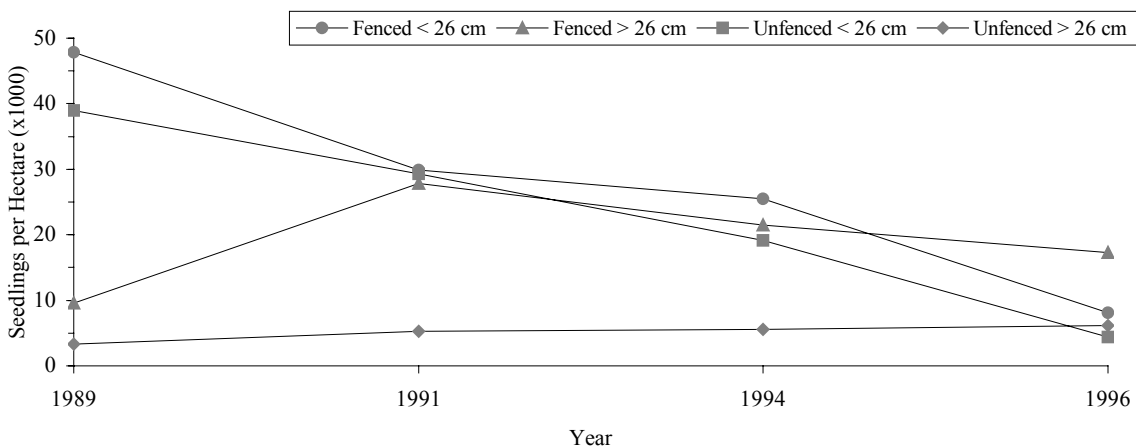


Figure 24. Average number of seedlings per hectare of tree, shrub, and total (tree and shrub) species by height class in the Fenced and Unfenced 10 x 10 m Demonstration Plots in Biesecker, Bushman Hill, Cobean, Pitzer, Slyder, and Spangler woodlots, Gettysburg National Military Park, in the 1989, 1991, 1994, and 1996 surveys.

Twelve shrub seedling species were recorded at least once among the fenced and unfenced plots in the six woodlots during the 1986-87, 1989, 1991, 1994, and 1996 surveys. Eastern redbud, *Rubus*, sassafras, serviceberry, smooth blackhaw, and spicebush were shrub species present in all surveys. *Rosa* was not recorded until 1991, while Tartarian honeysuckle (*Lonicera tatarica* L.) was not present until 1994. The four remaining shrub species were first recorded in either 1986-87 or 1989.

Smooth blackhaw was consistently a dominating shrub species from 1986-87 to 1994, but by 1996, blackhaw had reduced in importance. Spicebush was a dominating species in 1989 and 1994. *Rubus* and *Rosa* became the two most dominating shrub species in 1991 and continued to be through 1996.

From 1986-87 to 1996, the density of shrub seedlings per ha increased in both the fenced and unfenced plots (Figure 23). The density of shrub seedlings increased from 3,000 per ha in 1986-87 to 15,000 per ha in 1996 in the fenced plots and from 2,000 per ha in 1986-87 to 9,000 per ha in 1996 in the unfenced plots.

In both the fenced and unfenced plots, the density of shrub seedlings <26 cm in height increased from 1989 to 1994. By 1996, shrub seedling densities had returned to the 1989 levels (Figure 24). In each of the 1989 and 1996 surveys, shrub seedlings <26 cm in height totaled 4,000 stems per ha in the fenced plots and 3,000 stems per ha in the unfenced plots.

The density of shrub seedlings ≥ 26 cm in height increased from 1989 to 1996 in both the fenced and unfenced plots (Figure 24). Fenced shrub seedlings ≥ 26 cm in height totaled 2,000 stems per ha in 1989 and 10,000 stems per ha in 1996. Unfenced shrub seedlings ≥ 26 cm in height totaled 1,000 and 6,000 stems per ha in 1989 and 1996, respectively.

The increase in both fenced and unfenced shrub seedlings ≥ 26 cm in height suggests that although the growth of individual shrub species may have been affected by deer browsing, the influence of deer on shrub species as a group does not appear as strong as on tree species. Further, the increasing shrub densities from 1989 to 1994 for seedlings <26 cm in height suggest that conditions were favorable for the establishment of new shrub seedlings and, once established, the seedlings were able to grow into the ≥ 26 cm height class.

