

NPBIB - 271513
NRBIB: DEWA-0035
NPBIB - 35124
NPSPP-MS-103101

Early 18th century versus present-day (1980) forest composition of
the PA side of the Delaware Water Gap National Recreation Area.

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Final Report submitted to:

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February 19, 1997

Introduction

Ecological research has taught us that the study of forest history is essential for understanding current forest conditions. Questions dealing with the historical expansion of oak and pine and the decrease of hemlock and beech, for example, can be ascertained from a study of historical documents. A team of Penn State researchers has embarked on a study of biodiversity in hemlock and hardwood forests at the Delaware Water Gap NRA (DEWA) without any compiled material on the forest composition at the time of European settlement. Therefore, the objective~~s~~ of this study ^{were} ~~was~~ to characterize the witness tree composition, based on the original land surveys, across physiographic units at the DEWA. Witness tree data provide one of the only, and therefore best, picture of the forest composition and species distribution at the time of European settlement; i.e., what these forests were like in their "natural" condition. In addition, this study will² describe the forest composition and cover of DEWA in 1980, based on aerial photo interpretation, and how these forests differed from that at the time of European settlement.

Whitney (1994) extensively reviewed the literature dealing with the strengths and shortcomings of using witness tree data and concluded that early land survey records are still our best source of information of the presettlement forests; at their worst they indicate only the presence of certain tree species and at their best they constitute an unbiased sample of the vegetation. Nonetheless, a larger number of witness trees recorded and an even distribution of trees throughout the forest will result in a better approximation of species composition.

Study methods

1. Travel to the State Archives in Harrisburg and find the original survey maps (connected drafts) for the Pennsylvania townships comprising the DEWA. With the aid of topographic maps, each listed witness tree was recorded and mapped along with its physiographic position and township location. The major physiographic categories used in this study were upland, stream ravine, and river alluvial flats. These physiographic categories were used because they can be readily recognized from the original survey maps and the existing

topographic maps and because of the strong ecological contrast in forest composition that they represent.

2. The composition of the forests based on witness tree percentages (mainly from surveys conducted between 1750-1795) was compared with the 1980 forest type cover maps of the DEWA. Analysis of present-day forests was based upon the single most dominant tree species within mapping units from 1980 aerial photo interpretation provided by the DEWA. A complete description of the methods for the 1980 forest cover characterization of DEWA can be found in Myers and Irish (1981)

3. This final report includes 1) photocopies of three original township maps comprising the major portion of DEWA with witness trees locations (original maps in the Historical and Museum Commission Search Room, 1st Floor, State Archives Building, Harrisburg, PA), 2) tables of the percent composition for witness tree data compiled by township and physiographic unit, 3) forest type percentages, by dominant species, for the 1980 forests, 4) and an ecological interpretation of the presettlement forests and major differences with the present-day forests at the Delaware Water Gap NRA. Finally, a discussion of the availability of additional data and recommendations for future analysis of the presettlement forest composition and land-use history is included.

Results

A total of 16 species/genera were recorded among the 172 witness trees recorded in surveys conducted between 1750-1795 in the Pennsylvania portion of the DEWA (Table 1). The witness trees were evenly distributed throughout the park and therefore should provide a reasonably unbiased representation of the forest composition. At the time of European settlement, the most frequently cited witness trees in the forests were oak (47.7%; including white oak, black oak, chestnut oak and red oak), pine (23.8%), hickory (11.6%) and chestnut (7.6%).

White oak, black oak and pine were frequently recorded witness trees on both upland plateau and stream ravine sites. In contrast, the importance of hickory, chestnut, and chestnut oak decreased markedly on stream ravines compared to upland sites. Red oak and black gum appear to be somewhat more important on

stream ravine versus upland plateau at the time of European settlement. Sixteen witness trees of ten different species were recorded on alluvial flats adjacent to the Delaware River, with no one species being a clear dominant. Black walnut, basswood and sycamore were exclusive to the river flats. Hemlock represented only 1.2% of the witness trees, and was reported only on stream ravine sites in DEWA.

pennsylvania
The DEWA occurs primarily in three Pennsylvania townships, including Dingman, Delaware and Lehman. An additional 266 witness trees across 18 species/genera were recorded between 1750-1795 in these townships on properties outside the boundaries of DEWA; these data include the adjacent Milford Township (Table 2). Despite some subtle differences among the townships in witness tree composition, each were dominated by oak, pine, and chestnut, and the trees were fairly evenly distributed throughout. Species of secondary importance were red maple, hickory, white ash, and birch. A comparison of the witness tree composition within and outside DEWA in the four Pennsylvania townships indicates general similarity between locales (Table 3). Nonetheless, some noticeable differences between the DEWA and surrounding properties include the relatively high proportion of black oak and hickory and relatively low proportion of chestnut oak, red maple and white ash in the DEWA.

