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Long Term Monitoring of a Rare Riparian Community in the Delaware Water Gap National Recreation Area

Eastern Rivers and Mountains Network

Natural Resource Technical Report NPS/ERMN/NRTR—2011/495

ON THE COVER

Calcareous Riverside Outcrop at the Dingmans Ferry site in the Delaware Water Gap National Recreation Area.
Photograph by: Kristina Callahan.

Addendum (February 2012) to Long term monitoring of a rare riparian community in the Delaware Water Gap National Recreation Area: Eastern Rivers and Mountains Network (Natural Resource Technical Report NPS/ERMN/NRTR—2011/495).

In Table 8, the following changes were made:

- The "Percent of Total Cover occupied by Nonnative Species" under the "Point-Intercept Sampling" heading was corrected from 43.20% to 29.02%.
- The "Percent of Total Cover occupied by Native Species" under the "Point-Intercept Sampling" heading was corrected from 79.00% to 51.39%.
- Percent Cover of *Lythrum salicaria*, *Phalaris arundinacea*, *Elaeagnus umbellata*, and *Solidago gigantea* were added to the table.

In Figure 10, the following changes were made:

- The number of transects needed to detect 20% change in "Percent of Total Cover occupied by Native Species" was corrected from 99 to 30.
- The number of transects needed to detect 20% change in "Percent of Total Cover occupied by Nonnative Species" was corrected from 89 to 65.

Text in the "Comparison of Sampling Methods" and "Discussion" sections was modified to reflect and interpret the corrected data presented in Table 8 and Figure 10.

Long Term Monitoring of a Rare Riparian Community in the Delaware Water Gap National Recreation Area

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Natural Resource Technical Report NPS/ERMN/NRTR—2011/495

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Executive Summary

The Eastern Rivers and Mountains Network (ERMN) contains diverse, unique, and globally significant plant communities associated with the floodplains and other geomorphic and hydrologic features of large rivers. Due to the significance of these resources, long-term monitoring of these rare riparian communities was identified among the highest priority vital signs during the ERMN prioritization process. A study was conducted in 2010 at the Dingmans Ferry Calcareous Riverside Outcrop and Calcareous Riverside Seep site in the Delaware Water Gap National Recreation Area (DEWA) in order to: 1) Measure changes in the distribution, abundance, and composition of plant species within the Dingmans Ferry Site since 1998; and 2) Compare the effectiveness and efficiency of a plot-based sampling methodology utilized in 1998 to a point intercept sampling methodology.

This study documented changes in the distribution, abundance, and composition of plant species within the co-occurring Calcareous Riverside Outcrop and Calcareous Riverside Seep at the Dingmans Ferry site since 1998. Important findings include:

The appearance of three new invasive exotic plant species and the spread of eight other previously observed invasive exotic species were documented. Only two invasive exotic plant species showed any substantial declines between the two sampling periods. The data also suggest that native shrubs are being replaced by aggressive invasive exotic shrubs. This underscores the importance of monitoring and managing invasive exotic species at high priority natural resource sites. Without intervention, species such as autumn olive (*Elaeagnus umbellata*), Morrow's honeysuckle (*Lonicera morrowii*), mile-a-minute (*Polygonum perfoliatum*), narrowleaf bittercress (*Cardamine impatiens*), common wormwood (*Artemisia vulgaris*), and true forget-me-not (*Myosotis scorpioides*) will likely continue to spread in the Dingmans Ferry site.

Although the percent cover of purple loosestrife (*Lythrum salicaria*) did not measurably change between 1998 and 2010, the number of *L. salicaria* stems decreased significantly. It is unclear whether the 75% reduction in the number of *L. salicaria* stems observed between the two sampling periods can be attributed to the release of biocontrol beetles between 1996 and 2007. Defoliation of *L. salicaria* was observed at low levels throughout the site, confirming that the leaf-eating *Galerucella* beetles are feeding at the Dingmans site. It is likely that the biocontrol beetles and *L. salicaria* are exhibiting the classic cyclical pattern of abundance observed in many predator-prey relationships. The frequent scour from the Delaware River likely further affects the abundance of *L. salicaria* and the biocontrol beetles at the Dingmans Ferry site.