Over all six woodlots and all surveys, there were 30,000 seedlings per ha for the tree species and 10,000 seedlings per ha for the shrub species. The Bushman Hill woodlot had the greatest density of tree (63,000 stems per ha) and shrub (21,000 stems per ha) seedlings over the 10-year survey period. Lowest tree density (6,000 stems per ha) occurred in the Slyder woodlot, while the lowest shrub density (3,000 stems per ha) occurred in the Pitzer woodlot.

There was a steady decline in the relative abundance of tree seedlings and an increase in the relative abundance of shrub seedlings from 1986-87 to 1996. The dominance of tree seedlings decreased from 95% in 1986-87 to 91% in 1989, 66% in 1991, 58% in 1994, and 33% in 1996. The net effect of decreasing tree seedlings and increasing shrub seedlings resulted in 50,000, 48,000, 47,000, 36,000, and 18,000 combined tree and shrub seedlings per ha for 1986-87, 1989, 1991, 1994, and 1996, respectively.

The estimated density of combined tree and shrub seedlings <26 cm in height per ha decreased from 1989 to 1996 in both the fenced and unfenced plots (Figure 24). Fenced seedlings <26 cm

in height totaled 48,000 stems per ha in 1989, compared to 8,000 stems per ha in 1996. Unfenced seedlings totaled 39,000 and 4,000 stems per ha in 1989 and 1996, respectively. Conversely, the density of combined tree and shrub seedlings ≥ 26 cm in height increased in both the fenced and unfenced plots from 1989 to 1996. Fenced seedlings ≥ 26 cm in height totaled 10,000 and 17,000 stems per ha compared to 3,000 and 6,000 stems per ha for unfenced seedlings in 1989 and 1996, respectively.

The number of combined tree and shrub seedling species recorded in the six woodlots increased between the 1986-87 and 1996 surveys. There was an average of nine combined tree and shrub species per pair of fenced and unfenced plots in 1986-87 and 14 combined tree and shrub species per pair of plots in 1996. The number of combined tree and shrub seedling species ranged from 7 in the Cobean woodlot to 12 in the Biesecker woodlot in 1986-87 and from 11 in the Spangler woodlot to 17 in the Bushman Hill woodlot in 1996.

Among the six woodlots in 1986-87, the average number of combined tree and shrub seedling species was seven and six in the fenced and unfenced plots, respectively. By 1996, the average number of combined tree and shrub seedling species had increased to 13 in the fenced plots but had decreased to five in the unfenced plots.

The general trends in the densities of tree and shrub seedlings in both the fenced and unfenced plots for the six woodlots between 1986-87 and 1996 were (a) the number of species increased, (b) the density of tree seedlings per ha decreased, and (c) the density of shrub seedlings per ha increased. There were substantially more tree seedlings than shrub seedlings in 1986-87. By 1996, shrub seedlings were more abundant than tree seedlings and the difference between shrub and tree densities was more pronounced in the unfenced plots than in the fenced plots. Competing vegetation and white-tailed deer browsing appeared to have a greater influence on the establishment and growth of tree seedlings than shrub seedlings.

The species composition and abundance of herbaceous and vine species was determined within two square 1.0 m² subplots both inside and outside the fenced Demonstration plot in the Biesecker and Bushman Hill woodlots. Based on line-transect data, *Galium* spp. had the greatest importance value within the fenced Demonstration subplots, whereas cinquefoil (*Potentilla* spp.) had the greatest importance value in the nearby unfenced control subplots in the Bushman Hill woodlot. Four species were present in the fenced Demonstration subplots and eight in the control subplots, with only two in common between them. Virginia creeper [*Parthenocissus quinquefolia* (L.) Planch.] dominated the Biesecker fenced Demonstration subplots with an importance value 50% greater than that of the next species, spring beauty. However, in the control subplots, spring beauty was the only species encountered along the line-transects.

The coefficient of community similarity values were low, as few herbaceous and vine species were in common among or between woodlots. The coefficient values for the line-transect data were 0.143 and 0.182 between the fenced Biesecker and fenced Bushman Hill subplots and the unfenced Biesecker and unfenced Bushman Hill subplots, respectively. For the line-transect plus the complete subplot search data, the coefficient values were 0.100 and 0.214 between the fenced Biesecker and fenced Bushman Hill subplots and the unfenced Biesecker and unfenced Bushman Hill subplots, respectively.

Long Term Monitoring Plots

The 20 x 20 m Long Term Monitoring plots were established and inventoried in the six woodlots during 1990-92 to describe the status of forest plant communities. These initial data serve as a reference for future evaluations of the effects of closed canopy conditions on the establishment and growth of young woody stems. Further, a comparison of vegetation in fenced and unfenced 2 x 2 m subplots provide background data to determine the effects of feeding by white-tailed deer on forest regeneration.

