FIELD HANDBOOK: HEMLOCK ECOSYSTEM INVENTORY AND MONITORING PROJECT OF THE NEW RIVER GORGE NATIONAL RIVER AND GAULEY RIVER NATIONAL RECREATION AREA

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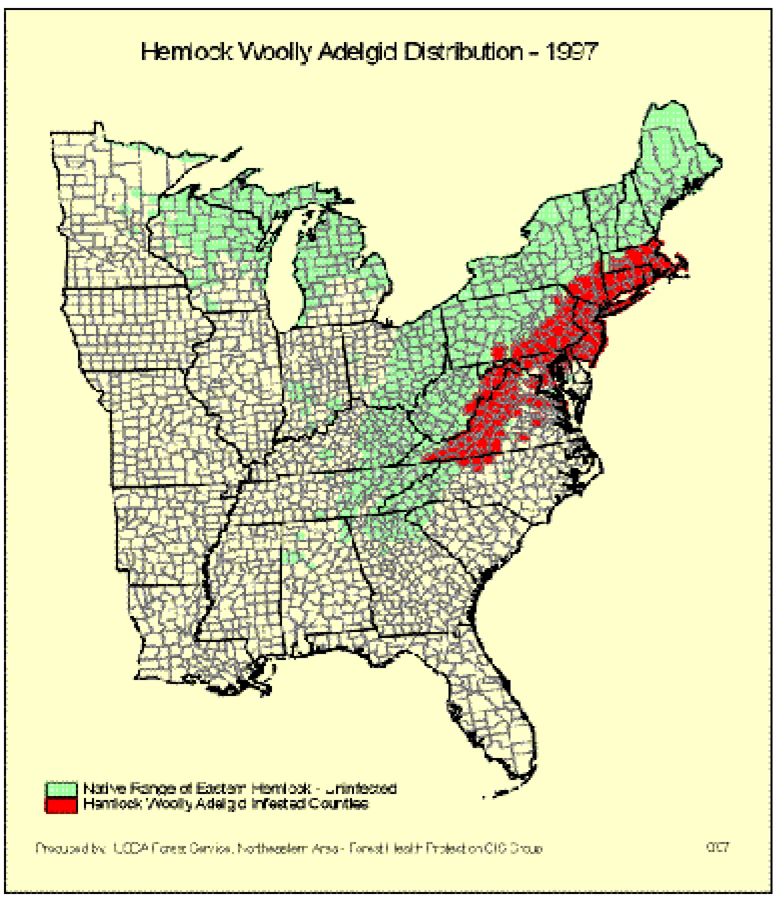

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SUMMARY

This handbook describes the field methods used to sample baseline vegetation data that were collected between November, 1998, and July, 1999, in 36 hemlock ecosystem monitoring plots located on hydric, mesic, and xeric sites in the New River Gorge National River (NERI) and Gauley River National Recreation Area (GARI), in Nicholas, Fayette, and Raleigh counties, West Virginia. The results of baseline vegetation sampling, and procedures for analyzing future data, are summarized in the companion final-report document (Wood 1999). Some of the tables and figures from the final report pertaining to field-sampling methodology have been included in this handbook. Field data sheets for resampling the plots are supplied in Appendix A of this handbook, with baseline-data species names already filled in (where appropriate). Blank space is left on the field data sheets for including any newly encountered species.

There may be environmental factors (weather, deer, other insects, etc.) besides HWA affecting the forest canopy, and it may be important to document these other causes so as not to confound their impacts with those of HWA. Therefore, all tree (≥8cm dbh) data for hemlocks and pines (see the ***Hemlock and Pine Trees*** field data sheet), and hardwoods (see the ***Tree Density and dbh*** field data sheet), should be resampled annually. Other vegetation data may not need to be resampled annually. The number of years between sampling periods for other vegetation data should be based on an evaluation of the long-term objective of the study, which is to document any potential impacts of hemlock woolly adelgid (HWA) (*Adelges tsugae* Annand) on the hemlock plant-community. Since it may not be logistically feasible to resample the other vegetation data every year, the other vegetation data should be resampled if and when significant differences are observed between baseline and resampled tree (≥8cm dbh) data. Each plot's center-stake and the four corner-stakes should be relocated and spray-painted every year. Flagging should be used sparingly so as not to draw attention to the plots, but is recommended for marking stakes concealed by a thick shrub layer. Some of the white-colored stakes at Carnifex were difficult and time-consuming to relocate, so they should be spray-painted orange in the future.

METHODS

Sampling Design

All plots are 400m^2 (Figure 1) and, depending on the site conditions, were placed either within a stand or an isolated patch of hemlock trees. On sites where hemlock was the co-dominant or non-dominant tree species, plot-centers were deliberately placed where there was a relatively significant amount of hemlock canopy cover. Most plots are square (20m by 20m), but four of the plots (CX1, FH1, MX2, and WH1) are rectangular (10m by 40m). Rectangular plots were used where a landscape feature, such as a creek bed or rock wall, did not allow placement of a square plot. Detailed directions and maps to each of the 36 plots are printed in Appendix A of the final report (Wood 1999). Four main categories of baseline vegetation data were collected from and should be resampled for each hemlock plot:

1. Density data (trees, saplings, shrubs, and vines)
2. Cover data (all vascular plants and structural components)
3. Frequency of occurrence data (all vascular plants)
4. Tree data
   --hemlock (dbh, crown ratio and vigor, straightness, HWA index)
   --pines (dbh, crown ratio and vigor, straightness)
   –all other trees (dbh)

Tree data should be collected for all trees $\geq$8cm dbh within the 400m^2 of each plot. All other data are subsampled along four transects radiating from the center-stake to the four corners of the plot (Figure 1). Density of all woody plants $\geq$1.4m tall, including saplings (trees < 8cm dbh), shrubs, and vines, are tallied in four 2m-by-10m rectangular belt-transects. Cover estimates of all vascular plants and certain structural components (Figure 2) are collected at 100 discrete points evenly spaced along each 10m line-transect. Frequency data for all understory plants < 1.4m tall, including tree seedlings, shrubs, vines, and all herbaceous species, are collected in twenty 0.25m^2 quadrats evenly spaced along each of the four transects. Specific methods used for collecting these data are detailed below.

Note that each transect has been assigned a permanent number, which is listed along with the azimuth (± a few degrees) from the center-stake to the corner stake in Table 1. Note that the starting point for transects in the 10m-by-40m plots is 5m from the center-stake, whereas the starting point for transects in the 20m-by-20m plots is 1m from the center-stake (except for transect 3 on plot CM1 and transect 3 on plot FX3, which start 2m from the center-stake because there is a tree trunk 1.0m away from the center-stake on these two lines).

How to Sample a Plot

The tree data listed under category #4 should be collected annually. The hemlock and pine tree data are sampled in November, while all other tree species are sampled during the following July. The belt-transect density data, line-transect cover data, and quadrat frequency data do not need to be collected annually, but should be collected when a significant change occurs in the canopy tree vigors, crown ratios, and/or HWA indexes. Wood (1999) describes statistical analyses that can be used to determine if there is significant difference between baseline data and data collected in subsequent years.

The center-stake should be located first, then the corners. Use the perimeter angles (Wood 1999, Appendix A) and transect angles (Table 1) to relocate lost corners by triangulation — stretching out several 15m nylon tapes along the compass bearings. Place a long piece of flagging directly above each corner-stake so that it will be visible from the center-stake. On steeply sloped plots and/or hydric plots with thick *Rhododendron*, it may be necessary to tie flagging to the end of a very long stick and prop the stick up so that the corner can be seen from the center-stake. Remove the long pieces of corner-stake flagging when finished, so as not to draw unnecessary attention to the plot.

Identify the azimuth and starting distance from the center-stake for Transect #1 and stretch the 10m tape out. Use chaining pins at either end of the tape to pull it tight. While stretching out the tape, run it as close to the ground as possible and check to see that the traverse is a straight line between the stakes. Once it is stretched out to the full 10-m length, walk behind the corner-stake to double check that the tape is straight. If it is not lined up properly between two stakes, the tape must be rewound to get around the obstruction(s) and stretched out again. Extreme care should be taken not to bend, break, or trample the vegetation along the transect. Expect it to take 15 to 20 minutes just to properly get the tape stretched out on some transects. Dead branches should not be broken off of live trees because this will bias the results obtained from sampling the Dead Vegetative Cover components. Although some human disturbance is inevitable, particularly on the steepest plots (MM3 and MX1), avoid creating a trail alongside stretched-out tapes.

There is no specific order in which the various types of vegetation data on a plot must be collected, although it is usually easier to identify diminutive plants (those sampled in the 0.25m^2 quadrats) before they are accidentally stepped on. On plots where there is not much shrub cover and it is relatively easy to walk back and forth along the transect, all of the frequency quadrats can be sampled, then all sapling and shrubs in the belt-transect, then cover along the entire 10m line-transect can be listed for each component. On plots with greater shrub cover, it may be more efficient and cause less disturbance to the plot to collect all the different types of data at the same time to avoid having to move back and forth along the transect. This can be done by collecting all the data in the first 1-m section of the 10-m tape, then all the data for the second 1-m section, etc. For example; first list cover for all components on the 0.1m, 0.2m, 0.3m,...0.9m, and 1.0m marks on the nylon tape (line-transect data), then note any saplings or shrubs that are $\leq$1.0m on either side of the tape (belt-transect data), then identify all species in the 0.25m^2 quadrat at the 0.5-m and 1.0-m marks, then repeat this process for each successive 1-m section.

When finished with Transect #1, repeat the entire procedure for transects 2-4. Before reeling in the 10m nylon tape, use it as a boundary-marker for collecting the specific data on individual trees (≥8cm dbh). Circle your way around the plot in a clockwise direction, taking measurements on each tree until you get back to the tape. That should prevent double-sampling any of the individual trees. Stretching out the tape for use as a plot boundary-marker also may be necessary in some plots to collect the hemlock and pine tree data in November.