Changes in abundance for many individual species were documented. These changes highlight three processes occurring in the Calcareous Riverside Outcrop and Calcareous Riverside Seep communities: a) species migration within the site, b) inter-annual variation in composition due to varying hydrologic conditions, and c) species migration among riverine sites within the park. The migration of species among sites underscores the importance of maintaining all three Calcareous Riverside Outcrop and Calcareous Riverside Seep sites in DEWA.

The cover of woody species increased significantly between 1998 and 2010, although the frequency of woody species showed no significant differences. It is likely that native shrubs

such as narrowleaf willow (*Salix exigua*) and common ninebark (*Physocarpus opulifolius*) are being replaced by aggressive invasive exotic shrubs such as autumn olive, Morrow's honeysuckle, and multiflora rose (*Rosa multiflora*).

This study also compared the original plot-based sampling methodology to a point-intercept sampling methodology. Though both methods yielded similar results, the plot method was clearly better at capturing more species and was more efficient per sampling unit. Given these findings and recommendations from other similar studies, the original plot method should be retained for future monitoring at the Dingmans Ferry site and the two other Calcareous Riverside Outcrop and Calcareous Riverside Seep sites in DEWA so that direct comparisons can be made with the 1998 data. Although the point-intercept method could be appropriate for other rare riparian communities in the ERMN that do not exhibit strong environmental or species gradients from woodland to river, the plot method will likely be more cost-effective given that each sampling unit requires less time, and that more species are captured by the plot method.

Introduction

The Eastern Rivers and Mountains Network (ERMN), with more than 211 miles of river, contains diverse, unique, and globally significant plant communities associated with the floodplains and other geomorphic and hydrologic features of large rivers (Podniesinski et al 2010). Due to the significance of these resources, the long-term monitoring of these rare riparian communities was identified among the highest priority vital signs during the ERMN prioritization process (Marshall and Piekielek 2007). This monitoring effort is a component of the ERMN Vital Signs monitoring program (Marshall and Piekielek 2007) as part of the nationwide NPS Inventory and Monitoring Program (Fancy et al. 2009). Within the ERMN, the parks that contain rare riparian plant communities include Delaware Water Gap National Recreation Area (DEWA), Upper Delaware National Scenic and Recreational River (UPDE), New River Gorge National River (NERI), Gauley River National Recreation Area (GARI), and Bluestone National Scenic River (BLUE).

The riparian zones of the Delaware, New, Gauley, and Bluestone rivers are very diverse, both floristically (taxa richness) and in terms of number of vegetation associations (plant communities). Eighteen different riparian vegetation associations were described on the Delaware River within UPDE and DEWA (Perles et al. 2007a, Perles et al. 2008). Twenty-three riparian vegetation associations were described within NERI, GARI, and BLUE (Vanderhorst et al. 2007, Vanderhorst et al. 2008, Vanderhorst et al 2010). Some of these associations are very common, found in numerous river systems in the eastern United States. However, 14 of the 39 riparian associations are globally rare; they occur in very few places in the world and are at moderate to high risk of elimination due to extreme rarity, very steep declines, or other factors (Sneddon 2010). These rare associations also provide unique habitats on which numerous rare plant species depend. Nearly 50 state-rare plant species and one species listed as federally threatened occur in the riparian zones of the Delaware, New, Gauley, and Bluestone rivers (Shank and Shreiner 1999, Perles et al. 2007a, Perles et al. 2008, Vanderhorst et al. 2007, Vanderhorst et al. 2008, Vanderhorst et al 2010).

Calcareous Riverside Outcrop and Calcareous Riverside Seep

Two of these rare riparian communities on the Delaware River are the Calcareous Riverside Outcrop and the Calcareous Riverside Seep, which co-occur at three sites within DEWA. These vegetation associations occur along the shoreline of the Delaware River where winter ice-scouring, limestone bedrock, and natural seepage co-occur (Perles et al. 2007b). The Calcareous Riverside Outcrop is ranked as Globally Imperiled (G2), which means it is at high risk of extinction or elimination due to very restricted range, very few occurrences, steep declines, or other factors. The Calcareous Riverside Seep is ranked as Globally Critically Imperiled (G1), which means the community is at very high risk of extinction or elimination due to extreme rarity, very steep declines, or other factors (Sneddon 2010).