During 1990-92, the six woodlots (74 to 94% stocked) were considered relatively mature with closed canopies. For the four woodlots surveyed in 1996, stocking levels ranged from 63 to 88%. The number of large sapling tree species was greater than that of overstory tree species in Biesecker, Pitzer, Herr Ridge, and Spangler woodlots in both the 1990-92 and 1996 surveys. Likewise, the number of large sapling shrub species was greater than that of overstory shrub species in each of the four woodlots in 1996. Conversely, the number of small sapling tree species was lower than that of overstory tree species in the Biesecker, Pitzer, and Spangler woodlots in both 1990-92 and 1996.

From 1990-92 to 1996, densities of tree species generally decreased for overstory, large sapling, and small sapling stems in Biesecker, Pitzer, Herr Ridge, and Spangler woodlots. Herr Ridge had a greater density of small sapling trees than overstory trees in both surveys, and was the only woodlot located north of Route 116 where the deer herd density was significantly lower than in the other woodlots (Storm *et al.* 1989). Additionally, in each of the four woodlots, densities of large and small sapling trees decreased from the 1990-92 to 1996 surveys. For overstory, large sapling, and small sapling shrubs, numbers of species and densities were generally lower than those of trees in the 1996 survey. These data indicate problems in maintaining mixed oak communities with high species diversity under the combined effects of overstory and understory competition and intensive foraging by white-tailed deer.

Cherry, hickory, and oak species were among the dominant sapling and overstory tree species in Biesecker, Pitzer, Herr Ridge, and Spangler woodlots in both the 1990-92 and 1996 surveys. Ash was a large component of the sapling and overstory density in three of the four woodlots in both surveys, while maple was a predominant species in two woodlots in 1990-92 and in one woodlot in 1996. Blackgum was a large component of the sapling and overstory tree densities in the Pitzer woodlot in 1990-92 but not in 1996. Except for oak species, densities of the dominant species generally were greater for saplings than for overstory trees. For oaks, overstory trees outnumbered sapling stems in each of the four woodlots during both surveys. Furthermore, over all four woodlots, densities of sapling and overstory oaks decreased from 1990-92 to 1996, again indicating a problem in maintaining oak-dominated communities at Gettysburg National Military Park.

The status of sapling and overstory shrubs in 1996 included a total of six sapling shrub species and four overstory shrub species among the Biesecker, Pitzer, Herr Ridge, and Spangler woodlots. For sapling shrubs, smooth blackhaw, flowering dogwood, and serviceberry were recorded in each of the four woodlots in the 1996 survey, while eastern redbud was a component of sapling shrubs in three of the four woodlots. Sassafras saplings were present in two woodlots, while hawthorn saplings were recorded in one woodlot. For overstory shrubs, sassafras and

serviceberry were recorded in two woodlots, while eastern redbud and flowering dogwood were present in one woodlot. No overstory shrub species were recorded in the Herr Ridge woodlot in 1996.

Differences in seedling density between fenced and unfenced subplots may be attributed not only to the absence or presence of white-tailed deer but also to differences in stand structure, resulting in variable light levels reaching the forest floor. Thus, to facilitate an evaluation of the effects of white-tailed deer alone, similar sapling and overstory structure among plots was desirable. For Biesecker and Pitzer woodlots, there were no significant differences in density or basal area of small sapling, large sapling, or overstory tree and shrub species between the fenced and unfenced treatments, thus the overstory and understory competition on seedling density was similar in the fenced and unfenced plots.

From 1990-92 to 1996, the unfenced total tree seedling density decreased in five of the six woodlots surveyed. Total density in 1990-92 ranged from 6,333 to 43,832 stems per ha across the six woodlots, compared to 2,500 to 26,500 stems per ha in 1996. Similarly, oak seedling density decreased in five of the six woodlots, ranging from 333 to 17,333 stems per ha in 1990-92, compared to 0 to 11,666 stems per ha in 1996. These data indicate a serious problem in regenerating the woodlots under the combined effects of low light levels and high deer densities.

