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**STAND-BASED STUDY SITE SELECTION FOR SAMPLING BIOLOGICAL
DIVERSITY IN HEMLOCK AND NON-HEMLOCK FORESTS AT
SHENANDOAH NATIONAL PARK**

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Biological diversity (biodiversity) associated with eastern hemlock (*Tsuga canadensis*) and non-hemlock forests will be sampled within established forest stands at Shenandoah National Park (SHEN) beginning in 1997. Boundaries of forest stands at SHEN were defined by vegetation cover type maps provided by resource managers at the Park. Cover type maps are based upon aerial, color infrared photographs of the entire Park (Teeter 1988). Fifty percent of mapped cover types were field-checked for accuracy at SHEN, with an overall accuracy rate of 70% for the seven forest cover types defined at the Park (Teeter 1988).

Potential hemlock and non-hemlock forest stands were selected based on a sampling design methodology proposed by USGS, Bureau of Research and Development (BRD) researchers at the Leetown Science Center in cooperation with other participants in the hemlock project (Smith et al. 1996, Appendix A). Potential study stands at SHEN were ground-truthed to check the appropriateness of using the proposed BRD methodology to stratify stands based on topographic type (Smith et al. 1996, Appendix A).

Hemlock stands were clustered into 3 topographic types (termed clusters 1, 2, and 3) based on their landscape attributes, as detailed in the sampling design methodology (Smith et al. 1996, Appendix A). Hemlock stands in each cluster type were then paired

with non-hemlock forest stands using multivariate analyses of landscape attributes. Forest stands were further stratified using the presence of streams.

Prior to ground-truthing potential stands to include in the hemlock project, stand maps were examined by researchers from the Leetown Science Center, Penn State, and SHEN. This initial inspection of stand maps excluded several stands from the study before field checks were employed. Based upon visual inspection of stand maps, stands were excluded for the following reasons (Appendix B):

1. Park resource managers indicated that the stand was severely affected by human development and use (e.g., stand was surrounded by private inholdings, paved road traverses stand, heavy visitor use etc.)
2. Stand was < 5 ha in size. Potential study stands should be ≥ 5 ha in size to minimize potential edge effects (Orwig and Abrams 1993).
3. Stand was located outside of the Park boundary.
4. Non-hemlock stands were excluded from terrestrial sampling if they were located adjacent to hemlock stands.

Remaining hemlock stands and non-hemlock pairs were field checked during 3 separate visits to SHEN: 12-13 December 1996, 17-18 December 1996, and week of 24-27 February 1997 (Appendices C-E). Carolyn Mahan, Project Associate at Penn State and SHEN personnel (Gary Hunt, James Akerson, or Tom Blount) ground-truthed stands at each visit. Other researchers also visited forest stands; including researchers from the Leetown Science Center (Dave Smith, Craig Snyder, John Young) and Penn State (Rich Yahner, K. C. Kim, Marc Abrams).

In addition to the aforementioned criteria, the following were used during field visits to determine if a stand should be included in the hemlock project:

1. Stand had to be fairly accessible (to facilitate the transportation of sampling equipment to the stand); all stands included as potential study stands required a ≤ 30 -minute walk to reach.
2. Non-hemlock forest stands could not have hemlock as a component in the canopy or be located adjacent to or downstream from hemlock stands.
3. Hemlock stands should be comprised of at least 40-50% hemlock in the canopy (based upon qualitative inspection of stand).
4. Stands should be located away (> 100 m) from human and natural disturbances such as paved roads, human habitation, landslide scars, and flood damage.

After field visits to SHEN, 7 hemlock stands and paired, non-hemlock stands were selected as potential study stands for terrestrial sampling (Table 1). In addition, two hemlock stands in advanced stages of decline due to hemlock woolly adelgid infestation were included as potential sampling sites. Only one hemlock stands and its non-hemlock pair was identified in cluster-3 as a potential sampling site. Other forest stands in cluster-3 were either too small or too inaccessible to include for study. All stands selected contain streams.