The Calcareous Riverside Outcrop is characterized by open, sparsely to densely vegetated sections of smooth Buttermilk Falls limestone outcrops of glacial origin and Devonian age. The outcrops extend for variable lengths from the woodland edge to the river edge. Areas of fractured limestone typically support denser vegetation in the crevices. All of the outcrops are gently to steeply sloped, with a north-northwest exposure and are fully exposed to the late day sun. The Calcareous Riverside Seep occurs interspersed with Calcareous Riverside Outcrop on sections of

the outcrop where the weathered bedrock has been broken into distinct rocks of various sizes. The seeps are restricted to areas where groundwater flows out and over the cobble substrate, supporting many calciphiles, rare species, and plants that are dependent on the groundwater seepage. By contrast, the Calcareous Riverside Outcrop does not contain groundwater seepage and its plants are generally xerophilic (Perles et al. 2007b). Not only are these vegetation associations unique due to their unique environmental setting and combination of plant species, but these communities also support 26 state-rare plant species (Shank and Shreiner 1999).

Winter ice-scour that removes tall vegetation and woody plants maintains the predominantly herbaceous vegetation at these sites. The floristic assemblages include species able to regenerate from buried rootstocks or from seeds dispersed along the shoreline. Seasonal and annual variation in water levels is another important process affecting the vegetation. These communities are prone to frequent flooding, however, they are also prone to severe drought periods that may stress or kill some vegetation. Within these sites, plant species are distributed patchily, probably due to microsite conditions. Species composition also shows substantial variation from site to site and from year to year (Perles et al. 2007b, Podniesinski et al. 2010).

Due to the globally rare nature of these plant communities and the large number of state-rare plants that they contain, an intensive study was conducted of the three sites in DEWA containing the Calcareous Riverside Outcrop and Calcareous Riverside Seep in 1997 and 1998. The primary objective of the study was to provide baseline data on the status of the 26 plant species of special concern and the two globally rare communities, specifically with respect to species composition, distribution and abundance. During the 1997 field season, populations of each state-rare plant species were completely censused, when possible, at each of the three sites. During the 1998 field season, a comprehensive community sampling was conducted at the Dingmans Ferry Site in order to establish a preliminary baseline against which later community sampling could be statistically compared. The 1998 study established long-term monitoring protocols and permanent sampling transects for future assessment of the distribution, abundance, and composition of plant species within these communities (Shank and Shreiner 1999). The study was conducted before the introduction of measures to control the spread of purple loosestrife (*Lythrum salicaria*), an invasive exotic plant.

As part of an integrated pest management approach to controlling *Lythrum salicaria* in DEWA, three groups of purple loosestrife-eating beetles were released in the park between 1996 and 2007. Releases totaling 119,750 leaf-eating *Galerucella* beetles (*G. calmariensis* and *G. pusilla*), 3,035 root-boring *Hylobius transversovittatus* beetles, and 4,338 flower-feeding *Nanophyes marmoratus* beetles were made. Overall, there were 23 release sites within the park. Four release sites in 1999 were located along the Delaware River shoreline, including the Dingmans river access that is directly across the river from the Dingmans Ferry Calcareous Riverside Outcrop and Calcareous Riverside Seep (Shreiner 2008).

By 2008, the *Galerucella* beetles were established throughout the park and had reduced *L. salicaria* abundance to acceptable levels at 9 of 14 biocontrol monitoring sites. Results of plot-based studies at the Birchenough wetland site demonstrated the cyclical relationship between *L. salicaria* abundance and *Galerucella* feeding damage, typical of predator-prey abundance cycles. Diverse arrays of primarily native species had replaced *L. salicaria* at all locations where the biocontrol beetles were effective (Shreiner 2008). The Dingmans Ferry

Calcareous Riverside Outcrop and Calcareous Riverside Seep was not one of the 14 biocontrol monitoring sites; thus, no quantitative data exists to assess the effect of the biocontrol beetles on *L. salicaria* abundance or community composition shifts in this rare community. The community composition data collected in 1998, the year before beetles were released on the Delaware River shoreline, provide an excellent opportunity to monitor the effects of the biocontrol efforts.

ERMN Pilot Study

In the larger context of the ERMN rare riparian monitoring program, the 1998 community sampling data from the Dingmans Ferry site provided a unique opportunity to conduct a pilot study that would inform the direction of the ERMN rare riparian monitoring program. The objectives of this pilot study fell into two broad categories.