Tree Diameters, Density, Vigor, Crown Ratio, and HWA Monitoring

All trees within or intersecting the outside perimeter of each 400m^2 plot are tallied by species. A tree that is close to the edge of a plot should be counted if any part of the trunk intersects the imaginary line between corner-stakes. Specific types and values of data collected for trees are summarized in Table 2. A "tree" is defined as any stem ≥8cm diameter at breast-height (dbh).

Data for hemlock and pine trees (live and dead) are collected some time during the November-April period in which the current season's HWA population typically exhibits woolly characteristics (Onken et al. 1994). I collected the baseline hemlock and pine data in late November, 1998. It may be easier, however, to observe HWA in the spring when the white woolly adelgid masses are more visible from a distance (Brad Onken, pers. comm.). At that time, each hemlock and pine tree is given a crown-vigor class rating, dbh is measured, and the HWA infestation on hemlocks is rated. Additional data that are not part of the Park Service's original Request for Proposal (RFP) but that should be collected for each hemlock and pine tree include the live crown-ratio, and the straightness of the main stem, which identifies uprooted, stressed, or potentially stressed individual trees. Crown ratio is the percentage of total tree height with live foliage. The technique for estimating crown ratio is based on the guidelines given by Miller et al. (1998), in *Section 2.6.3.2 Live Crown Ratio*. The ranges for the values of the vigor, straightness, and HWA indexes are listed at the bottom of the Hemlock and Pine Trees field data sheet in Appendix A. If possible, hemlock vigor and HWA data should be visually estimated between 10am and 2pm, using binoculars, for optimal crown visibility.

Species identification and diameter data for all other tree species except hemlock and pines are collected the following July when the hardwood trees are leafed-out. Dead trees, except for hemlocks and pines, do not have to be tallied by species. The field data sheet for Tree Density and dbh in Appendix A lists all tree species encountered in the July, 1999, baseline data sampling period. The blank lines on the data sheet can be used to add any new species present in future surveys. The dbh of each individual tree should be recorded on the line reserved for each species.

All of the hemlock and pine trees that were ≥8cm dbh in November, 1998, have an aluminum nail on the side of the stem facing the center-stake of the plot. Dbh should be remeasured immediately below each nail. There are no nails in the other trees, so expect some observer bias to occur when remeasuring their dbh. Since trees are grouped by 10-cm diameter classes for data analyses, the magnitude of the observer bias, however, should be relatively small.

Sapling and Shrub Density (belt-transects)

The number of live saplings (trees < 8cm dbh and ≥1.4m in height) and shrubs (woody stems ≥1.4m in height) are tallied by species on each of the four $20m^2$ belt-transects nested within each $400m^2$ plot (Figure 1) during the July sampling period. The Sapling and Shrub Density field data sheet in Appendix A is designed for tallying these data and lists all species encountered in 1999. Any new species can be added on the blank lines. Based on the methods developed by Martin et al. (1997), each shrub stem that originates ≤10cm above ground level is counted as a separate individual. The total numbers of dead saplings and shrub stems also are tallied on each belt-transect, regardless of species. A 1.4-m section of PVC pipe, with a mark at 10cm and 1.0m can be carried to check plant heights and to determine if stems are within the perimeter of the belt-transect (± 1.0m on either side of the 10-m section of nylon tape).

Understory Species Frequency (quadrats)

The occurrence of each species of tree seedling (< 8cm dbh and < 1.4m in height), shrub (< 1.4m in height), and herbaceous species is listed for each of the twenty $0.25m^2$ (1.0m-by-0.25m) quadrats centered every half-meter along each 10m line-transect during the July sampling period. Except for vines, all species must be rooted in the quadrat. The first quadrat-sample is aligned with the 0.5-m mark along the nylon tape, then at the 1.0-m, 1.5-m, 2.0-m….and 10.0-m marks (Figure 3). Each species that is found in a quadrat is counted only one time in that quadrat. For example, if one or more hemlock seedlings are rooted in five of the twenty quadrats along a transect then, regardless of how many individual hemlock seedlings there are in each quadrat, the percent frequency of occurrence of hemlock on that transect is 25%. The number (i.e., density) of tree seedlings in each quadrat was not counted, but could be collected during future sampling periods if desired. Due to the ephemeral nature of seedlings, however, I think the belt-transect sapling density data will be a more reliable indicator of long-term plant-community changes.

Stratified Cover Sampling (line-transects)

Cover of the structural and vegetative components outlined in Figure 2 is counted on each of the four line-transects in each plot, during the July sampling period, by noting the presence of each component on 100 discrete points (i.e., every decimeter) along a 10-meter section of nylon tape. The data are vertically stratified, based on the layers, or strata, of vegetation present along each line (Figure 2). Data are tallied for live vegetative components (primarily leaf coverage, but also live boles and stems intercepting the line), dead vegetative components (leaf litter, standing or fallen boles, stems, and branches that are not attached to living trees or shrubs), and structural components (bare ground, bare rock, and live tree trunks). Live vegetative components include hemlocks, pines, hardwoods, and other major groups or growth forms of plants. I repeat; dead branches that are still attached to living trees and shrubs are not counted.

Each component is "assigned" to one of the eight vertical strata listed in Figure 2 (i.e., supercanopy, canopy, subcanopy, high midstory, low midstory, shrub layer, understory, or uprooted trees). The "assigned" stratum is defined by the maximum height of the component. The minimum height at which a component intercepts a transect determines its range of vertical stratification. Uprooted trees are a special group that should be recorded separately from other trees. Uprooted trees do not constitute a stratum *per se*, but the simplest way to keep track of their occurrence is to use the words "uprooted trees" on the 10m Line-Transect Cover field data sheet (Appendix A) in the column reserved for the "assigned" stratum.

Unlike other sampling techniques that aggregate cover-component data, regardless of height-class, into pre-defined height ranges (e.g., 0-1m, 1-5m, 5-10m, etc.), this sampling technique will generate cover data for multiple height-classes of the *same* cover component. A cover component can be counted in more than one stratum at the same point on a line-transect when it intercepts one or more of the vertical strata below its "assigned" stratum. To illustrate this concept (Figure 4), assume that the tallest hemlock trees intercepting a transect are "assigned" to the canopy stratum, and the live crown on these trees ranges in height from 1.5 to 20m. Hardwood trees, also assigned to the canopy, range in height from 4.0 to 20m. There also are smaller hemlock trees assigned to the subcanopy and midstory strata, with live crowns ranging in height from 1.3 to 15m, and 0.8 to 8.0m, respectively. Evergreen shrubs are assigned to the shrub layer, ranging in height from 0.8 to 4.0m. Given this scenario, cover of the canopy hemlock trees are tallied in three strata; 1.5 to 4.0m (canopy hemlock in the shrub layer), 4.0 to 8.0m (canopy hemlock in the midstory), and 8 to 20m (canopy hemlock in the canopy). Canopy hemlock in the subcanopy is difficult to differentiate in the field, so it is included with the canopy stratum. Although there are none in Figure 4, the same applies to any supercanopy trees — i.e, combine any subcanopy and canopy cover with the supercanopy stratum when encountered. Subcanopy hemlock-tree foliage in this example (Figure 4) intercepts all lower strata, so its cover is recorded in four separate layers: subcanopy hemlock in the subcanopy layer (the "assigned" stratum), subcanopy hemlock in the midstory, subcanopy hemlock in the shrub layer, and subcanopy hemlock in the understory. The hemlock trees assigned to the midstory also intercept the shrub layer and the understory. Note that it is only necessary to use the "High" and "Low" adjectives when both midstories occur on the same plot, even though Wood (1999) routinely used the "Low" adjective when only one midstory was present on a plot. Evergreen shrubs in Figure 4 are tallied in two height ranges; > 1.4 to 4.0m (the amount of shrub-layer evergreen shrubs in the shrub layer), and 0.0 to 1.4m (the amount of shrub-layer evergreen shrubs in the understory stratum).

Except for those components with a maximum height of ≤1.4m that are "assigned" to the understory stratum, the minimum and maximum heights of components in all other strata are determined on each line-transect at the time of sampling. There is no predetermined height range for any of the other strata. Therefore, the same component potentially can have different minimum and maximum heights on different transects in the same plot. As previously noted in the example (Figure 4), canopy components intercepting the subcanopy are usually too difficult to see, so they are combined with the canopy stratum. Supercanopy cover data that intercepts the canopy and subcanopy, likewise, are too difficult to differentiate, so they should be combined.

Since the understory stratum always is ≤1.4m, all foliage between 0.0 and 1.4m always is recorded as understory in the "vertical stratification" column on the field data sheet. If there is no vegetation "assigned" to the midstory layer, and the subcanopy foliage extends down into the shrub layer (Figure 5), then the minimum height of the subcanopy is lowered to the maximum height of the shrub layer. Compare the data sheets in Figures 4 (with midstory) and Figure 5 (without midstory). Midstory drops out of the vertical stratification column for each assigned stratum and the minimum heights of the canopy and subcanopy hemlocks change from 8m to 4m. If there also is no shrub layer, and a taller layer extends down into the understory, then the minimum height of the taller layer always becomes 1.4m. For example, in Figure 6, where the lowest assigned stratum is the subcanopy, the minimum height of the subcanopy stratum is 1.4m. Note also how the minimum heights of the canopy vegetation change between Figure 5 and Figure 6 because of the absence of the shrub layer.