REFERENCES:

Orwig, D. A. and M. D. Abrams. 1993. Land-use history (1720-1992), composition, and dynamics of oak-pine forests within the Piedmont and Coastal Plain of northern Virginia. *Can. J. For. Res.* 24:116-125.

Smith, D. A., C. Snyder, and J. A. Young. 1996. Sampling design methodology -
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Laboratory, Biological Resources Division, USGS, Leetown, West Virginia.

Teeter, A. 1988. Identification and mapping of vegetation communities in Shenandoah
National Park, Virginia. MAR-34, Final Report, USDI, National Park Service,
Mid-Atlantic Region.

Table 1. Potential stand pairs for hemlock study at Shenandoah National Park (February 1997)

Hemlock			Non-hemlock Pair			
Stand No.	Stand Name	Cluster	Stand No.	Stand Name	Euclidean Distance	Comments
18	Hemlock Springs	3	5805	Lower Hawksbill	0.6	only cluster 3 stand with stream that fits size criteria of > 5 ha, and is accessible
35	Staunton River	1	6028	Upper Cedar Run	1.02	
21	Negro Run	1	6978	Switchback to Camp Hoover	0.88	maybe some problems with stand #6978
40	Hazel River	2	2145	Matthew's Arm	0.64	very good match to Hazel River but I may prefer to match Matthew's Arm with Limberlost
20	Limberlost	1	2145	Matthew's Arm	0.95	see comments listed above
20	Limberlost	1	7022	Upper Huckleberry Cliffs	1.16	not as good a match as Matthew's Arm
26	Hogcamp Branch	2	9345	Simmon's Gap	0.97	one of two potential pairs with the Hogcamp Branch Hemlock stand
26	Hogcamp Branch	2	9195	Swift Run Tributary	0.87	a better pair to Hogcamp Branch Hemlock stand based on distance, but this tributary may be inaccessible if flooding occurs
?	Camp Hoover	?	?	no pairs identified yet because of misidentification of Camp Hoover as a non-hemlock stand		

Hemlock		
Stand No.	Stand Name	Cluster
5	Pass Run	1

Non-hemlock Pair		
Stand No.	Stand Name	Comments
		Pass Run is a stand that has been severely affected by HWA; would like to sample in this stand but should be establish pairs?
7221	Jeremy's Run	Jeremy's Run is a stand that also has been severely affected by HWA; would like to sample and pairs, but first it must be correctly classified as hemlock veg. type or the veg. map for SHEN

Note: other hemlock stands that were included in Cluster 2 are unacceptable because of size, proximity to private land, access, or flood damage.

Appendix A

Sampling Design Methodology for Hemlock and Non-hemlock Forest Stands at Shenandoah National Park

David Smith, Craig Snyder, John Young; Aquatic Ecology Laboratory, Leetown Science
Center, Leetow, West Virginia

Sampling Design Methodology

Hemlock Biodiversity Research Program

This document describes the construction of a sampling design for use in Delaware Water Gap National Recreation Area and Shenandoah National Park to determine the importance of Eastern hemlock (*Tsuga canadensis*) in structuring aquatic and terrestrial communities. The goal of this effort was to stratify field samples using landscape attributes so that large-scale influences on biota could be accounted for and effectively removed from consideration when making comparisons between different forest types. The procedure for laying out sample stands, after several iterations, consisted of the following steps:

1) **Landscape attributes were generated park-wide from digital representations of topography.** Using a 1:24,000 digital elevation model (based on USGS topography), park-wide layers were generated depicting:

- elevation
- slope (percent)
- aspect (as "northness index"), a continuous scaled variable ($\cos(\text{aspect})$) such that north = 1 and south = -1.
- ↖ solar radiance, a relative incident light variable calculated from sun angle and position at the equinox.
- terrain shape or topographic position index, calculated using a method proposed by McNab (1989), a continuous variable depicting slope convexity and concavity; this variable determines whether the local environment is a ravine, ridge, side slope, or bottom.
- stand size (sq. meters), and perimeter
- occurrence of 1st, 2nd and 3rd order streams.