1. Measure changes in the distribution, abundance, and composition of plant species within the Dingmans Ferry site since 1998, specifically:

    a. Measure the change in percent cover and frequency of occurrence of *Lythrum salicaria* between sampling periods. [The management objective of the beetle release in DEWA was to suppress purple loosestrife abundance to less than 25% foliage cover at infested sites (Shreiner 2008).]

    b. Document changes in community composition between sampling periods, including species richness and the abundance of nonnative versus native species.

2. Compare the original plot-based sampling methodology to a point-intercept sampling methodology, specifically each method's effectiveness and efficiency to detect changes in the distribution, abundance, and composition of plant species. The results of this comparison will guide the direction of future rare riparian monitoring efforts in the ERMN.

Methods

Dingmans Ferry Site

The Dingmans Ferry site encompasses 2.6 km (1.6 mi) of shoreline south of the Dingmans Ferry Bridge (Route 560) in Sandyston Township on the New Jersey side of the Delaware River (Figure 1). The site is easily accessed by a trail leading from the small parking area south of Route 560, immediately east of the Bridge. The northern quarter mile of the site is heavily used by fishermen; however, the remainder of the site is relatively free of all but occasional anthropogenic disturbance.

The shoreline at the Dingmans Ferry site is approximately 15 – 20 meters wide and is highly variable throughout its length, with a range of substrates including: 'solid' limestone outcrop, 'latticed' outcrop, 'cobbled' sections of shoreline, and alluvial shoreline (Shank and Shreiner 1999). Forty-two percent of the site's length is solid outcrop and thirty percent of the site's length is latticed outcrop with extensive crevices and fissures in the rock. The solid outcrops are interrupted by areas of cobbled riverstones and glacial deposits mixed with alluvial deposits. The smallest portion of the site is an area of alluvial deposits at the north end. Seeps occur scattered throughout the site primarily on solid and latticed outcrops, but also occur in some of the cobbled sections of river shoreline. Some sections of this site are densely vegetated while others are very sparsely vegetated. In 1998, there was a dense band of vegetation, which contained primarily *Lythrum salicaria*, immediately adjacent to the river along most of the site's length (Shank and Shreiner 1999).

Plot Sampling

The plot sampling consists of 50 transects stratified along the length of the site. Each transect contains three 1 m^2 plots, one each in the upper, middle, and lower sections of the transect, for a total of 150 plots throughout the site. Plant species and groundcover within the plot are characterized by percent cover. A detailed Standard Operating Procedure for the plot sampling field methodology is provided in Appendix A.

Shank and Shreiner (1999) determined that sampling 150 plots across 50 transects was adequate to detect changes in species richness, abundance and frequency of occurrence of individual species, and small changes in percent cover of purple loosestrife within an acceptable margin of error. This sampling design also was adequate to evaluate species richness and abundance within the upper, middle and lower sections of river shoreline (50 plots per section), which are distinct floristically (Shank and Shreiner 1999).

For the 1998 sampling, the Dingmans Ferry site was subjectively divided into 18 Locations (Figure 2) based on the four substrate types identified above. The locations were delineated because it was hypothesized that substrate type significantly affected the plant species composition and the distribution of rare plants within the site. The boundaries between these Locations were marked by trees with tags attached to the tree bole above the typical flood elevation. These tagged trees enabled the Location Boundaries to be relocated for subsequent sampling. All of the original Location Boundaries were located in 2010. The descriptions of the Location Boundaries, updated based on 2010 conditions, are located in Appendix B. The 50 transects were stratified across Locations, with the number of transects proportionally allocated