Given the way vegetative cover data are "assigned" to particular stratum based on maximum height, consider a scenario in which only the lowest branches, between 0 and 1.4m off the ground, of a 20-m tall hemlock tree that is "assigned" to the canopy stratum intersect the first 3m of a line-transect. Assuming there were no subcanopy, midstory, or shrub-layer strata on that transect, cover data for this tree would be tallied in this way:

Assigned Stratum (code)	Component (code)	Total Cover	Vertical Stratification (code)	Min Height (m)	Max Height (m)	Points (dm)
Canopy (2)	Hemlock trees (1)	30	Canopy (2)	1.4	20.0	
			Understory (8)	0.0	1.4	1-30

The seven-page 10m Line-Transect Cover field data sheet in Appendix A includes rows for filling in all possible combinations of cover components and vegetation strata sampled in 1999. The numbers in parentheses (1= supercanopy, 2= canopy, etc...) after each stratum can be used for transcribing the data into a computer file, instead of typing the strata names. It is recommended that you use the seven-page field data sheet on at least several of the first transects that are measured during each new sampling period to familiarize yourself with the sampling procedure. Alternatively, there is a blank page of this field data sheet provided in Appendix A, or you may wish to continue to use certain pages of the seven-page data sheet for specific strata while using the blank page for the remaining strata. Page 1 of 7 includes all possible components that can occur (i.e, that can be "assigned") in the supercanopy stratum (see Figure 2), and all vertical strata that may intercept the transect. Page 2 of 7 includes all possible components that can be assigned in the canopy stratum, page 3 of 7 is for components assigned to the subcanopy, page 4 of 7 is for high midstory, page 5 of 7 is for low midstory, page 6 of 7 is for shrub layer, and page 7 of 7 is for understory components.

The total cover of any particular component in its "assigned" stratum is determined by adding all of the points in all strata. Each point only counts once for total cover, regardless of how many vertical strata a particular component intercepts, so the sum can never be greater than 100 percent. A column is included on the 10m Line-Transect Cover field data sheets for calculating total cover, which can be done later in the office. A Statistical Analysis System (SAS Institute, Inc. 1989) computer program for calculating total cover as it is entered in Figures 4-6 is included in Appendix B. For example, the canopy hemlock trees in Figure 4 intercept the transect at points 11-27 and 51-67, so the total cover is 34%.

Photographs

Take four photographs in each of the 36 plots during the November and July vegetation sampling periods; two photographs from the designated plot corner, one photograph from the beginning of transect #1, and one photograph from the beginning of transect #3. The Photograph Log field data sheet in Appendix A can be used to keep track of the exposures. Please be aware that the azimuths listed on this field data sheet and in Table 1 were taken with a low-quality (Silva Ranger) compass, possibly with a hammer, clipboard, or other piece of metal in my other hand, and may be off by as much as 10° from the actual bearing. Since the azimuths to the four corners in the 20m by 20m plots should be roughly 90° apart, a quick look at all four azimuths should determine which corner is which even if some of the azimuths are pretty far off the values listed in Table 1.

Field Equipment Checklist

— roll flagging for temporarily marking the corner-stakes.
— compass
— 15m nylon tapes (2)
— metric dbh tapes
— leather tool belt for carrying items while moving around in the plot
— microcassette recorder, tapes, and batteries (for recording data, if working alone)
— binoculars for identification of and specific data on individual trees
— field data sheets (Appendix A), clip board, mechanical pencils, extra lead
— plot-location maps and descriptions (Wood 1999, Appendix A), transect angles (Table 1)
— waterproof pack cover to protect field equipment in case of rain
— safety glasses
— chaining pins
— camera and disks or 35mm slide film
— plant identification guides (optional)

<u>Equipment needed only during the November sampling period</u>

— hammer and aluminum nails for marking hemlocks (2" roofing nails for big trees and 1.25" white finishing nails for smaller trees). Eventually, trees will grow over the existing nails and a new nail will need to be nailed into the tree. Saplings that grow into the 8-15cm dbh class will need a nail, too.

Equipment needed only during July sampling period

— orange spray paint (the kind that sprays upside down works best for remarking the stakes). Requires three to four 11oz cans to remark all 36 plots.
— 8.5" by 14" ledger-book for pressing small samples of unknown plants. Use masking tape to attach plants to the page. Write down the name used for the unknown plant on the field data sheet and in the ledger. Write down other pertinent information on the ledger (e.g., plot number, transect number, etc.) next to the plant sample.
— 1.4m stick or PVC marked at 10cm and 1.0m for counting sapling and shrub stems
— $0.25m^2$ quadrat (Figure 3) for collecting frequency of occurrence data

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Table 1. Transect starting points (distance in meters) and azimuths (from magnetic north) measured from the center-stake of each hemlock plot. Each plot is identified by a three-character code. The first character of the code represents the geographic location of the plot: F= Fayetteville, W= Wolf Creek, K= Kates Branch, G= Grandview, M= Meadow River, and C= Carnifex Ferry State Park. The second character equates with the principle study design, which consists of 3 levels along a moisture gradient; H= Hydric, M= Mesic, and X= Xeric. The third character is the replication number.

	Transect 1		Transect 2		Transect 3		Transect 4	
Plot	Starting Point	Azimuth	Starting Point	Azimuth	Starting Point	Azimuth	Starting Point	Azimuth
CH1	1	347	1	79	1	168	1	265
CH2	1	33	1	122	1	208	1	302
CH3	1	14	1	108	1	196	1	284
CM1	1	55	1	135	2	237	1	328
CM2	1	346	1	75	1	167	1	258
CM3	1	340	1	70	1	160	1	248
CX1[a]	5	20	5	172	5	195	5	353
CX2	1	2	1	91	1	180	1	270
CX3	1	64	1	157	1	248	1	336
FH1[a]	5	20	5	45	5	206	5	234
FH2	1	100	1	182	1	276	1	4
FH3	1	22	1	110	1	200	1	294
FX1	1	324	1	54	1	144	1	234
FX2	1	45	1	134	1	225	1	315
FX3	1	2	1	92	2	182	1	272
GM1[b]	1	110	1	175	1	260	1	310
GM2	1	48	1	136	1	224	1	316
GM3	1	46	1	136	1	222	1	314
KM1	1	222	1	318	1	46	1	136
KM2	1	274	1	358	1	90	1	180
KM3	1	304	1	32	1	128	1	218
MH1	1	22	1	106	1	199	1	290
MH2	1	73	1	167	1	259	1	347
MH3	1	4	1	95	1	185	1	273
MM1	1	360	1	90	1	180	1	270
MM2	1	22	1	110	1	204	1	298
MM3	1	312	1	48	1	122	1	232
MX1	1	342	1	78	1	154	1	254
MX2[a]	5	336	5	122	5	148	5	308
MX3	1	320	1	40	1	140	1	230
WH1[a]	5	44	5	75	5	216	5	244
WH2	1	3	1	95	1	175	1	276
WH3	1	16	1	106	1	204	1	292
WX1	1	20	1	110	1	196	1	290
WX2	1	49	1	135	1	225	1	319
WX3	1	33	1	122	1	208	1	306

[a] Perimeter dimensions on these plots are 10x40m. All other plots are 20x20m.
[b] Transects 1 and 4 in plot GM1 do not point to the plot corners; they were moved to prevent the transects from crossing a creek bed. A small rock spray-painted orange was placed at the 10-m mark on each of these transects.

Table 2. Types and descriptions of data collected for each individual tree ($\geq$8cm dbh) occurring on each 400m^2 plot during November, 1998, and July, 1999.

Data Type	Description	Species (Month) Measured
dbh	Diameter at breast height, measured in centimeters, using a dbh tape	Hemlock (November) Pines (November) All other trees (July)
Live Crown Ratio	Percentage of total tree height with live foliage, visually estimated (see Miller et al. 1998)	Hemlock (November) Pines (November)
Crown Vigor	Index of the health of the Live Crown, in terms of branch mortality, twig dieback, foliage discoloration, and/or leaf dwarfing (Onken et al. 1994). The entire crown was inspected using binoculars: 1= > 95% healthy crown 2 = > 75-95% 3= > 50-75% 4 = > 25-50% 5 = > 0-25% 6 = snag/dead	Hemlock (November) Pines (November)
Straightness	Index of the angle or slope between the base and top of the tree (visually estimated): 1= 0-45 degrees (straight) 2= > 45-90 degrees (leaning/bowed to horizontal) 3= > 90 degrees (severely bowed, or uprooted facing down slope)	Hemlock (November) Pines (November)
HWA	Index of hemlock woolly adelgid infestation severity: 1 = heavily speckled and visible from 30m 2 = moderately speckled 3 = lightly speckled — only a few scattered specks 4 = none	Hemlock (November)