2) **Landscape attributes occurring within each hemlock and non-hemlock forest stand were tabulated.** Z-scores were used to standardize the landscape variables to mean zero and unit variance. GIS overlay methods were used to compute summary statistics of landscape variables within each stand.

3) **Hemlock stands were clustered into 3 basic types based on their landscape attributes.** Multi variate clustering on Z-score means for hemlock stands was used to group stands into similar topographic types. Stands were initially clustered into between 3-5 types. We decided to use 3 cluster types because class types were easily interpretable and accurately depicted the major differences in hemlock stands. Clustering stands into more than 4 types provided no additional information about topographic variation.

4) **Stands were separated based on presence of streams.** Both hemlock and non-hemlock stands were analyzed to determine the length of streams within the stand using GIS overlay techniques. Those stands with some stream length occurring in the stand were separated from those stands which did not contain streams for further analysis.

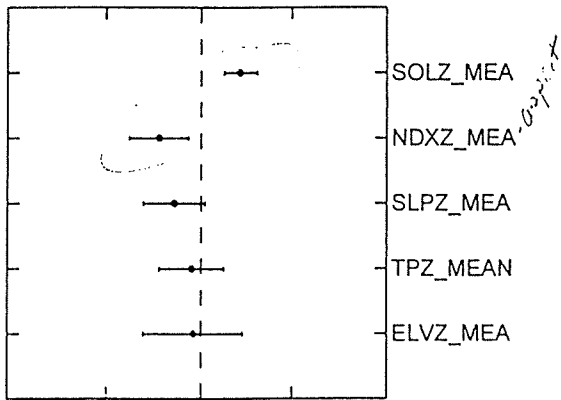
5) **The remaining hemlock stands were matched to non-hemlock forest stands by calculating a multi-variate distance using landscape variables.** An attempt was made to match hemlock stands to non-hemlock forest stands in order to find stands with similar physiographic environments, but different forest composition. A function was constructed in Splus ("match pair()", D. Smith) that computes a multi-variate distance between hemlock and non-hemlock forest stands based on landscape variables. Matching between stands was conducted using 5 variables: elevation, slope, solar radiance, topographic position, and northness.. These variables accounted for most of the topographic variation. Matching was constrained within hemlock stand types and within stream groupings. Multi-variate distances were ranked and the top 20 "closest" non-forest stands were used to select replicates for each hemlock stand. Initially, hemlock stands were matched only against "cove hardwood" (SAF 2001) stands. It was necessary to reduce the available stands against which to match (in order for the program to run), and it was felt that cove hardwoods would provide the nearest correlate to hemlock in terms of topographic structure.

6) **Stands were mapped to facilitate field checks.** Since accuracy of this method is highly dependent on GIS data layers, field checks will be used to facilitate accuracy assessment of cluster types, and matched stand pairs. A stand ID is given to each hemlock and non-hemlock forest stand based on the polygon ID of the GIS coverage. (Note: this polygon number will not be the same as the park's VEG layers). Tables listing the matched hemlock and non-hemlock stands can be used along with the printed maps to locate sample sites. All proposed sites should be visited to check the appropriateness of using this methodology to stratify stands based on topographic type.

Sampling methods developed by David Smith, Craig Snyder, and John Young, Aquatic Ecology Laboratory, Biological Resources Division, USGS, Leetown, West Virginia.