There exist many dramatic differences in species composition between the forests at the time of European settlement and the 1980 forests at the DEWA (Tables 1 and 4). The 1980 forests were comprised mainly of 20 dominant species, approximately the same number recorded as witness trees. While most of the major species occur in the surveys of both the original and present-day forests (excluding chestnut and hickory), there exist many differences in the minor species recorded in each survey. Presently, DEWA forests are dominated by red oaks (including red oak and black oak), chestnut oak, red maple and sugar maple, white pine, and sweet birch (Table 4). Compared to the witness tree record, 1980 forests have substantially less white oak, pine, hickory, and chestnut (eliminated in 1920s chestnut blight). Dominant tree species that have greatly increased abundance in present-day forests are red oaks, red maple, sugar maple, and sweet birch. Hemlock and chestnut oak have similar frequency between the original and present-day forests.

Discussion

The Pennsylvania portion of the Delaware Water Gap NRA lies within the Appalachian Plateau, but just north of the Ridge and Valley Province in northeastern Pennsylvania. Its primary physiographic features include the Pocono Plateau and the Delaware River. Stream ravines cut through the Poconos creating a specialized mesic habitat. The composition of the presettlement forests of DEWA was very similar to that of Ridge and Valley forests in Pennsylvania, having been dominated by oak, pine, hickory and chestnut (Abrams and Ruffner 1995). This is in contrast to typical pre-European Appalachian Plateau forests, which were dominated by beech, hemlock and maple. Oak, pine, hickory and chestnut are each considered to be well adapted to drought and fire; fire is thought to have been a pervasive ecological influence in the pre-European oak forests of Pennsylvania (Abrams 1992, Nowacki and Abrams 1992). The decrease in hickory, chestnut oak, and chestnut from upland ridges to stream ravines within the DEWA is consistent with the xerophytic nature of these species. Similarly, the increase in red oak, black oak and hemlock in stream ravines supports the mesophytic reputation of these species. Chestnut grew on ridge sites in central Pennsylvania, and is a known calciophobe, which kept its distribution away from valley floor and indented streambed sites in the Ridge and Valley (Abrams and Ruffner 1995)

There are substantial differences in species composition and dominance between the original and present-day forests of DEWA. Many of these differences are consistent with changes I have reported in other forests of the mid-Atlantic region. For example, the dramatic increase of red oak in DEWA has been seen repeatedly in other forests, and is attributed to the opportunistic behavior of red oak following extensive logging and fire during post-European settlement, including the charcoal iron industry, and the chestnut blight in the 1920s (Abrams and Ruffner 1995, Abrams and McCay 1996). The post-European decrease in white oak at DEWA may be explained by the relatively low ability of white oak to recover or compete following catastrophic disturbances, such as intensive logging, fire, the chestnut blight and gypsy moth defoliation, and is also consistent with other studies. A decrease in hickory from pre- to post-European settlement has also been reported in other Pennsylvania forests (Abrams and Ruffner 1995), possibly due to similar challenges facing white oak.

The loss of former pine dominance, particularly white pine, is attributed to its inability to sprout following cutting and burning, in contrast to its hardwood competitors. Interestingly, hemlock maintained a similar level of dominance, albeit low, in the original versus present-day forests, despite the important tanbark industry using hemlock bark in the region and its inability to sprout after cutting. This suggests that hemlock successfully recolonized stream ravine sites it has historically dominated even after post-European logging, and that other competing tree species were not quick to dominate these sites after hemlock was logged. The loss of chestnut at DEWA is readily explained by its elimination due to the chestnut blight in the 1920s. Post-European increases in red maple, sugar maple and sweet birch have been reported elsewhere and seem to be related to the ability of these species to invade disturbed areas during the late 1800s to early 1900s, as well as the period of fire exclusion after 1900 (Abrams and McCay 1996).

Despite that many ecological patterns of DEWA are consistent with other forests there exist some substantial limitations in the witness tree and present-day forest data bases. The 438 witness trees recorded within the four Pennsylvania townships which contain DEWA is an adequate number to make some reasonable conclusions about pre-European settlement forest composition. However, a surprisingly large number of posts and stone piles were used as property markers, which reduced the number of witness trees we would normally expect to find in an area of this size (see original survey maps). Interestingly, we have explored the possibility of studying the witness tree surveys on the New Jersey side of DEWA, and have located these records in the State Archives. We have learned that the surveyors in New Jersey used witness trees exclusively to mark property corners and did not use posts or stone piles. Therefore, an analysis of the New Jersey witness tree record may provide an even better database for reconstructing the presettlement forest composition than this analysis of the Pennsylvania portion of DEWA.