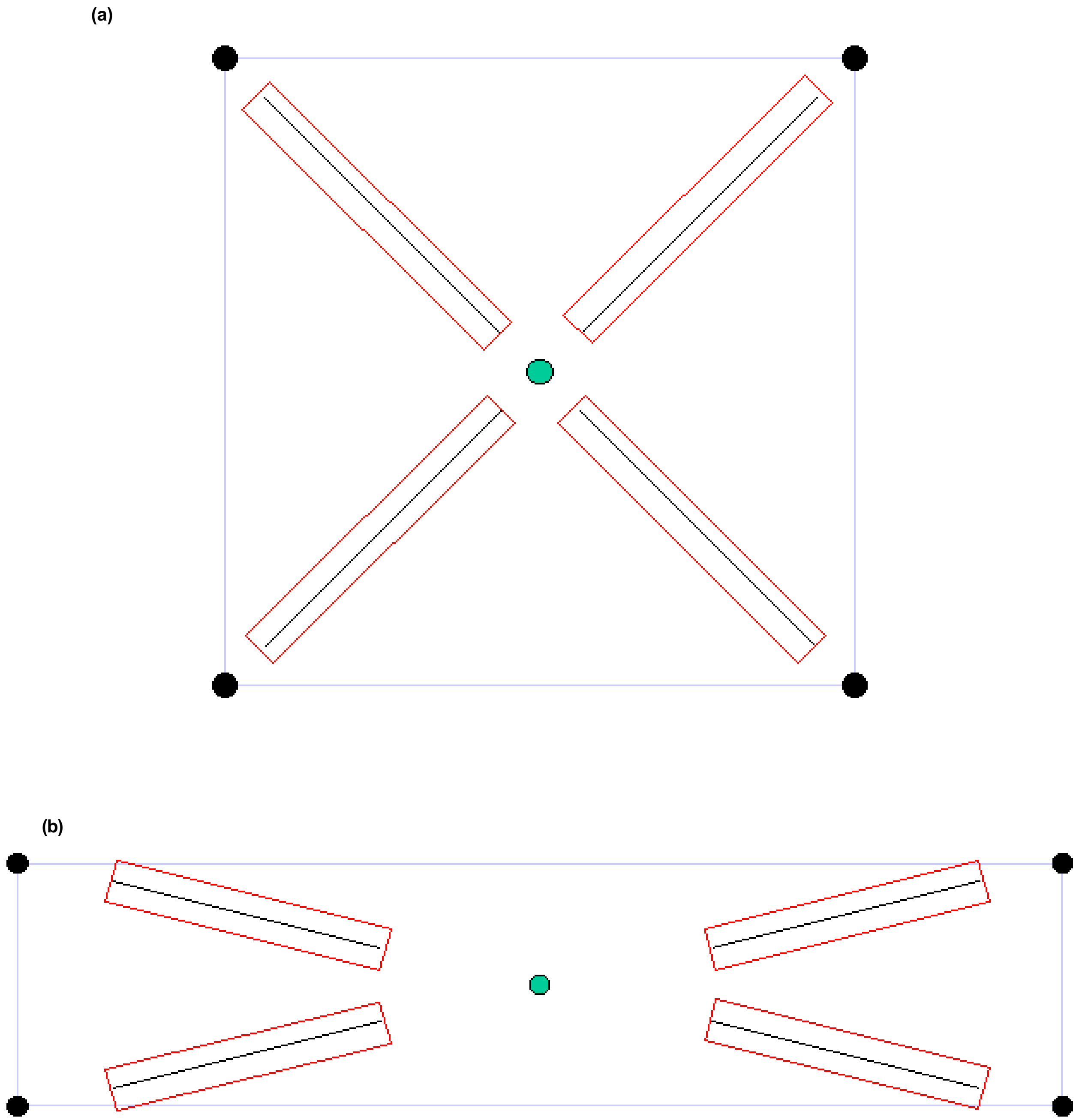


Figure 1. Schematic representation of (a) 20x20m and (b) 10x40m hemlock plots. The green circle at the center represents the center-stake. The four black lines represent the four 10m line-transects radiating from the center-stake toward each corner stake (black circles). The red rectangles represent the four 2 x10m belt-transects. The light-blue line represents the perimeter of the plot. Unless noted in Table 2, both the line-transects and belt-transects begin 1m from the center-stake in 20x20m plots and 5 m from the center-stake in 10x40m plots.

Vegetation Strata	Supercanopy Canopy Subcanopy High Midstory Low Midstory Shrub Layer <--------------------Uprooted Trees -----------------> Understory
Live Vegetative Components	Hemlock trees ---> Hardwood trees --> Pine trees ---> Vines ---> Evergreen shrubs---> Deciduous shrubs--> Clubmosses Bryophytes Ferns Broadleaf Herbs Grasses/Sedges
Dead Vegetative Components	Boles (trunks of trees)--> Stems (branches > 1 inch diameter)- -----------------> Sticks (branches $\le$1 inch diameter)--------------------> Leaf Litter
Structural Components	Bare Ground Bare Rock Live Tree Trunks

Figure 2. Cover components measured on line-transects and the vegetation strata where they would be expected to occur. For example, "Hemlock Trees" would be expected to occur in all vegetation strata, whereas "Leaf Litter" only would be expected to occur in the Understory stratum. The Uprooted Trees stratum would be expected to overlap with several of the lower strata.

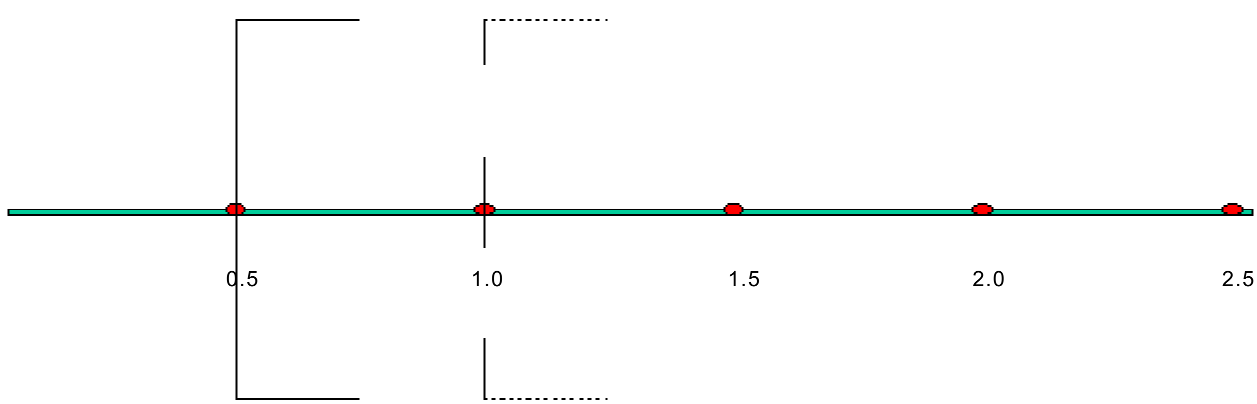
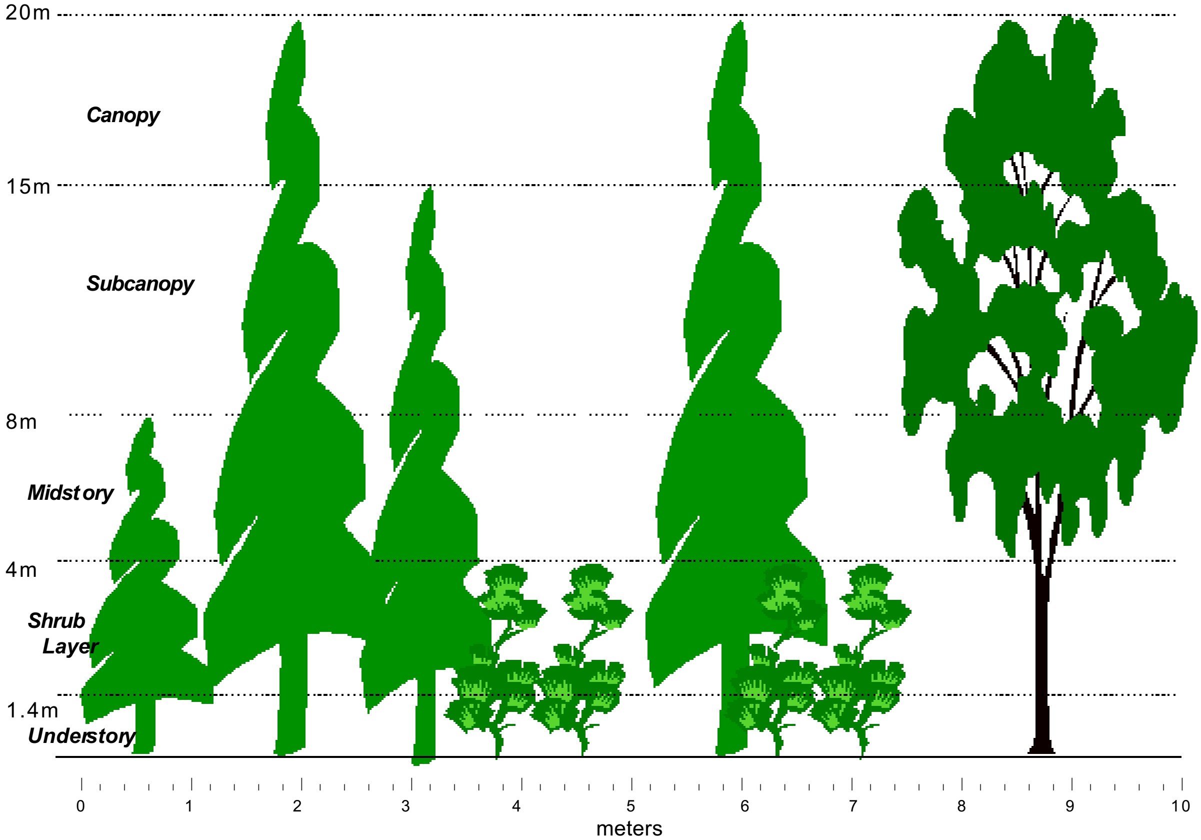
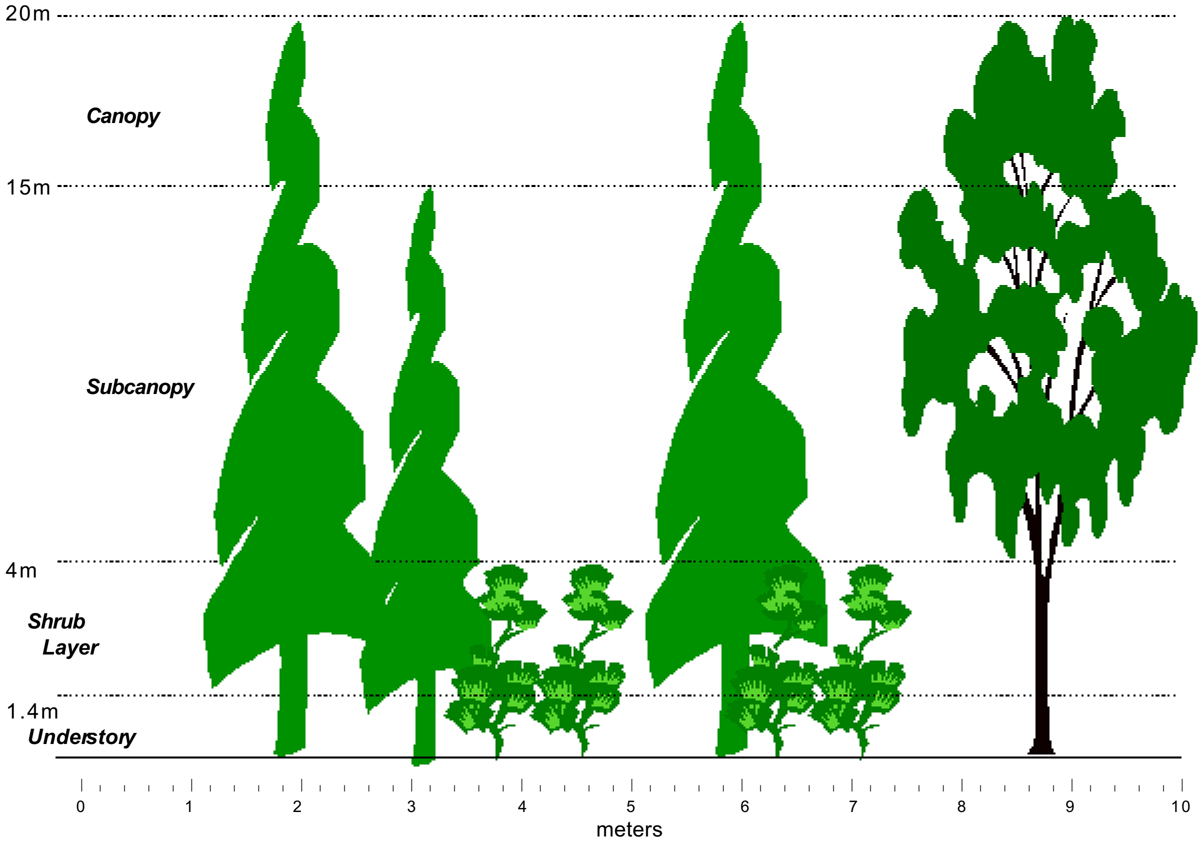