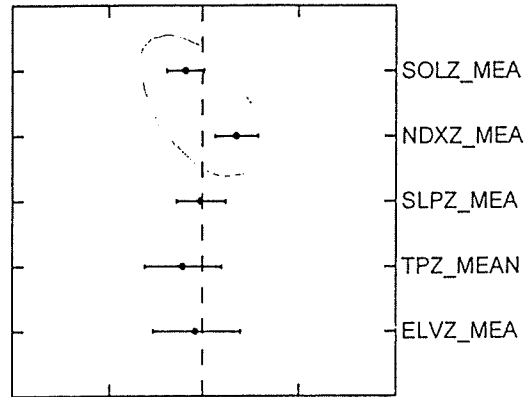
Cluster Profile Plots - SHEN

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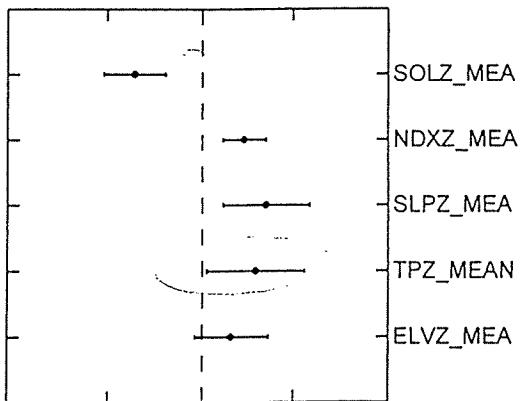


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Appendix B. Stands that were NOT field-checked but were deemed inappropriate for the hemlock study at Shenandoah National Park (12/12/96).

Stand #	Type	Cluster	Stream Present?	Size (ha)	Include/Exclude	Comments
8828	Non-hemlock	2	yes	8.5	Exclude	drains a hemlock stand; influenced by proximity to a hemlock stand
7822	Non-hemlock	2	yes	2	Exclude	too small and hemlock influenced
7768	Non-hemlock	2	yes	28	Exclude	far from road, no close access
6634	Non-hemlock	2	yes		Exclude	hemlock influenced
48	Hemlock	2	yes	10	Exclude	access is good but may be influenced by suburban development and recent flood events; requires access to private land (angry landowners)
7749	Non_hemlock	2	yes	4.7	Exclude	small and influenced by recent flood events
4744	Non-hemlock	2	yes	24.5	Exclude	hemlock influenced
4431	Non-hemlock	2	yes	12	Exclude	hemlock influenced
1468	Non-Hemlock	2	yes	19	Exclude	very far from road; access is poor
6761	Non-Hemlock	3	yes	7.5	Exclude	is located very near a stream and cluster 3 sites are "no stream" sites

Stand # 7 or 8	Type	Cluster	Stream Order	Size (ha)	Include/Exclude	Comments
	Hemlock	3	no	13	Exclude	no hemlocks here.... probably white pine
9729	Non-Hemlock	3	no		Exclude	poor access...a 2.5 mile hike into the stand
9824	Non-hemlock	2	yes	9.3	Exclude	this stand's pair (#26) may not be included in hemlock project; this stand may be located too far south
9362	Non-hemlock	2	yes		Exclude	located > 1.5 miles from nearest road
9198	Non-hemlock	2	yes		Exclude	located along Walls' Run in S. district; 2.5 miles from nearest road, access is difficult.

Appendix C. Stands that were field-checked and could be included in long-term hemlock study at Shenandoah National Park (12/12/96)

Stand #	Type	Cluster	Stream	Size (ha)	Pair Stand #	Include/Exclude	Location and Comments
20	Hemlock	1	yes	89		Include	Limberlost=LTEM site
21	Hemlock	1	yes	16		Include	Negro Run=LTEM site
18	Hemlock	3	no stream may be below stand or on stand edge	14		Include	Hemlock Springs (along Skyline Drive) Shenandoah salamanders here
4398	Non-Hemlock	3	no	6	57	Include	Byrd's nest #3 stunted oak, birch, cherry trees; laurel, very steep, S. aspect
5511	Non-hemlock	1	yes	17	20	Include?	bottom of stand has about 50% hemlock; but upper part of stand may be more oak dominated.

Appendix D. Stands that were field-checked but should NOT be included in hemlock study at Shenandoah National Park.....see comments for explanation.

Stand #	Type	Cluster	Stream Order	Size (ha)	Pair Stand #	Include/Exclude	Location	Comments
5504	Non-hemlock	2	yes	44	20	Exclude	next to Limber Lost	very close to Limber Lost so it is a hemlock-influenced stand
4	Hemlock	1	yes	77		Exclude as a hemlock stand	Thornton Gap	not a hemlock stand but a good cove/hardwood stand
5	Hemlock	1	yes	15		Exclude as a good, healthy hemlock stand	Pass Run	this stand has been severely affected by HWA.....may be a good stand to evaluate the effects of heavy HWA infestation; many standing dead hemlocks

Appendix E. Stand number and descriptive information for all stands visited at Shenandoah National Park during the week of 24 February 1997.