For unfenced shrub seedlings, total density decreased in four of the six woodlots from 1990-92 to 1996. Total density ranged from 3,666 to 45,667 stems per ha in 1990-92, compared to 1,667 to 63,167 stems per ha in 1996. *Rubus* was the most abundant shrub seedling (34,500 stems per ha) in one of the six woodlots (Herr Ridge) in 1990-92. Japanese barberry was the most abundant species in Biesecker and Powers Hill (13,750 and 34,500 stems per ha, respectively) in 1996. Flowering dogwood was also the most abundant species in two woodlots, Pitzer and Spangler (1,750 and 1,176 stems per ha, respectively) in 1996. In the 1990-92 and 1996 surveys, Japanese barberry was present in Bushman Hill and Powers Hill woodlots with densities that decreased slightly in Bushman Hill (500 to 333 stems per ha, respectively), but increased substantially in Powers Hill (5,833 to 34,500 stems per ha, respectively). Multiflora rose was not present in any woodlot during the 1990-92 survey, but was in four of the six woodlots in 1996, with densities that ranged from 500 to 3,269 stems per ha. The growth rate of these non-native shrub species possibly warrants control measures.

In the Biesecker and Pitzer woodlots from 1990-92 to 1996, the density of tree seedlings in the unfenced subplots decreased. The total unfenced tree seedling densities in Biesecker and Pitzer were 7,000 and 13,001 stems per ha, respectively, in 1990-92, and 2,500 and 7,500 stems per ha, respectively, in 1996. The number of tree species also decreased over the same time period. Between 1990-92 and 1996, the number of unfenced seedling tree species growing in Biesecker decreased from eight to three species and in Pitzer woodlot declined from seven to four species. Unfenced oak seedling density decreased in both Biesecker and Pitzer woodlots, from 1,001 and 1,666 stems per ha, respectively, in 1990-92, compared to 0 and 417 stems per ha, respectively, in 1996. These data indicate a serious problem in regenerating the woodlots under the combined effects of low light levels and high deer densities.

Conversely, the density and number of shrub species in the unfenced Biesecker subplots increased from 1990-92 to 1996. In 1990-92, there were no shrub species growing in the unfenced Biesecker subplots, but in 1996, there were five species with a density of 17,917 stems per ha. Japanese barberry was the dominant species with a density of 13,750 stems per ha.

Flowering dogwood was second most abundant with 2,917 stems per ha in 1996. In Pitzer woodlot from 1990-92 to 1996, the density of unfenced shrub seedlings decreased from 8,667 to 3,500 stems per ha, respectively, and the number of species increased from three to four, respectively. Smooth blackhaw and flowering dogwood (4,500 and 3,500 stems per ha, respectively) were the most abundant unfenced shrub seedlings in 1990-92. In 1996, flowering dogwood (1,750 stems per ha) and spicebush (750 stems per ha) were most abundant.

In 1996, average total herbaceous coverage in the unfenced subplots combined ranged from 11 to 42% among the six woodlots surveyed. Average forb coverage was greatest in five of the six woodlots, ranging from 8 to 22%. Average grass coverage ranged from <1 to 12%, while average vine coverage ranged from 1 to 13% over all woodlots. In the Biesecker woodlot, average forb, vine, and total herbaceous coverage values were greater in fenced subplots than in unfenced subplots, whereas average grass coverage was greater in unfenced than in fenced subplots. Conversely, average forb, vine, and total coverage values were greater in unfenced subplots than in fenced subplots in the Pitzer woodlot. Average grass coverage was 1% in the Pitzer woodlot in both fenced and unfenced subplots. In the Biesecker woodlot, there were no significant differences between fenced and unfenced subplots in average grass, forb, vine, or total coverage. In the Pitzer woodlot, average forb and total coverage values were statistically greater in unfenced than in fenced subplots.

In summary, the 1990-92 and 1996 surveys described the status of the forest plant communities at Gettysburg National Military Park. Further, these data provided for an evaluation of the effects of closed canopy conditions and foraging by white-tailed deer on the establishment and growth of understory vegetation. Under the combined effects of low light levels and high deer densities, problems in maintaining the mixed oak woodlots with high species diversity were indicated by (1) decline in overstory, large sapling, and small sapling tree species, (2) decline in large and small sapling tree densities, (3) low numbers of species and densities for overstory, large sapling, and small sapling shrubs, (4) decline in overstory and sapling oak densities, (5) decline in total tree seedling and oak seedling densities, and (6) increased seedling densities of non-native Japanese barberry and multiflora rose. From these data, creating openings in the canopy, controlling deer herd densities, and controlling non-native shrub species should be considered as necessary management actions needed to maintain the historic woodlot condition.

Canopy Treatment Plots

The woodlots for the canopy treatments were selected as representative of the range of conditions that the resource managers would need to account for when developing a park woodlot management program. Thus, the effects of woodlot represent the range of responses to be expected rather than some unique woodlot-specific conditions that would alter the development of a management program. Furthermore, the effects of canopy treatment have park-wide application in the development of a management program, accounting for the variability among woodlots.