Another potential weakness in the databases at DEWA relates to the quantifying of present-day forests based aerial photos (with a limited amount of ground-truthing), rather than land-based forest surveys. This analysis involved the division of aerial photos into a series of 1 ha mapping units (Myers and Irish 1981). Within each mapping unit, the three dominant tree species for the forested areas

was recorded. However, there are many other tree species within the 1 ha unit that were not recorded. Therefore, the existing database reflects tree species that typically occur as dominants within a forest unit, e.g., a forest type, but is biased against species that usually occur in a more subordinate role. Thus, the decrease in white oak from 25% presettlement to 0.1% today may be due, at least in part, to the fact that white oak rarely exists as a pure dominant in forests of DEWA. Indeed, the forests presently contain a substantial white oak component, probably 15-20% (personal observation), not reflected in the existing data base. Moreover, black oak was another important tree species in the original forests that was not listed as a component of the present DEWA forests. Black oak certainly does exist now at DEWA, but in the aerial photo interpretation it was apparently lumped with red oak. The lack of hickory in the present-day forests is probably also related to the fact that this genus typically grows in mixed-oak forests and rarely occurs as a sole dominant.

Recommendation for future work

Study 1. Conduct an analysis of the witness trees on the New Jersey side of the DEWA and a spatially paired data set comparison of exact witness tree location within the 1980 forest cover for the entire DEWA.

Study 2. Study long-term changes in vegetation cover and land-use history, including the logging of forests and changes in forest distribution and boundaries, the establishment of plantations, and changes in farm boundaries. This analysis will be based on information from aerial photos, logging records, and cultural records.

Study 3. Start a forest survey and monitoring program at the DEWA. At the minimum, the ground truthing of aerial photo data should be conducted, with particular emphasis on the accuracy of the dominant tree species listed in a large sample of mapping units. In addition, co-dominant tree species in a large sample of the mapping units should be studied by ground surveys. Ideally, a vast majority of the forested area in DEWA should be studied by direct ground surveys to establish stand tables and permanent plots. This will enable the most accurate analysis of temporal and spatial changes in forest composition and structure for future studies.

I would like to obtain funding for graduate student support and travel to complete Study 1. The park should consider initiating some or all elements of Studies 2 and 3 in relation to other vegetation monitoring programs that may occur within the near future.

I would also recommend a study of presettlement versus present-day forest composition and distribution at Shenandoah National Park in the near future. The compilation of witness tree data for SHEN will be time consuming because the hundreds of individual land (witness tree) surveys have not been organized into connected drafts, as in the case of the Pennsylvania portion of DEWA. Similarly, the New Jersey portion of DEWA is not in connected draft form. Nonetheless, these are extremely important data for both SHEN and DEWA and should be analyzed for future reference.

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Table 1. Delaware Water Gap Witness Tree Distribution - Pennsylvania Portion (1750-1795). N = number of trees; % = percent.

Species	Uplands		Streams		River		Grand Total	Percent
	N	%	N	%	N	%		
White Oak	22	21.8	19	34.5	2	12.5	43	25.0
Pine	28	27.7	11	20.0	2	12.5	41	23.8
Black Oak	13	12.9	7	12.7	2	12.5	22	12.8
Hickory	16	15.8	3	5.5	1	6.2	20	11.6
Chestnut	11	10.9	2	3.6	0	0	13	7.6
Chestnut Oak	7	6.9	3	5.5	1	6.2	11	6.4
Red Oak	1	1.0	3	5.5	2	12.5	6	3.5
Red Maple	1	1.0	2	3.6	0	0	3	1.7
Birch	0	0	1	1.8	2	12.5	3	1.7
Black Gum	0	0	2	3.6	0	0	2	1.2
Hemlock	0	0	2	3.6	0	0	2	1.2
Basswood	0	0	0	0	2	12.5	2	1.2
Sugar Maple	1	1.0	0	0	0	0	1	0.6
Red Cedar	1	1.0	0	0	0	0	1	0.6
Black Walnut	0	0	0	0	1	6.2	1	0.6
Sycamore	0	0	0	0	1	6.2	1	0.6
Total	101		55		16		172	

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Hickory	16	15.8	3	5.5	1	6.2	20	11.6
Chestnut	11	10.9	2	3.6	0	0	13	7.6
Chestnut Oak	7	6.9	3	5.5	1	6.2	11	6.4
Red Oak	1	1.0	3	5.5	2	12.5	6	3.5
Red Maple	1	1.0	2	3.6	0	0	3	1.7
Birch	0	0	1	1.8	2	12.5	3	1.7
Black Gum	0	0	2	3.6	0	0	2	1.2
Hemlock	0	0	2	3.6	0	0	2	1.2
Basswood	0	0	0	0	2	12.5	2	1.2
Sugar Maple	1	1.0	0	0	0	0	1	0.6
Red Cedar	1	1.0	0	0	0	0	1	0.6
Black Walnut	0	0	0	0	1	6.2	1	0.6
Sycamore	0	0	0	0	1	6.2	1	0.6
Total	101		55		16		172	

Table 2. Count of Witness Trees (1750-1795) Outside the Boundary of Delaware Water Gap NRA in the Pennsylvania Townships which include the Park. N = number of trees; % = percent.