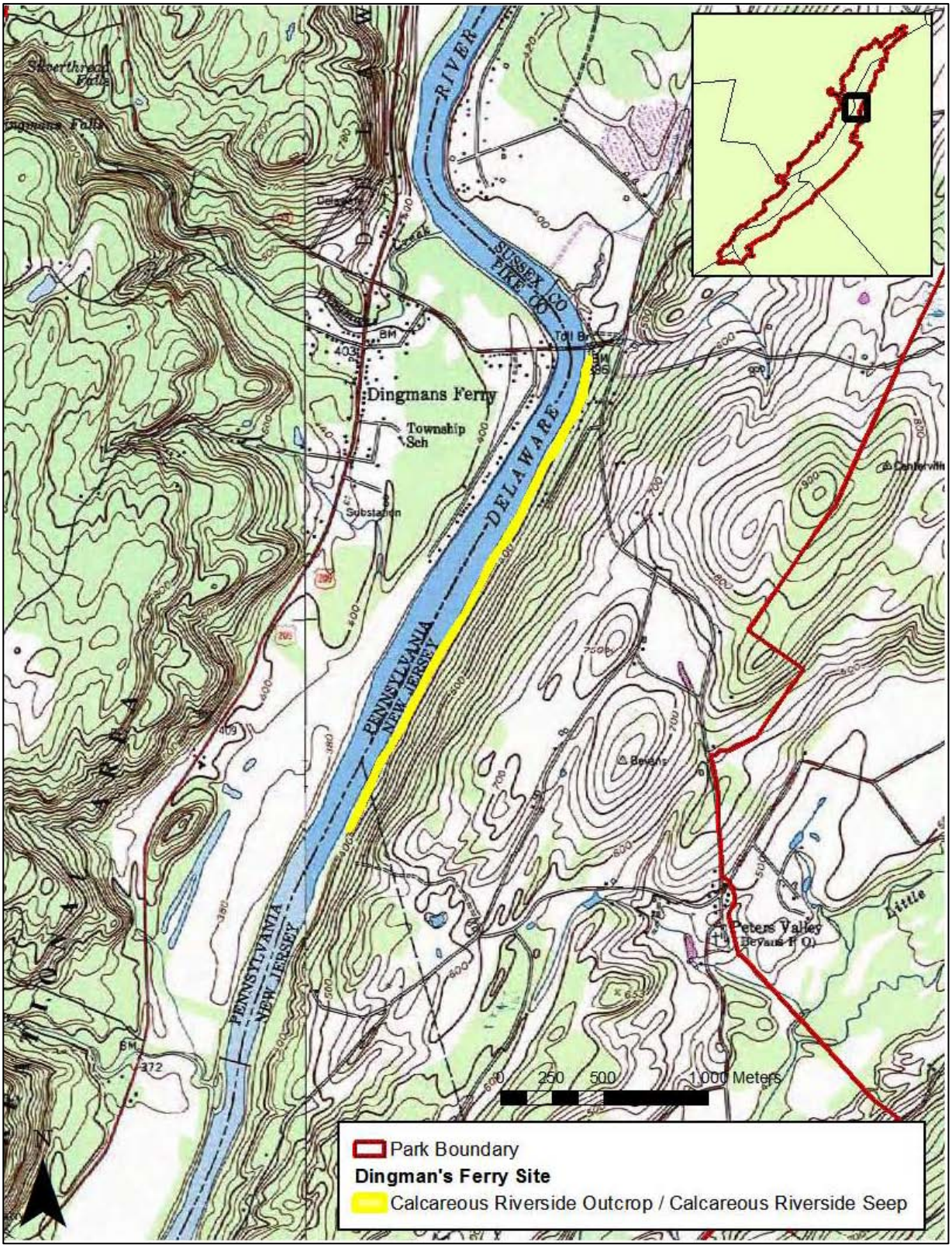

Figure 1. Dingmans Ferry Calcareous Riverside Outcrop and Calcareous Riverside Seep site in the Delaware Water Gap National Recreation Area.

Figure 2. Locations and Location Boundaries (tagged trees) within the Dingmans Ferry Calcareous Riverside Outcrop and Calcareous Riverside Seep site in the Delaware Water Gap National Recreation Area. Note: There is no Location 2.

based on the length of the Location. Each Location received, at minimum, one transect, with the longest Location receiving 10 transects.

Potential sample transect positions occurred every two meters within a Location, beginning at the Location's marked southern boundary. From a random number table, an even number between 0 and (total Location length – 2) was selected for each transect. This randomly generated number was the Transect Position, in meters, as measured from the southern boundary point. A baseline tape was run parallel to the water from the southern Location Boundary. The Transect Positions were located along this baseline tape. The original 1998 Transect Positions were used for the 2010 sampling, even though the transects were not permanently marked in 1998. The Location lengths were accurately measured in 2010 (as confirmed by the tagged trees), therefore we feel confident that the Transect Positions were also accurately replicated.