In 1996, four years after canopy treatment, sixteen overstory tree species were recorded across the three woodlots, compared to twelve sapling tree species, and only eight seedling tree species. Furthermore, the dominant overstory tree species was white oak, accounting for 23% of all overstory trees. However, white oak seedlings represented 3% of the total tree seedling density, and white oak saplings accounted for 0% of the total tree sapling density. In 1996, Powers Hill had the greatest number of overstory tree, shrub, and total species. Herr Ridge had the greatest

overstory tree and total densities. The closed canopy treatments had the greatest number of overstory species and density of tree and total species, whereas the partially open canopy treatments had the greatest number of overstory shrub species and density. The 11-20.9 cm diameter class consistently had the greatest number of species and density of tree, shrub and total species. No overstory tree species >100 cm dbh and no shrub species >40 cm dbh were recorded in 1996.

The average number of sapling-sized tree, shrub, and total species in Herr Ridge and Powers Hill decreased from 1994 to 1996, but remained the same in Bushman Hill. The number of tree, shrub, and total species in the closed and partially open canopy treatments decreased over the same time period. From 1994 to 1996, number of species and density generally decreased across woodlots and canopy treatments for sapling tree, shrub, and total species. In 1996, Herr Ridge had the greatest number of species and density of sapling tree and total species, whereas sapling shrub species and density were greatest in Powers Hill. In 1996, the closed canopy treatments had the greatest number of tree, shrub, and total sapling species and the greatest shrub and total sapling densities. The open canopy treatments had the greatest density of sapling trees.

Significantly greater tree sapling density in the open canopy treatments may have been due to increased tree vigor under full sunlight. Another factor may have been some physical protection from browsing provided by the dense herbaceous vegetation that developed in the open canopy. Nevertheless, tree, shrub, and total sapling densities decreased from 1994 to 1996 regardless of canopy opening level, possibly demonstrating the overriding adverse effects of high deer densities on sapling stems. The decrease in tree sapling density was primarily due to losses of black cherry (54 stems per ha), ash (47 stems per ha), and mockernut hickory (19 stems per ha). Black oak, hackberry (*Celtis occidentalis* L. var. *occidentalis*), and white oak were present in 1994 but were not recorded in 1996. Densities of sweet cherry, Norway maple, and yellow poplar increased slightly from 1994 to 1996. The decrease in shrub sapling density was primarily due to losses of spicebush (84 stems per ha), Tartarian honeysuckle (38 stems per ha), and smooth blackhaw (23 stems per ha). Shrub species present in 1994 but not recorded in 1996 included Japanese barberry, Tartarian honeysuckle, and sumac (*Rhus* spp.). Flowering dogwood and autumn olive (*Elaeagnus umbellata* Thunb.) increased slightly from 1994 to 1996. High deer densities may have resulted in the reduction or elimination of many sapling tree and shrub species. For tree, shrub, and total sapling species, number of species and density decreased from 1994 to 1996 in the one cm diameter class but generally increased or remained constant in the larger diameter classes. These data suggest that deer may have affected the one cm diameter class, but once stems grew out of the reach of deer, conditions were favorable for saplings to grow into the upper diameter classes.

From 1994 to 1996, seedling tree species and density decreased across all woodlots and canopy treatments. Conversely, seedling shrub species increased in Bushman Hill and Powers Hill woodlots and across all canopy treatments. There was no consistent change across woodlots or canopy treatments in seedling shrub density. In 1996, Bushman Hill had the greatest number of species and density of seedling tree, shrub, and total species. The closed canopy treatments had the greatest number of tree and total species and density, whereas seedling shrub species and density were greatest in the open canopy treatments in 1996. Reduced seedling tree species and density in the open canopy treatments may have been due to increased competition from shrubs combined with the prolonged competition of 101% total herbaceous coverage from 1994 to 1996. In the closed and partially open canopy treatments, seedling shrub densities decreased slightly from 1994 to 1996. Conversely, 1996 total herbaceous coverage values in the closed and partially open canopy treatments were 2.6 and 1.9 times greater, respectively, than those in 1994.