Species	Township								Grand Total	Percent
	Dingman		Delaware		Milford		Lehman			
	N	%	N	%	N	%	N	%		
Pine	31	45.6	12	16.7	17	28.3	10	15.2	70	26.3
White Oak	10	14.7	21	29.2	17	28.3	21	31.8	69	25.9
Chestnut Oak	5	7.3	10	13.9	5	8.3	12	18.2	32	12.0
Black Oak	9	13.2	6	8.3	6	10.0	3	4.5	24	9.0
Chestnut	6	8.8	4	5.6	5	8.3	4	6.1	19	7.1
Red Maple	1	1.5	5	6.9	3	5.0	2	3.0	11	4.1
Hickory	0	0	2	2.8	2	3.3	3	4.5	7	2.6
White Ash	0	0	3	4.2	1	1.7	2	3.0	6	2.3
Birch	1	1.5	0	0	2	3.3	2	3.0	5	1.9
Red Oak	0	0	3	4.2	0	0	1	1.5	4	1.5
Hemlock	2	2.9	1	1.4	1	1.7	0	0	4	1.5
Black Ash	1	1.5	1	1.4	0	0	1	1.5	3	1.1
Spruce	0	0	1	1.4	1	1.7	1	1.5	3	1.1
Poplar	2	2.9	0	0	0	0	1	1.5	3	1.1
Walnut	0	0	1	1.4	0	0	1	1.5	2	0.8
Ironwood	0	0	0	0	0	0	2	3.0	2	0.8
Sugar Maple	0	0	1	1.4	0	0	0	0	1	0.4
Bur Oak	0	0	1	1.4	0	0	0	0	1	0.4
Total	68		72		60		66		266	

Table 3. Witness Tree Count Within and Outside Delaware Water Gap NRA in Four Pennsylvania Townships (Based on 528 Individual Surveys).

Species	Within DEWA	Outside DEWA	Total	Percent
White Oak	43	69	112	25.6
Pine	41	70	111	25.3
Black Oak	22	24	46	10.5
Chestnut Oak	11	32	43	9.8
Chestnut	13	19	32	7.3
Hickory	20	7	27	6.2
Red Maple	3	11	14	3.2
Red Oak	6	4	10	2.3
Birch	3	5	8	1.8
White Ash	0	6	6	1.4
Hemlock	2	4	6	1.4
Black Ash	0	3	3	0.7
Spruce	0	3	3	0.7
Poplar	0	3	3	0.7
Walnut	1	2	3	0.7
Ironwood	0	2	2	0.5
Sugar Maple	1	1	2	0.5
Black Gum	2	0	2	0.5
Basswood	2	0	2	0.5
Burr Oak	0	1	1	0.2
Red Cedar	1	0	1	0.2
Sycamore	1	0	1	0.2
Total	172	266	438	100%

Table 4. Cover and frequency of native tree species in the 1980 forests
(Pennsylvania and New Jersey portions) of the Delaware Water Gap NRA.

Species	Cover (ha)	% Cover	Frequency ¹	% Frequency
Bigtooth Aspen	68.69	0.30	11	0.49
Quaking Aspen	36.14	0.16	11	0.49
Black Locust	106.82	0.46	30	1.34
Chestnut Oak	2422.88	10.48	150	6.68
Red Oak	12395.96	53.63	798	35.53
White Oak	20.89	0.09	3	0.13
Gray Birch	6.18	0.03	3	0.13
Sweet Birch	1372.96	5.94	144	6.41
Yellow Birch	4.05	0.02	2	0.09
Pin Cherry	80.50	0.35	12	0.53
Red Maple	1764.57	7.63	339	15.09
Silver Maple	393.57	1.70	54	2.40
Sugar Maple	2904.83	12.56	349	15.54
White Ash	127.09	0.55	26	1.16
White Pine	912.70	3.95	214	9.53
Red Pine	61.84	0.27	20	0.89
Balsam Fir	1.29	0.01	1	0.04
Hemlock	263.22	1.14	38	1.69
Red Cedar	167.38	0.72	40	1.78
White Spruce	3.29	0.01	1	0.04
	23114.88	100%	2246	100%

¹ Frequency = the number of occurrences as the dominant tree in the 1 ha mapping units on the DEWA aerial photos.