Figure 3. Example of proper placement of open-ended 0.25 m quadrat (solid black lines) at the first of 20 sampling points along a 10-m section of nylon tape. The quadrat is then moved to the 1.0-m mark (dashed black lines) on the nylon tape to measure the second sampling point , etc., up to the 10.0-m mark. By maintaining the orientation of the 0.25m quadrat as shown, each sampling points is spaced 0.25 m away from the previous point. The quadrat is open-ended, meaning that it only has three sides, so that it can be maneuvered around trees and shrubs. The center of the long side of the quadrat frame should be marked in order to properly position it over the sampling point on the nylon tape.



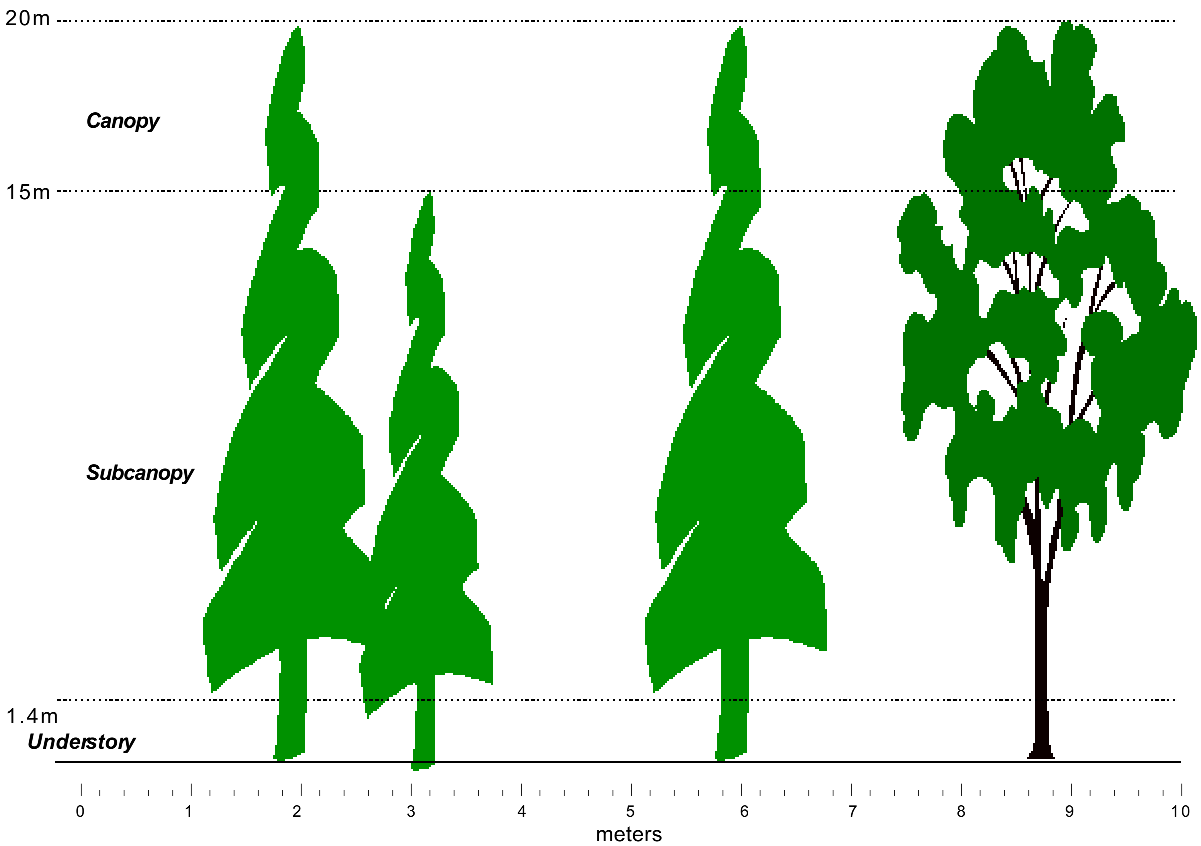
Assigned Stratum (code)	Component (code)	Total Cover	Vertical Stratification (code)	Min Height (m)	Max Height (m)	Points (dm)
Canopy (2)	Hemlock trees (1)	34	Canopy (2)	8.0	20.0	14-25, 54-65
			Midstory (5)	4.0	8.0	12-26, 52-66
			Shrub Layer (6)	1.5	4.0	11-27, 51-67
Canopy (2)	Hardwood trees (2)	27	Canopy (2)	8.0	20.0	74-100
			Midstory (5)	4.0	8.0	75-99
Subcanopy (3)	Hemlock trees (1)	13	Subcanopy (3)	8.0	15.0	28-32
			Midstory (5)	4.0	8.0	26-36
			Shrub Layer (6)	1.4	4.0	25-37
			Understory (8)	1.3	1.4	25-27
Midstory (5)	Hemlock trees (1)	12	Midstory (5)	4.0	8.0	03-09
			Shrub Layer (6)	1.4	4.0	01-12
			Understory (8)	0.8	1.4	01-12
Shrub Layer (6)	Evergreen Shrubs	37	Shrub Layer (6)	1.4	4.0	34-50, 59-76
			Understory (8)	0.8	1.4	33-49, 58-75

Figure 4. Hypothetical 10m line-transect and the data entered onto the field data sheet.



Assigned Stratum (code)	Component (code)	Total Cover	Vertical Stratification (code)	Min Height (m)	Max Height (m)	Points (dm)
Canopy (2)	Hemlock trees (1)	34	Canopy (2)	4.0	20.0	12-26, 52-66
			Shrub Layer (6)	1.5	4.0	11-27, 51-67
Canopy (2)	Hardwood trees (2)	27	Canopy (2)	4.0	20.0	74-100
Subcanopy (3)	Hemlock trees (1)	13	Subcanopy (3)	4.0	15.0	26-36
			Shrub Layer (6)	1.4	4.0	25-37
			Understory (8)	1.3	1.4	25-27
Shrub Layer (6)	Evergreen Shrubs	37	Shrub Layer (6)	1.4	4.0	34-50, 59-76
			Understory (8)	0.8	1.4	33-49, 58-75

Figure 5. Hypothetical 10m line-transect and the data entered onto the field data sheet when the midstory layer is absent.



Assigned Stratum (code)	Component (code)	Total Cover	Vertical Stratification (code)	Min Height (m)	Max Height (m)	Points (dm)
Canopy (2)	Hemlock trees (1)	34	Canopy (2)	1.5	20.0	11-27, 51-67
Canopy (2)	Hardwood trees (2)	27	Canopy (2)	4.0	20.0	74-100
Subcanopy (3)	Hemlock trees (1)	13	Subcanopy (3)	1.4	15.0	25-37
			Understory (8)	1.3	1.4	25-27

Figure 6. Hypothetical 10m line-transect and the data entered onto the field data sheet when midstory and shrub layers are absent.