Thus, reduced seedling tree species and density in the closed and partially open canopy treatments may primarily have been due to competition from herbaceous vegetation in 1996. For tree, shrub, and total seedling species, number of species and density generally decreased from 1994 to 1996 in the <26 and 26-50.9 cm height classes but increased in the 51-75.9, 76-100.9, 101-125.9, and 126-150 cm height classes. The increased seedling densities suggest that, once established, conditions were favorable for seedlings to grow into the upper height classes. The decreased seedling densities in the lower height classes indicate unfavorable conditions for recruitment of new seedlings. Competition from herbaceous vegetation and foraging by white-tailed deer and small mammals may have been factors influencing seedling establishment. Thus, in addition to a reduction in grape (*Vitis spp.*) and non-native shrub species, a reduction in herbaceous coverage and control of deer densities will be warranted.

From 1994 to 1996, the sharp decline in tree seedling density was primarily due to losses of yellow poplar (14,259 to 463 stems per ha, respectively), ash (21,204 to 9,537 stems per ha, respectively), and white oak (7,685 to 463 stems per ha, respectively). Seedling tree species present in 1994 but not recorded in 1996 included blackgum, eastern red cedar, sweet cherry, pignut hickory, red maple, and chestnut oak. Black oak was the only species to have an increase in seedling density from 1994 (278 stems per ha) to 1996 (1,574 stems per ha). Reductions in seedling tree species and in white oak reproduction present concerns not only in maintaining understory tree species diversity but also in restoring the woodlots to Civil War condition, in which oak was the dominant vegetation.

The slight increase in shrub seedling density was primarily due to an increase in grape and non-native shrub species, which offset a decrease in native shrub species. Grape was not present in 1994, but had 6,019 stems per ha in 1996. Between 1994 and 1996, non-native Japanese barberry, Tartarian honeysuckle, and multiflora rose increased by 5,648, 741, and 648 stems per ha, respectively, while native eastern redbud and flowering dogwood decreased by 4,722 and 3,241 stems per ha, respectively. Shrub species present in 1994 but not recorded in 1996 included blueberry (*Vaccinium spp.*), autumn olive, serviceberry, sumac, and witch hazel (*Hamamelis virginiana* L.). To promote seedling recruitment and survival of desirable tree species, a reduction in the competitive influence of non-native shrub species should be considered.

Averaged over the three woodlots, grass, forb, and total herbaceous coverage increased but vine coverage decreased from 1994 to 1996. Powers Hill had the greatest total herbaceous coverage (80%) due to a 41% increase in grass coverage in 1996. Forb and vine coverage values both decreased in Powers Hill from 1994 to 1996. Herr Ridge had the lowest total herbaceous coverage (43%) in 1994, but the second highest total herbaceous coverage (65%) in 1996, due to a 19% increase in forb coverage and a 7% increase in grass coverage. Total herbaceous coverage remained fairly constant in Bushman Hill from 1994 (47%) to 1996 (50%) due to an increase in forb coverage offsetting decreases in grass and vine coverage values. Over all woodlots, the open canopy treatment total average herbaceous coverage was 101% in 1994 and 1996. Grass and forb coverage values increased in the open canopy treatments by 25 and 3%, respectively, while vine coverage decreased by 28%. From 1994 to 1996 over all woodlots, grass, forb, vine, and total herbaceous coverage increased in both the closed and partially open canopy treatments, and remained the same in the open canopy treatments. In 1996, total average herbaceous coverage was 29% in the closed canopy treatments, representing an 18% increase from 1994. In the partially open canopy treatments, total average herbaceous coverage was 65%, representing a 31% increase.

Although the inventory procedures did not require the breakdown of herbaceous plants by species, non-native silt grass (*Microstegium vimineum* (Trin.) A. Camus) was a frequent and dominating plant, particularly at Powers Hill. Impact of this plant on establishing and maintaining desirable shrub and tree seedlings is not clear, but when silt grass was present it dominated the plots and there were few desirable seedlings present.

In summary, the general trends over all canopy treatments from 1994 to 1996 for herbaceous plants, seedlings, and saplings were (1) grass, forb, vine, and total herbaceous coverage increased (except vine coverage decreased in the open canopy treatments), (2) seedling tree species and density decreased, seedling shrub species increased (except in the partially open canopy treatments), and seedling shrub densities decreased (except in the open canopy treatments), and (3) sapling tree species decreased (except in the open canopy treatments), sapling shrub species decreased, and sapling tree and shrub densities decreased. Of the 16 overstory tree species recorded in 1996, white oak was dominant. To maintain understory tree species diversity and to successfully regenerate oak, it will be necessary to reduce the degree to which the overstory dominates the woodlots. However, it is essential that all non-native species and high deer densities be controlled before there is any attempt to reduce the overstory.