Interestingly, the intensive surveys in 1997 of the rare plant species at the three Calcareous Riverside Outcrop and Calcareous Riverside Seep sites in DEWA indicated that the rare species were not restricted to nor found more commonly on any particular substrate type. Additional analysis of the 1998 plot data revealed no distinct patterns in community composition among substrate types (Appendix C). Thus, the original stratification of transects by Substrate Location likely does not provide any advantages for this sampling effort besides ensuring that transects are spaced throughout the site.

Each Transect was aligned perpendicular to the river shoreline at the Transect Position within the Location. The upper end of the transect was not permanently marked. Thus, the location of the transect's upper end was subjectively determined based on three criteria: a) the lower edge of a small rock ledge; b) the break in slope from a steeper slope in the woods to a shallower slope on the shoreline; c) the line of small-trunked trees and saplings. Each transect was established from the woodland edge towards the river along the azimuth specified for that transect in 1998. The water's edge marked the lower end of the transect. Transect length generally ranged between 15 – 20 meters.

In 1998, the transect length from woodland to water was divided by 3, creating three sections of equal length within each transect: upper (closest to the woods), middle, and lower (closest to the water). One plot was placed in each section, with Plot #1 in the upper section closest to the woods, Plot #2 in the middle section, and Plot #3 in the lower section closest to the river. Potential plot positions occurred every 0.5 m along the transect, beginning at 0 m at the top of the transect closest to the woods. For each section, a whole or half number between 0 and (section length – 0.5) was selected from a random number table in 1998. The randomly generated number was the Plot Position, in meters, as measured from the upper end of the transect closest to the woods. The original 1998 Plot Positions were used for 2010 sampling, except in the few circumstances when the water levels precluded using the original Plot Position. The 1 m^2 plots sampled using a PVC frame 0.5 meters wide by 2 meters long. The frame was placed on the up-river side (to the north) of the transect, with the up-slope, 2-m long edge of the plot aligned on the randomly selected Plot Position point. A diagram of the Locations, Transect Positions, and Plot Positions is provided in Figure 3. The transect positions, transect azimuths, transect lengths, and plot positions used in the 1998 and 2010 samplings are listed in Appendix D.

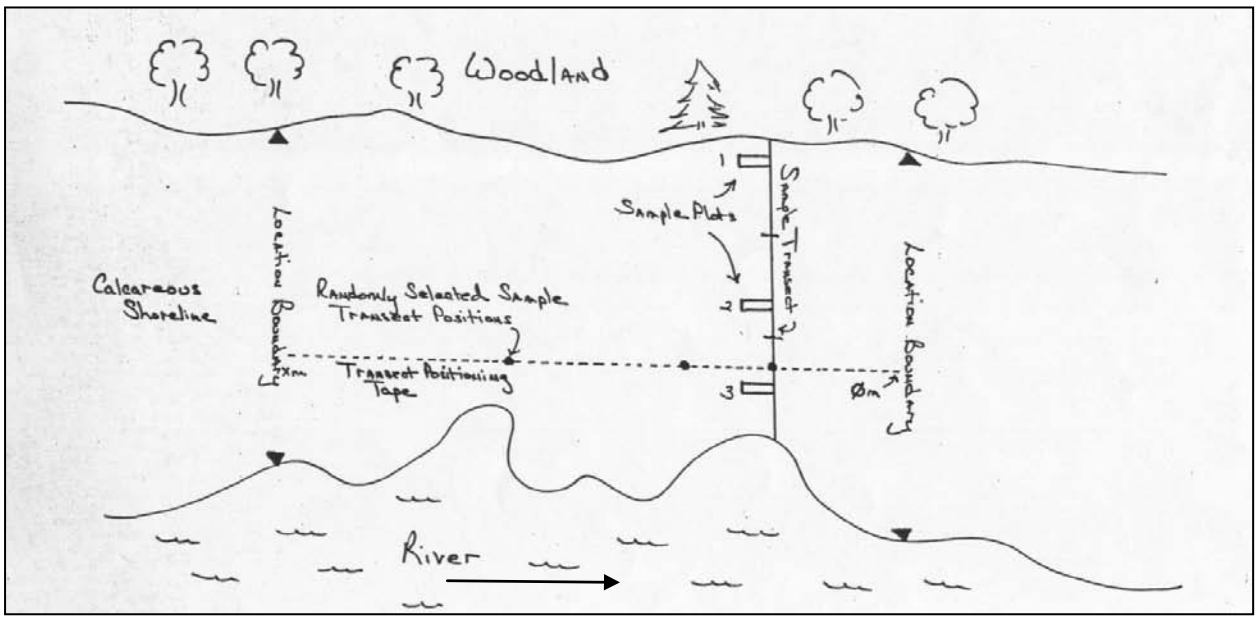

Figure 3. Conceptual diagram of Location Boundaries, Transect Positions, and Plot Positions used in plot sampling on the Dingmans Ferry site.