Hemlock Ecosystem Monitoring Plots — Hemlock and Pine Trees— Field Data Sheet

Plot ________ **Date** November, ________ **Observer(s)** ____________________

Species	dbh ($\geq$8cm)	crown ratio (%)	crown vigor index	Straightness index	HWA index
Tsuga canadensis					
‖					
‖					
‖					
‖					
Tsuga canadensis					
Pinus strobus					

Vigor index

1 = > 95% healthy crown
2 = > 75-95%
3 = > 50-75%
4 = > 25-50%
5 = > 0-25%
6 = snag/dead

Straightness index

1= 0-45 degrees (straight)
2= > 45-90 degrees (leaning/bowed to horizontal)
3= > 90 degrees (severely bowed, or uprooted facing down slope)

HWA index

1 = heavily speckled and visible from 30m
2 = moderately speckled
3 = lightly speckled — only a few scattered specks
4 = none

Hemlock Ecosystem Monitoring Plots — Tree Density and dbh — Field Data Sheet

Plot ________ **Date** July, ____________ **Observer(s)** ______________________

Species	diameter at breast height ($\geq$8 cm)
Acer pensylvanicum	
Acer rubrum	
Acer saccharum	
Acer spicatum	
Betula alleghaniensis	
Betula lenta	
Carya glabra	
Carya ovata	
Carya tomentosa	
Cornus florida	
Fagus grandifolia	
Ilex opaca	
Liriodendron tulipifera	
Magnolia acuminata	
Magnolia fraseri	
Nyssa sylvatica	
Oxydendrum arboreum	
Prunus serotina	
Quercus alba	
Quercus coccinea	
Quercus prinus	
Quercus rubra	
Quercus velutina	
Rhododendron maximum	
Sassafras albidum	
Tilia americana	
Snags	

Hemlock Ecosystem Monitoring Plots — Sapling and Shrub Density — Field Data Sheet

Plot _____ **Transect** ___ **Date** July, _______ **Observer(s)** _______________________

Growth Form (code)	Species	Number of stems ($\geq$1.4 m tall) that originate $\leq$10 cm above ground level
	Acer pensylvanicum	
	Acer rubrum	
	Betula lenta	
	Carya glabra	
	Fagus grandifolia	
	Liriodendron tulipifera	
Trees < 8cm dbh (1)	Magnolia fraseri	
	Magnolia tripetala	
	Nyssa sylvatica	
	Oxydendrum arboreum	
	Prunus serotina	
	Sassafras albidum	
	Tsuga canadensis	
dead Trees < 8cm dbh (2)	Tsuga canadensis	
	All other trees	
	Clethra acuminata	
	Hamamelis virginiana	
	Ilex montana	
Shrubs (3)	Ilex opaca	
	Kalmia latifolia	
	Prunus pensylvanica	
	Rhododendron maximum	
	Rhus glabra	
dead Shrubs (4)	all species	
Vines (5)	Vitis aestivalis	

Hemlock Ecosystem Monitoring Plots — Frequency of Occurrence — Field Data Sheet

Plot _____ Transect ___ Date July,_______ **Observer(s)** ______________________

Quadrat	**Location (m)**	**Presence/Absence** [list the species that are present in each quadrat]
1	0.5	
2	1.0	
3	1.5	
4	2.0	
5	2.5	
6	3.0	
7	3.5	
8	4.0	
9	4.5	
10	5.0	
11	5.5	
12	6.0	
13	6.5	
14	7.0	
15	7.5	
16	8.0	
17	8.5	
18	9.0	
19	9.5	
20	10.0	

List any new species (and new four-letter codes):

Hemlock Ecosystem Monitoring Plots — Frequency of Occurrence — Field Data Sheet

Suggested Four-letter Species Codes

ACNE	Acer negundo
ACPE	Acer pensylvanicum
ACRU	Acer rubrum
ACRS	Acer rubrum/spicatum (combined in frequency quadrats)
ACSA	Acer saccharum
ACSP	Acer spicatum
ALSP	Aralia spinosa
AMBR	Amphicarpaea bracteata
ANLA	Anemone lancifolia
ARSP	Arisaema triphyllum
ASSP	Aster spp.
BEAL	Betula alleghaniensis
BELE	Betula lenta
BOCY	Boehmeria cylindrica
CAGL	Carya glabra
CAOV	Carya ovata
CATO	Carya tomentosa
CHMA	Chimaphila maculata
CIAR	Cinna arundinacea
CLAC	Clethra acuminata
CNFL	Cornus florida
COAM	Conopholis americana
CPSP	Cypripedium spp.
CXDI	Carex digitalis
CXLU	Carex intumescens
CXPL	Carex laxiflora
CYFR	Cymophyllus fraseri
DBQU	Dioscorea quaternata
DSSP	Disporum spp.
DTCO	Danthonia compressa
DYCA	Dryopteris carthusiana
DYMA	Dryopteris marginalis
EPRO	Eupatorium rugosum
EUAM	Euonymus americanus
FAGR	Fagus grandifolia
FRAM	Fraxinus americana
GAPR	Gaultheria procumbens
GLCI	Galium circaezans
GLTR	Galium triflorum
GOPU	Goodyera pubescens
HMVI	Hamamelis virginiana
HEVI	Hexastylis virginica
HYAR	Hydrangea arborescens
ILMO	Ilex montana
ILOP	Ilex opaca
KALA	Kalmia latifolia
LITU	Liriodendron tulipifera
LPAM	Lycopus americanus
LUMU	Luzula multiflora
LYDI	Lycopodium digitatum
MAAC	Magnolia acuminata
MAFR	Magnolia fraseri
MATR	Magnolia tripetala
MEVI	Medeola virginiana
MIRE	Mitchella repens
MOSS	Mosses
NYSY	Nyssa sylvatica
OHLI	Osmorhiza longistylis
OLAC	Oxalis acetosella
OSVI	Ostrya virginiana
OXAR	Oxydendrum arboreum
PABO	Panicum boscii
PADI	Panicum dichotomum
PBQU	Panax quinquefolius
PIST	Pinus strobus
PMAC	Polystichum acrostichoides
PNSP	Prenanthes sp.
PRPE	Prunus pensylvanica
PRSE	Prunus serotina
PTQU	Parthenocissus quinquefolia
QUAL	Quercus alba
QUCO	Quercus coccinea
QUPR	Quercus prinus
QURU	Quercus rubra
QUVE	Quercus velutina
RHMA	Rhododendron maximum
RHSP	Rhododendron sp.
RSGL	Rhus glabra
RUHI	Rubus hispidus
RUSP	Rubus spp.
SCEL	Scutellaria elliptica
SEAU	Senecio aureus
SMEC	Smilax ecirrata
SMGL	Smilax glauca
SMRO	Smilax rotundifolia
SRRA	Smilacina racemosa
SSAL	Sassafras albidum
THNO	Thelypteris noveboracensis
TIAM	Tilia americana
TORA	Toxicodendron radicans
TSCA	Tsuga canadensis
UVPE	Uvularia perfoliata
VAVA	Vaccinium pallidum
VBAC	Vibirnum acerifolium
VBCA	Viburnum nudum var. cassinoides
VIBL	Viola blanda
VICU	Viola cucullata
VIHA	Viola hastata
VTAV	Vitis aestivalis

Hemlock Ecosystem Monitoring Plots — 10m Line-Transect Cover — Field Data Sheets

Plot __________ **Transect** __________ **Date** July, ______________ **Observer(s)** ______________ **Page 1 of 7**

Assigned Stratum (code)	Component (code)	Total Cover	Vertical Stratification (code)	Min Height (m)	Max Height (m)	Points (dm)
Supercanopy (1)	Hemlock trees (1)		Supercanopy (1)			
			High Midstory (4)			
			Low Midstory (5)			
			Shrub Layer (6)			
			Understory (8)			
	Hardwood trees (2)		Supercanopy (1)			
			High Midstory (4)			
			Low Midstory (5)			
			Shrub Layer (6)			
			Understory (8)			
	Pine trees (3)		Supercanopy (1)			
			High Midstory (4)			
			Low Midstory (5)			
			Shrub Layer (6)			
			Understory (8)			

Hemlock Ecosystem Monitoring Plots — 10m Line-Transect Cover — Field Data Sheets

Plot __________ **Transect** __________ **Date** July, ______________ **Observer(s)** ____________

Assigned Stratum (code)	Component (code)	Total Cover	Vertical Stratification (code)	Min Height (m)	Max Height (m)	Points (dm)
Canopy (2)	Hemlock trees (1)		Canopy (2)			
			High Midstory (4)			
			Low Midstory (5)			
			Shrub Layer (6)			
			Understory (8)			
	Hardwood trees (2)		Canopy (2)			
			High Midstory (4)			
			Low Midstory (5)			
			Shrub Layer (6)			
			Understory (8)			
	Pine trees (3)		Canopy (2)			
			High Midstory (4)			
			Low Midstory (5)			
			Shrub Layer (6)			
			Understory (8)			
	Vines (4)		Canopy (2)			
			High Midstory (4)			
			Low Midstory (5)			
			Shrub Layer (6)			
			Understory (8)			
	Boles (13)		Canopy (2)			

Hemlock Ecosystem Monitoring Plots — 10m Line-Transect Cover — Field Data Sheets

Plot ________ **Transect** ________ **Date** July, ____________ **Observer(s)** ____________ **Page 3 of 7**

Assigned Stratum (code)	Component (code)	Total Cover	Vertical Stratification (code)	Min Height (m)	Max Height (m)	Points (dm)
Subcanopy (3)	Hemlock trees (1)		Subcanopy (3)			
			High Midstory (4)			
			Low Midstory (5)			
			Shrub Layer (6)			
			Understory (8)			
	Hardwood trees (2)		Subcanopy (3)			
			High Midstory (4)			
			Low Midstory (5)			
			Shrub Layer (6)			
			Understory (8)			
	Pine trees (3)		Subcanopy (3)			
			High Midstory (4)			
			Low Midstory (5)			
			Shrub Layer (6)			
			Understory (8)			
	Vines (4)		Subcanopy (3)			
			High Midstory (4)			
			Low Midstory (5)			
			Shrub Layer (6)			
			Understory (8)			
	Boles (13)		Subcanopy (3)			

Hemlock Ecosystem Monitoring Plots — 10m Line-Transect Cover — Field Data Sheets

Plot __________ **Transect** __________ **Date** July, ______________ **Observer(s)** ______________ **Page 4 of 7**