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Appendices

Appendix A. Scientific and common names of tree and shrub species in Biesecker, Bushman Hill, Cobean, Pitzer, Slyder, and Spangler woodlot Demonstration Plots, Gettysburg National Military Park, from 1986-87 to 1996.

Tree

Aceraceae	<i>Acer platanoides</i> L. – Norway maple
Aceraceae	<i>Acer rubrum</i> L. – red maple
Cupressaceae	<i>Juniperus virginiana</i> L. – eastern redcedar
Fabaceae	<i>Robinia pseudoacacia</i> L. – black locust
Fagaceae	<i>Quercus alba</i> L. – white oak
Fagaceae	<i>Quercus prinus</i> L. – chestnut oak
Fagaceae	<i>Quercus rubra</i> L. – northern red oak
Fagaceae	<i>Quercus velutina</i> Lam. – black oak
Juglandaceae	<i>Carya glabra</i> (P. Mill.) Sweet – pignut hickory
Juglandaceae	<i>Carya ovata</i> (P. Mill.) K. Koch – shagbark hickory
Juglandaceae	<i>Carya tomentosa</i> (Lam. ex Poir.) Nutt. – mockernut hickory
Magnoliaceae	<i>Liriodendron tulipifera</i> L. – yellow poplar
Nyssaceae	<i>Nyssa sylvatica</i> Marshall – blackgum
Oleaceae	<i>Fraxinus</i> spp. – ash species
Rosaceae	<i>Prunus avium</i> (L.) L. – sweet cherry
Rosaceae	<i>Prunus serotina</i> Ehrh. – black cherry
Simaroubaceae	<i>Ailanthus altissima</i> (P. Mill.) Swingle – tree-of-heaven
Ulmaceae	<i>Ulmus</i> spp. – elm species

Shrub

Berberidaceae	<i>Berberis thunbergii</i> DC. – Japanese barberry
Caesalpiniaceae	<i>Cercis canadensis</i> L. – eastern redbud
Caprifoliaceae	<i>Lonicera tatarica</i> L. – Tartarian honeysuckle
Caprifoliaceae	<i>Viburnum prunifolium</i> L. – smooth blackhaw
Cornaceae	<i>Cornus florida</i> L. – flowering dogwood
Lauraceae	<i>Lindera benzoin</i> (L.) Blume – spicebush
Lauraceae	<i>Sassafras albidum</i> (Nutt.) Nees – sassafras
Rosaceae	<i>Amelanchier arborea</i> (Michx.f.) Fern. – serviceberry
Rosaceae	<i>Rosa</i> spp. – mainly multiflora rose
Rosaceae	<i>Rubus</i> spp. – blackberry, dewberry or black raspberry
Smilacaceae	<i>Smilax rotundifolia</i> L. – greenbriar
Vitaceae	<i>Vitis</i> spp. – grape species

Appendix B. Scientific and common names of tree and shrub species in Biesecker, Bushman Hill, Herr Ridge, Pitzer, Powers Hill, and Spangler woodlot Long Term Monitoring Plots, Gettysburg National Military Park, from 1990-92 to 1996.

Tree

Aceraceae	<i>Acer platanoides</i> L. – Norway maple
Aceraceae	<i>Acer rubrum</i> L. – red maple
Cupressaceae	<i>Juniperus virginiana</i> L. – eastern redcedar
Fagaceae	<i>Quercus alba</i> L. – white oak
Fagaceae	<i>Quercus coccinea</i> Muenchh. – scarlet oak
Fagaceae	<i>Quercus prinus</i> L. – chestnut oak
Fagaceae	<i>Quercus rubra</i> L. – northern red oak
Fagaceae	<i>Quercus velutina</i> Lam. – black oak
Juglandaceae	<i>Carya glabra</i> (P. Mill.) Sweet – pignut hickory
Juglandaceae	<i>Carya ovata</i> (P. Mill.) K. Koch – shagbark hickory
Juglandaceae	<i>Carya tomentosa</i> (Lam. ex Poir.) Nutt. – mockernut hickory
Juglandaceae	<i>Juglans nigra</i> L. – black walnut
Moraceae	<i>Morus</i> spp. – mulberry species
Nyssaceae	<i>Nyssa sylvatica</i> Marshall – blackgum
Oleaceae	<i>Fraxinus</i> spp. – ash species
Pinaceae	<i>Pinus strobes</i> L. – eastern white pine
Pinaceae	<i>Pinus virginiana</i> P. Mill. – Virginia pine
Platanaceae	<i>Platanus occidentalis</i> L. – American sycamore
Rosaceae	<i>Prunus avium</i> (L.) L. – sweet cherry
Rosaceae	<i>Prunus serotina</i> Ehrh. – black cherry
Ulmaceae	<i>Celtis occidentalis</i> L. var. <i>occidentalis</i> – hackberry
Ulmaceae	<i>Ulmus rubra</i> Muhl. – slippery elm