Stand #	Type	Cluster	Stream Order	Size (ha)	Acceptable/Unacceptable	Description	Comments	Location
6	Hemlock (lower Pass Run)	1		31	U	adjacent to private land; < 30 percent hemlock in stand; stand is approx. 50 m wide	this stand is a continuation of the hemlock stand that exists all along Pass Run	along the lower portion of Pass Run
11 & 12	Hemlock (Hazel River)	2		8.2	A	extensive hemlock stand although there is a lot of canopy thinning and mortality; stand is 60 m wide	can drive to within 15 min of the stand; intermediate size hemlocks are present all along trail to main stand	located across Skyline Dr. from Meadow Springs
14	Hemlock?	3		13.5	U	not a hemlock stand; consists of scattered w. pine, mountain laurel, and chestnut oak	misclassified on vegetation map	along Skyline Drive
26	Hemlock (Dark Hollow Falls; Hogcamp Branch)	2		23.2	A	downstream of Dark Hollow Falls on right side of hiking trail; some canopy thinning and mortality in stand; stand is 60 m wide	may have relatively high human use during the summer; best park of stand is a 15-20 min. hike from Dark Hollow Falls	located downstream of Dark Hollow Falls along the Hogcamp Branch
25	Hemlock	1		1.2	U	very small mixed hemlock stand; continuation of stand # 24	too small	located downstream of stand #26 near confluence with Rose River
24	Hemlock (Rose R.)	1		27.2	U	very narrow hemlock stand; only 20 m wide right along the Rose River	too narrow; there would be a lot of edge effects associated with this stand	located 1.5 miles below Dark Hollow Falls along the Rose River
31	Hemlock (Huckleberry Cliffs)	2		8.6	A/U	< 50% hemlock crown closure; mixed stand with chestnut oak, birch	not first choice for hemlock site; a one hour hike will bring one to a more extensive portion of stand	located right off of Skyline Drive; to reach the more extensive portion of stand would be a 1/2 day trip

29	Hemlock (W. Branch Naked Creek)	1	20.8	U	the hemlock portion of stand is mixed with w. pine and constitutes a 30 m wide swath along stream	this stand was severely damaged by flooding; approx. 30 min. hike in to stand (no trail)	located right along the stream corridor of W. branch of Naked Creek
36	Hemlock (Big Creek)	1	4.9	U	small stand of hemlocks located right next to private "homestead"	access is near private land; stand is small	located along stream corridor of Big Creek
33	Hemlock (Falls Hollow)	1	15.7	U	narrow (25 m) strip of hemlocks; private homes are scattered throughout the stand	too much private in-holdings	located downstream of stand #36 along Big Creek
39	Hemlock	2	8.1	U	small mixed stand of hemlocks; very heavy adelgid infestation; spring seeps out of stand	approx. 20 min. hike up to stand; although this is a "no stream" stand, there is a spring located here	must drive through private inholdings to reach this access to Park
35	Hemlock (Staunton River)	1	18.9	A	extensive hemlock stand that is approx. 100 m wide; old growth trees are scattered throughout stand (> 300 years old?); stand is > 600 m long	long travel (car) time to reach this stand; it is very remote; approx. 1 1/2 h. drive from Headquarters	
34	Hemlock (Upper Rapidan)	1	16.1	U	hemlock comprises an understory component to stand; part of stand is on state land	hemlocks are not a large component of the overstory of this stand	located 20 min drive from Camp Hoover if road is accessible
37	Hemlock (Lower Rapidan)	1	5.2	U	hemlocks are scattered through stand but do not constitute the majority of overstory trees	relatively small stand	located another 5 min. down road from stand # 34