Assigned Stratum (code)	Component (code)	Total Cover	Vertical Stratification (code)	Min Height (m)	Max Height (m)	Points (dm)
High Midstory (4)	Hemlock trees (1)		High Midstory (4)			
			Low Midstory (5)			
			Shrub Layer (6)			
			Understory (8)			
	Hardwood trees (2)		High Midstory (4)			
			Low Midstory (5)			
			Shrub Layer (6)			
			Understory (8)			
	Pine trees (3)		High Midstory (4)			
			Low Midstory (5)			
			Shrub Layer (6)			
			Understory (8)			
	Vines (4)		High Midstory (4)			
			Low Midstory (5)			
			Shrub Layer (6)			
			Understory (8)			
	Boles (13)		High Midstory (4)			

Hemlock Ecosystem Monitoring Plots — 10m Line-Transect Cover — Field Data Sheets

Plot ________ **Transect** ________ **Date** July, ______________ **Observer(s)** ______________

Assigned Stratum (code)	Component (code)	Total Cover	Vertical Stratification (code)	Min Height (m)	Max Height (m)	Points (dm)
Low Midstory (5)	Hemlock trees (1)		Low Midstory (5)			
			Shrub Layer (6)			
			Understory (8)			
	Hardwood trees (2)		Low Midstory (5)			
			Shrub Layer (6)			
			Understory (8)			
	Pine trees (3)		Low Midstory (5)			
			Shrub Layer (6)			
			Understory (8)			
	Vines (4)		Low Midstory (5)			
			Shrub Layer (6)			
			Understory (8)			
	Evergreen Shrubs (5)		Low Midstory (5)			
			Shrub Layer (6)			
			Understory (8)			
	Deciduous Shrubs (6)		Low Midstory (5)			
			Shrub Layer (6)			
			Understory (8)			
	Boles (13)		Low Midstory (5)			
	Stems (14)		Low Midstory (5)			
	Sticks (15)		Low Midstory (5)			
Uprooted Trees (7)	Hemlock trees (1)		Low Midstory (5)			
			Shrub Layer (6)			
			Understory (8)			
Uprooted Trees (7)	Hardwood trees (2)		Low Midstory (5)			
			Shrub Layer (6)			
			Understory (8)			

Plot __________ **Transect** __________ **Date** July, ______________ **Observer(s)** ______________ **Page 6 of 7**

Assigned Stratum (code)	Component (code)	Total Cover	Vertical Stratification (code)	Min Height (m)	Max Height (m)	Points (dm)
Shrub Layer (6)	Hemlock trees (1)		Shrub Layer (6)			
			Understory (8)			
	Hardwood trees (2)		Shrub Layer (6)			
			Understory (8)			
	Pine trees (3)		Shrub Layer (6)			
			Understory (8)			
	Vines (4)		Shrub Layer (6)			
			Understory (8)			
	Evergreen Shrubs (5)		Shrub Layer (6)			
			Understory (8)			
	Deciduous Shrubs (6)		Shrub Layer (6)			
			Understory (8)			
	Boles (13)		Shrub Layer (6)			
	Stems (14)		Shrub Layer (6)			
	Sticks (15)		Shrub Layer (6)			
Uprooted Trees (7)	Hemlock trees (1)		Shrub Layer (6)			
			Understory (8)			
Uprooted Trees (7)	Hardwood trees (2)		Shrub Layer (6)			
			Understory (8)			

Hemlock Ecosystem Monitoring Plots — 10m Line-Transect Cover — Field Data Sheets

Plot __________ **Transect** __________ **Date** July, ______________ **Observer(s)** ______________ **Page 7 of 7**

Assigned Stratum (code)	Component (code)	Total Cover	Vertical Stratification (code)	Min Height (m)	Max Height (m)	Points (dm)
Understory (8)	Hemlock trees (1)		Understory (8)			
	Hardwood trees (2)		Understory (8)			
	Pine trees (3)		Understory (8)			
	Vines (4)		Understory (8)			
	Evergreen Shrubs (5)		Understory (8)			
	Deciduous Shrubs (6)		Understory (8)			
	Boles (13)		Understory (8)			
	Stems (14)		Understory (8)			
	Sticks (15)		Understory (8)			
	Clubmosses (7)		Understory (8)			
	Bryophytes (8)		Understory (8)			
	Ferns (9)		Understory (8)			
	Broadleaf Herbs (10)		Understory (8)			
	Grasses/Sedges (11)		Understory (8)			
	Leaf Litter (12)		Understory (8)			
	Bare Ground (16)		Understory (8)			
	Bare Rock (17)		Understory (8)			
	Live Tree Trunks (18)		Understory (8)			
Uprooted Trees (7)	Hemlock trees (1)		Understory (8)			
	Hardwood trees (2)		Understory (8)			

Hemlock Ecosystem Monitoring Plots — 10m Line-Transect Cover — Field Data Sheets

Plot __________ **Transect** __________ **Date** July, ____________ **Observer(s)** ______________ **Page** of

Assigned Stratum (code)	Component (code)	Total Cover	Vertical Stratification (code)	Min Height (m)	Max Height (m)	Points (dm)

Hemlock Ecosystem Monitoring Plots — Photograph Log— Field Data Sheet
Month/Year ___________

Plot	Azimuth to Corner	Roll/Disk # and Exposure #s	Transect #1 Aximuth	Roll/Disk # and Exposure #	Transect #3 Aximuth	Roll/Disk # and Exposure #
CH1	75		347		168	
CH2	200		33		208	
CH3	0		14		196	
CM1	140		55		237	
CM2	170		346		167	
CM3	260		340		160	
CX1	200		20		195	
CX2	270		2		180	
CX3	150		64		248	
FH1	200		20		206	
FH2	210		100		276	
FH3	200		22		200	
FX1	145		324		144	
FX2	40		45		225	
FX3	180		2		182	
GM1 [a]	175		110		260	
GM2	45		48		224	
GM3	50		46		222	
KM1	130		222		46	
KM2	180		274		90	
KM3	130		304		128	
MH1	10		22		199	
MH2	330		73		259	
MH3	290		4		185	
MM1	2		360		180	
MM2	230		22		204	
MM3	140		312		122	
MX1	90		342		154	
MX2	145		336		148	
MX3	45		320		140	
WH1	45		44		216	
WH2 [b]	225		3		175	
WH3	300		16		204	
WX1	200		20		196	
WX2	305		49		225	
WX3	300		33		208	

[a] Transect #1 does not point to the corner-stake. It was moved to avoid the creek bed.
[b] The "azimuth to corner" points to half-way between the uphill corner-stakes, not to a corner-stake.

Appendix B. SAS computer program for reading raw data and calculating total cover from the 10m Line-Transect Cover field data sheet.

```
/************************************************
 *  Raw data (see Figure 4 and page 35):         *
 *                                               *
 *  Assigned Stratum (Astratum) and              *
 *  Vertical Stratification (Vstratum)           *
 *  numerical codes:                             *
 *         1 = supercanopy                       *
 *         2 = canopy                            *
 *         3 = subcanopy                         *
 *         4 = high midstory                     *
 *         5 = low midstory                      *
 *         6 = shrub layer                       *
 *         8 = understory                        *
 *                                               *
 *  Note: Omit commas between point values:      *
 *        (do type "14-25 54-65")                *
 *        (do not type "14-25,54-65")            *
 *                                               *
 *  Input statement allows for 30 point-readings *
 *        (cov1, cov2, ... cov30).               *
 *        Enter a range of points with a dash    *
 *        between high and low values.           *
 *        Enter single points separated by a     *
 *        blank space.                           *
 *                                               *
 ************************************************/

options ls=180 nocenter nodate pageno=1;

proc format;
  value str

   1 = 'Supercanopy'
   2 = 'Canopy'
   3 = 'Subcanopy'
   4 = 'High Midstory'
   5 = 'Low Midstory'
   6 = 'Shrub Layer'
   8 = 'Understory';

data cover;
     length component $15 cov1 $7 cov2 $7 cov3 $7 cov4 $7 cov5 $7
            cov6 $7 cov7 $7 cov8 $7 cov9 $7 cov10 $7 cov11 $7 cov12 $7
            cov13 $7 cov14 $7 cov15 $7 cov16 $7 cov17 $7 cov18 $7 cov19 $7
            cov20 $7 cov21 $7 cov22 $7 cov23 $7 cov24 $7 cov25 $7 cov26 $7
            cov27 $7 cov28 $7 cov29 $7 cov30 $7;
     infile 'c:\AppendB.dat' missover pad;
     input plot $ tran year Astratum component $ Vstratum
           lowht hiht cov1-cov30 $;
     if tran=. then delete;
     if hiht=. then delete;   run;
```

Appendix B. Continued.

```
 data cov2;   set cover;

     ARRAY COVR(30) $ cov1-cov30;
     ARRAY ennd(30)  e1-e30;
     ARRAY beg(30)   b1-b30;
     ARRAY len(30)   x1-x30;
     DO J=1 TO 30 WHILE (COVR(J) NE ' ');
        if index(COVR(J),'-') then do;
           dash1 = substr(COVR(J),3,1);
           dash2 = substr(COVR(J),4,1);
                if dash1='-' then do;
                   ennd(J)=substr(COVR(J),4,3)*1;
                   beg(J)=substr(COVR(J),1,2)*1;
                   len(J)=ennd(J)-beg(J)+1;
                end;
                else if dash2='-' then do;
                   ennd(J)=substr(COVR(J),5,3)*1;
                   beg(J)=substr(COVR(J),1,3)*1;
                   len(J)=ennd(J)-beg(J)+1;
                end;
           else len(J)=0;
        end;
        else if not index(COVR(J),'-') then len(j)=1;
     END;
        VERTcov = sum(of x1-x30);

data cov3;   set cov2;

     ARRAY pnt(100) p1-p100;
     DO Y=1 to 100;

     %macro REP (rr);
       if b&rr=. and cov&rr ne ' ' then do;
          W=cov&rr*1;
          if Y=W then pnt(Y)=1;
        end;
       if b&rr ne . then do;
           start=b&rr;  stop=e&rr;
           if start=0 then start=1;
           DO Z = start to stop;
              pnt(Z)=1;
           end;
        end;
     %mend REP;
     %rep (1);    %rep (2);    %rep (3);    %rep (4);    %rep (5);
     %rep (6);    %rep (7);    %rep (8);    %rep (9);    %rep (10);
     %rep (11);   %rep (12);   %rep (13);   %rep (14);   %rep (15);
     %rep (16);   %rep (17);   %rep (18);   %rep (19);   %rep (20);
     %rep (21);   %rep (22);   %rep (23);   %rep (24);   %rep (25);
     %rep (26);   %rep (27);   %rep (28);   %rep (29);   %rep (30);

     END;
```