Shrub

Berberidaceae	<i>Berberis thunbergii</i> DC. – Japanese barberry
Caesalpiniaceae	<i>Cercis canadensis</i> L. – eastern redbud
Caprifoliaceae	<i>Viburnum prunifolium</i> L. – smooth blackhaw
Cornaceae	<i>Cornus florida</i> L. – flowering dogwood
Lauraceae	<i>Lindera benzoin</i> (L.) Blume – spicebush
Lauraceae	<i>Sassafras albidum</i> (Nutt.) Nees – sassafras
Rosaceae	<i>Amelanchier arborea</i> (Michx.f.) Fern. – serviceberry
Rosaceae	<i>Crataegus</i> spp. – hawthorn species
Rosaceae	<i>Rosa multiflora</i> Thunb. ex Murr. – multiflora rose
Rosaceae	<i>Rubus</i> spp. – blackberry, dewberry or black raspberry

Appendix C. Scientific and common names of tree and shrub species in Bushman Hill, Herr Ridge, and Powers Hill Canopy Treatment Plots, Gettysburg National Military Park, from 1992 to 1996.

Tree

Aceraceae	<i>Acer platanoides</i> L. – Norway maple
Aceraceae	<i>Acer rubrum</i> L. – red maple
Cupressaceae	<i>Juniperus virginiana</i> L. – eastern redcedar
Fagaceae	<i>Quercus alba</i> L. – white oak
Fagaceae	<i>Quercus prinus</i> L. – chestnut oak
Fagaceae	<i>Quercus rubra</i> L. – northern red oak
Fagaceae	<i>Quercus velutina</i> Lam. – black oak
Juglandaceae	<i>Carya glabra</i> (P. Mill.) Sweet – pignut hickory
Juglandaceae	<i>Carya ovata</i> (P. Mill.) K. Koch – shagbark hickory
Juglandaceae	<i>Carya tomentosa</i> (Lam. ex Poir.) Nutt. – mockernut hickory
Juglandaceae	<i>Juglans nigra</i> L. – black walnut
Magnoliaceae	<i>Liriodendron tulipifera</i> L. – yellow poplar
Nyssaceae	<i>Nyssa sylvatica</i> Marshall – blackgum
Oleaceae	<i>Fraxinus</i> spp. – ash species
Rosaceae	<i>Prunus avium</i> (L.) L. – sweet cherry
Rosaceae	<i>Prunus serotina</i> Ehrh. – black cherry
Ulmaceae	<i>Celtis occidentalis</i> L. var. <i>occidentalis</i> – hackberry
Ulmaceae	<i>Ulmus</i> spp. – elm species

Shrub

Aceraceae	<i>Acer negundo</i> L. – boxelder
Anacardiaceae	<i>Rhus</i> spp. – sumac species
Berberidaceae	<i>Berberis thunbergii</i> DC. – Japanese barberry
Caesalpiniaceae	<i>Cercis canadensis</i> L. – eastern redbud
Caprifoliaceae	<i>Lonicera tatarica</i> L. – Tartarian honeysuckle
Caprifoliaceae	<i>Viburnum acerifolium</i> L. – mapleleaf viburnum
Caprifoliaceae	<i>Viburnum prunifolium</i> L. – smooth blackhaw
Cornaceae	<i>Cornus florida</i> L. – flowering dogwood
Elaeagnaceae	<i>Elaeagnus umbellata</i> Thunb. – autumn olive
Ericaceae	<i>Vaccinium</i> spp. – blueberry species
Hamamelidaceae	<i>Hamamelis virginiana</i> L. – witch hazel
Lauraceae	<i>Lindera benzoin</i> (L.) Blume – spicebush
Lauraceae	<i>Sassafras albidum</i> (Nutt.) Nees – sassafras
Rosaceae	<i>Amelanchier arborea</i> (Michx.f.) Fern. – serviceberry
Rosaceae	<i>Rosa multiflora</i> Thunb. ex Murr. – multiflora rose
Rosaceae	<i>Rubus</i> spp. – blackberry, dewberry or black raspberry
Smilacaceae	<i>Smilax rotundifolia</i> L. – greenbriar
Vitaceae	<i>Vitis</i> spp. – grape species

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