Within each plot, groundcover was characterized by recording the percent cover for the following categories: bare rock, bare soil, litter, garbage, moss, and water. The hydrology of the plot was recorded as one of six hydrologic categories used in the 1998 sampling. The percent tree canopy cover was also recorded. Each plant species rooted in or overhanging the plot was recorded and assigned a percent cover. All percent cover was estimated to the nearest percent. The number of stems of *Lythrum salicaria* rooted in the plot was noted, along with the amount of defoliation observed on *L. salicaria*, using standardized defoliation categories (Blossey 1997). The data sheet for plot sampling in 2010 (adapted from the data sheet from 1998) is shown in Appendix E.

In 1998, all 50 transects were sampled between August 4 and August 26. Twenty of the transects were also sampled earlier in the summer between June 4 and June 25. However, the researchers concluded that only one sampling effort in August was needed to capture long term changes in community composition. The majority of species captured in the June sampling were also captured in the more extensive August sampling and no additional information was gained by sampling in June. In 2010, the transects were sampled between August 9 and August 20.

Point-Intercept Sampling

This sampling conducted in 2010 consists of 67 transects stratified along the length of the site. A sampling pole was systematically lowered along each transect and “hits” were tallied when contact was made with a plant species or groundcover class. Percent cover was calculated as the number of hits for each plant species or groundcover class divided by the total number of samples per transect. A detailed Standard Operating Procedure for the point-intercept sampling field methodology is provided in Appendix F.

The number of transects established for this sampling was based on estimates from a similar monitoring project on rare riparian environments in the Cumberland Piedmont Network (CUPN). The CUPN averages approximately 1,000 point intercepts within their rare riparian sites (Nora Murdock, Ecologist, pers. com., 02/22/2010). By assuming an average of 15-m long transects in the Dingmans Ferry site, it was determined that we needed 67 transects with intercepts every 1 m along the transects to match the CUPN sampling efforts. However, once point-intercept sampling began at Dingmans Ferry, it was determined that 1-m intervals between intercepts were not capturing sufficient vegetation along the transect. Since most point-intercept sampling methodologies use 0.2-m or 0.5-m intervals, we chose to sample the transects using 0.5-m intervals. At the conclusion of the sampling, 2,018 intercepts were sampled along the 67 transects, with an average of 30 intercepts per transect.

Since the four categories of substrate defined in 1998 were not a strong influence on the vegetation composition (Appendix C), the Locations established in 1998 were combined into five larger Sections for the point-intercept sampling (Table 1). These Sections used the original tagged trees at the Location Boundaries to locate the beginning and end of each section in the field. The 67 transects were proportionally allocated to the Sections based on the length of the Section compared to total site length. Potential sample transect positions occurred every meter within a Section, beginning at the Section's marked southern boundary. From a random number generator, a whole number between 0 and the (total Section length - 1) was selected for each transect. This randomly generated number was the Transect Position, in meters, as measured from the southern boundary point of the Section. A baseline tape was run parallel to the water from the Section's southern boundary point. The Transect Positions were located along this baseline tape.

Each Transect was aligned perpendicular to the river shoreline at the Transect Position within the Section. The upper end of the transect at the woodland edge was permanently marked by placing a 12" galvanized metal spike upslope of the transect start. The distance and azimuth from the spike to the transect start was recorded. The distance from the transect start to the water's edge was recorded as the transect length. The azimuth of the transect was also recorded.

Along each transect, intercepts were sampled at 0.5-m intervals starting at 0.5-m from the transect start. Intercepts were sampled by lowering the 0.6-cm (0.236-in) diameter sampling pole vertically to the ground at a distance of 6.5 cm (2.5 in) away from the transect on the north side of the transect tape. At each interval, one hit was recorded for each plant species within 1.75 meters of the ground that touched the pole. One tally was also recorded for the appropriate

Table 1. Information on the Sections used for point intercept sampling in 2010 at the Dingmans Ferry site.