Appendix B. Continued.

```
   * Vcov_chk=sum(of p1-p100);

proc print  uniform  data=cov3  heading=horizontal;
     var plot tran year Astratum component Vstratum
         lowht hiht VERTcov cov1-cov30;
     format Astratum str. Vstratum str.;
     title 'Raw Cover Data Matrix';
     run;

proc sort  data=cov3;   by plot tran Astratum component;

proc summary  data=cov3  nway;
     classes plot tran Astratum component;
     var p1-p100;
     output  out=layersum  sum=;

data layersum(keep=plot tran Astratum component TOTALcov c1-c100);
     set layersum;   by plot tran Astratum component;

     ARRAY pnt(100) p1-p100;
     ARRAY cnt(100) c1-c100;
     DO Y=1 to 100;
        if pnt(Y) >=1 then cnt(Y)=1;
       end;

     TOTALcov=sum(of c1-c100);

 data cov3(keep=plot tran year Vstratum Astratum
               lowht hiht component VERTpct VERTcov TOTALcov p1-p100);
      merge cov3 layersum;   by plot tran Astratum component;
      VERTpct = VERTcov/TOTALcov*100;

data cov3;   set cov3;   by plot tran Astratum component;
      if not first.component then TOTALcov=.;

proc print  data=cov3  uniform  heading=horizontal;
     var plot tran year Astratum VERTpct component Vstratum
         lowht hiht VERTcov TOTALcov p1-p100;
     format Astratum str. Vstratum str. VERTpct 5.1;
     title 'Cover Data -- Vstratum totals and percents, Astratum totals';
     run;
```

Appendix B. Continued.

```
/****************************************************
          APPENDB.DAT (data read by infile statement on page 32)
 ****************************************************



EX1 4 2001 1 Hemlock    1  8.0 20.0 14-25 54-65
EX1 4 2001 1 Hemlock    5  4.0  8.0 12-26 52-66
EX1 4 2001 1 Hemlock    6  1.5  4.0 11-27 51-67

EX1 4 2001 1 Hardwoods  1  8.0 20.0 74-100
EX1 4 2001 1 Hardwoods  5  4.0  8.0 75-99

EX1 4 2001 2 Hemlock    2  8.0 15.0 28-32
EX1 4 2001 2 Hemlock    5  4.0  8.0 26-36
EX1 4 2001 2 Hemlock    6  1.4  4.0 25-37
EX1 4 2001 2 Hemlock    8  1.3  1.4 25-27

EX1 4 2001 5 Hemlock    5  4.0  8.0 03-09
EX1 4 2001 5 Hemlock    6  1.4  4.0 01-12
EX1 4 2001 5 Hemlock    8  0.8  1.4 01-12

EX1 4 2001 6 EvergreenShrubs 6  1.4  4.0 34-50 59-76
EX1 4 2001 6 EvergreenShrubs 8  0.8  1.4 33-49 58-75


 ****************************************************/
```

Appendix B. Continued. Raw Cover Data Matrix

Obs	plot	tran	year	Astratum	component	Vstratum	lowht	hiht	VERTcov	cov1	cov2	cov3	cov4	cov5	cov6	cov7	cov8	cov9	cov10
1	EX1	4	2001	Supercanopy	Hemlock	Supercanopy	8.0	20.0	24	14-25	54-65								
2	EX1	4	2001	Supercanopy	Hemlock	Low Midstory	4.0	8.0	30	12-26	52-66								
3	EX1	4	2001	Supercanopy	Hemlock	Shrub Layer	1.5	4.0	34	11-27	51-67								
4	EX1	4	2001	Supercanopy	Hardwoods	Supercanopy	8.0	20.0	27	74-100									
5	EX1	4	2001	Supercanopy	Hardwoods	Low Midstory	4.0	8.0	25	75-99									
6	EX1	4	2001	Canopy	Hemlock	Canopy	8.0	15.0	5	28-32									
7	EX1	4	2001	Canopy	Hemlock	Low Midstory	4.0	8.0	11	26-36									
8	EX1	4	2001	Canopy	Hemlock	Shrub Layer	1.4	4.0	13	25-37									
9	EX1	4	2001	Canopy	Hemlock	Understory	1.3	1.4	3	25-27									
10	EX1	4	2001	Low Midstory	Hemlock	Low Midstory	4.0	8.0	7	03-09									
11	EX1	4	2001	Low Midstory	Hemlock	Shrub Layer	1.4	4.0	12	01-12									
12	EX1	4	2001	Low Midstory	Hemlock	Understory	0.8	1.4	12	01-12									
13	EX1	4	2001	Shrub Layer	EvergreenShrubs	Shrub Layer	1.4	4.0	35	34-50	59-76								
14	EX1	4	2001	Shrub Layer	EvergreenShrubs	Understory	0.8	1.4	35	33-49	58-75								

Obs	cov11	cov12	cov13	cov14	cov15	cov16	cov17	cov18	cov19	cov20	cov21	cov22	cov23	cov24	cov25	cov26	cov27	cov28	cov29	cov30
1																				
2																				
3																				
4																				
5																				
6																				
7																				
8																				
9																				
10																				
11																				
12																				
13																				
14																				

Appendix B. Continued. Cover Data -- Vstratum totals and percents, Astratum totals

Obs	plot	tran	year	Astratum	VERTpct	component	Vstratum	lowht	hiht	VERTcov	TOTALcov	p1	p2	p3	p4	p5	p6	p7	p8	p9	p10	p11	p12	p13	p14	p15	p16	p17	p18	p19	p20
1	EX1	4	2001	Supercanopy	100.0	Hardwoods	Supercanopy	8.0	20.0	27	27	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
2	EX1	4	2001	Supercanopy	92.6	Hardwoods	Low Midstory	4.0	8.0	25	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
3	EX1	4	2001	Supercanopy	70.6	Hemlock	Supercanopy	8.0	20.0	24	34	.	.	.	.	.	.	.	.	.	.	.	.	.	1	1	1	1	1	1	1
4	EX1	4	2001	Supercanopy	88.2	Hemlock	Low Midstory	4.0	8.0	30	.	.	.	.	.	.	.	.	.	.	.	.	1	1	1	1	1	1	1	1	1
5	EX1	4	2001	Supercanopy	100.0	Hemlock	Shrub Layer	1.5	4.0	34	.	.	.	.	.	.	.	.	.	.	.	1	1	1	1	1	1	1	1	1	1
6	EX1	4	2001	Canopy	38.5	Hemlock	Canopy	8.0	15.0	5	13	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
7	EX1	4	2001	Canopy	84.6	Hemlock	Low Midstory	4.0	8.0	11	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
8	EX1	4	2001	Canopy	100.0	Hemlock	Shrub Layer	1.4	4.0	13	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
9	EX1	4	2001	Canopy	23.1	Hemlock	Understory	1.3	1.4	3	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
10	EX1	4	2001	Low Midstory	58.3	Hemlock	Low Midstory	4.0	8.0	7	12	.	.	1	1	1	1	1	1	1	.	.	.	.	.	.	.	.	.	.	.
11	EX1	4	2001	Low Midstory	100.0	Hemlock	Shrub Layer	1.4	4.0	12	.	1	1	1	1	1	1	1	1	1	1	1	1	.	.	.	.	.	.	.	.
12	EX1	4	2001	Low Midstory	100.0	Hemlock	Understory	0.8	1.4	12	.	1	1	1	1	1	1	1	1	1	1	1	1	.	.	.	.	.	.	.	.
13	EX1	4	2001	Shrub Layer	94.6	EvergreenShrubs	Shrub Layer	1.4	4.0	35	37	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
14	EX1	4	2001	Shrub Layer	94.6	EvergreenShrubs	Understory	0.8	1.4	35	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.

Obs	p21	p22	p23	p24	p25	p26	p27	p28	p29	p30	p31	p32	p33	p34	p35	p36	p37	p38	p39	p40	p41	p42	p43	p44	p45	p46	p47	p48	p49	p50	p51	p52	p53	p54	p55	p56	p57	p58	p59	p60	p61
1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
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3	1	1	1	1	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	1	1	1	1	1	1	1
4	1	1	1	1	1	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	1	1	1	1	1	1	1	1	1
5	1	1	1	1	1	1	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	1	1	1	1	1	1	1	1	1	1
6	.	.	.	.	.	.	.	1	1	1	1	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
7	.	.	.	.	.	1	1	1	1	1	1	1	1	1	1	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
8	.	.	.	.	1	1	1	1	1	1	1	1	1	1	1	1	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
9	.	.	.	.	1	1	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
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14	.	.	.	.	.	.	.	.	.	.	.	.	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	.	.	.	.	.	.	.	.	1	1	1	1

Obs	p62	p63	p64	p65	p66	p67	p68	p69	p70	p71	p72	p73	p74	p75	p76	p77	p78	p79	p80	p81	p82	p83	p84	p85	p86	p87	p88	p89	p90	p91	p92	p93	p94	p95	p96	p97	p98	p99	p100
1	.	.	.	.	.	.	.	.	.	.	.	.	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
2	.	.	.	.	.	.	.	.	.	.	.	.	.	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	.
3	1	1	1	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
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5	1	1	1	1	1	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
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13	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
14	1	1	1	1	1	1	1	1	1	1	1	1	1	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.