2221	Hemlock (Jeremy's Run)	322	A?	a very extensive hemlock stand with very extensive mortality; good stand to use a "dead" site	20 min. hike down to stand; not classified as hemlock on veg. map	trail to this stand is located right along Skyline Drive
56	Hemlock (S. River Falls)	7	A/U	hemlocks constitute a 20 m swath along stream; possible to sample on w. side of stream (would require crossing stream); hemlocks mixed with oak	could drive along fire road to get to within 1/2 mile of the stand; otherwise it is a 25 min. hike in	located along the South River Falls Trail
57 & 58	Hemlock	10.8, 8.0	U	hemlock stands are located along a steep mountainside that appears almost inaccessible	no clear way to access the stands	located across S. River "gorge"; these stands are visible from trail
2187	Hemlock (Little Devil's Stairs)	35.2	U	a very narrow (10-15 m) stand; hemlocks are mixed with birch and oak;	stand is only 4-5 trees wide but very long	a 30 min. hike from a fire road
2145	Non-hemlock	29.7	A	mixed hardwood stand comprised of w. oak, birch, some w. pine	pairs with Hemlock stand #11 (Hazel R.) or stand #20 (Limberlost)	located along Matthew's Arm trail
2531	Non-hemlock	20.7	U	a lot of gypsy moth mortality in stand; stand is primarily comprised of chestnut oak; access is difficult	stream that is in this stand is very small; resembles a seep; the overstory tree mortality is high with many blowdowns	located near Elk Wallow picnic Area
3200	Non-hemlock	12.2	U	stream that is in this stand emerges from a spring and appears to be intermittent;	not a good pair to other hemlock stands that have much higher stream flow	located near Beahm's Gap Overlook

5511	Non-hemlock?	17.5	U	although this is classified as non-hemlock, there are hemlocks throughout the drainage; some appear to be old growth	definitely not a good non-hemlock site because of the presence of hemlocks	located a 15 min. drive down fire road that accesses Limberlost
5805	Non-hemlock	15.8	A	upper elevation hardwood stand dominated by striped maple, w. oak, and r. oak	pairs well with hemlock springs; hemlock stand # 18	access is along a trail from lower Hawksbill parking area
6281	Non-hemlock?	27.2	U	although this is classified as non-hemlock, there is a large stand of hemlock trees; some of which are very tall	definitely not a good non-hemlock site because of the presence of hemlocks	located above Rose River Falls off of Skyline Drive
9345	Non-hemlock	100.8	A	mixed hardwood stand of yellow poplar, red oak, hickory; permanent first order stream in stand	some herbaceous exotics in stand, e.g., garlic mustard, orchard grass; sampling should be conducted away from fire road; pairs with hemlock stand # 26 (Hogcamp Branch)	located along fire road near Simon's Gap
9228	Non-hemlock	26.1	U	there is no stream in this stand and this stand is too close to the Park's property line	stand extends into private land	
9195	Non-hemlock	86	A	hardwood stand dominated by yellow poplar, birch, w. and r. oak; located along tributary to Swift Run	pairs with Hemlock Stand #26, Hogcamp Branch; may be difficult to cross Swift Run if it is flooded; should conduct sampling away from powerline that parallels Swift Run	located of Rte. 33 in the upper portion of S. district; park near old gated road.

7022	Non-hemlock	23.3	A	located 1000' above Huckleberry Cliffs hemlock stand; I think it is far enough away to use as a non-hemlock site	pairs with hemlock stand #20 (Limberlost);	located right along Skyline Drive; I like the part of the stand that is on the west side of Skyline Dr.
6978	Non-hemlock	9.4	A/U?	this is a very narrow swath of cove hardwoods running along the stream (20-25 m wide); one side of the stream is severely affected by gypsy moth mortality;	may be too narrow a stand to measure the effects of cove hardwoods, but is only identified pair to Negro Run, hemlock stand #21	located along fire road to Camp Hoover
6028	Non-hemlock	10.2	A	this stand is dominated by oak; maple, yellow poplar; stream flows out of underground about 10 min. hike down the trail	pairs with hemlock stand #35 Staunton River	located along Cedar Run trail; use non-trail side of stream to avoid human use