Section	Locations Included in Section	Length of Section (m)	Percent of Total	Number of Transects within Section
A	1 through 6	666	26.4%	18
B	7	505	20.0%	13
C	8 through 10	517	20.5%	14
D	11 through 14	656	26.0%	17
E	15 through 18	178	7.1%	5
Total		2522	100.0%	67

category of groundcover (i.e. litter, soil, rock, water, moss, or vascular plant) at each intercept. Point-intercept sampling was completed between August 23 and September 1, 2010. The data sheet for point-intercept sampling is shown in Appendix G.

Data Analysis

Several different data analyses were conducted for this pilot study.

To measure changes in the Dingmans Ferry site between 1998 and 2010, one of the following tests was run on the plot data as appropriate: paired t-tests for samples with equal variance, paired t-tests with Welch approximation to the degrees of freedom for samples with unequal variance, or Wilcoxon signed rank test with continuity correction for skewed data without a normal distribution. The variables subjected to these tests included: percent cover and number of stems of *Lythrum salicaria*; tree canopy cover; percent cover of soil, litter, rock and moss; species richness per plot, percent of total cover attributed to woody species, nonnative species, native species, and generic taxa; and percent of total frequency attributed to woody species, nonnative species, native species, and generic taxa. Frequency is the number of plot in which a species was observed. A chi-square test was run on the hydrology data to compare the number of plots assigned to different hydrology categories in 1998 and 2010. All of these tests were run in the R 2.8.0 software (R Development Core Team 2008).

To assess shifts in community composition in the Dingmans Ferry site between 1998 and 2010, non-metric multidimensional scaling analyses (NMS) were performed using both the percent cover of species and the environmental variables from the plots. NMS is an ordination technique well-suited to non-normal data sets (Kruskgal and Wish 1978). For a detailed discussion of NMS, refer to McCune and Grace (2002). This analysis was run in the PC-ORD 5.0 software (McCune and Grace 2010). Sorensen distance measure, a random starting configuration, and a stability criterion of 0.00001 were employed. Fifty runs were performed with the real data, with a maximum of 200 iterations. In addition, relative importance values were calculated by species for several data sets. Relative importance value for Species Y = [((Total percent cover for Species Y / Total percent cover for all species) x 100) + ((Total frequency for Species Y / Total frequency for all species) x 100)] / 2.

To compare the plot-based sampling methodology to the point-intercept sampling methodology, two sample t-tests for samples with equal variance or two sample t-tests with Welch approximation to the degrees of freedom for samples with unequal variance were run in the R 2.8.0 software (R Development Core Team 2008). The variables subjected to these tests included: average species richness per transect; average percent of total cover attributed to native and nonnative species per transect; and percent cover of soil, litter, and rock.

In addition, power analyses were run in SAS 9.1 on the variables listed in the preceding paragraph to assess the number of transects needed by each sampling method to detect 20% change in the variables with alpha = 0.1 and power = 0.8. Alpha is the probability of detecting a "false change," or falsely detecting a change when it did not occur. Beta is the probability of "missed change," or wrongly concluding no change occurred when it actually did. Power is equal to 1 – beta. Commonly accepted values of alpha and beta range from 0.01 to 0.2 (Irwin 2008). We also calculated the coefficient of variation (CV = 100 x standard deviation / mean) as a standardized measure of variability of the response variables for each method.

Results

Changes in the Dingmans Ferry site between 1998 and 2010

The following results describe the changes in the vegetation observed in the 150 plots that were sampled in 1998 and 2010. The point intercept data were not used in these analyses.

Purple Loosestrife

Although the percent cover of purple loosestrife (*Lythrum salicaria*) showed a slight decrease between 1998 and 2010, this change was not significant (p= 0.1552, Figure 4). No significant changes were found for *L. salicaria* cover when plots were analyzed separately by their position on the shoreline (i.e., plot positions 1, 2, and 3 analyzed separately). The number of *L. salicaria* stems decreased significantly (p<0.0001), an average decrease of 9.3 stems/m^2 (Figure 4).

In 2010, a low level of defoliation (1–5% of *Lythrum salicaria* foliage) was observed in 50% of the plots that contained *L. salicaria* (Figure 5). Thirty percent of plots with *L. salicaria* contained defoliation levels greater than 5%, while 20% of these plots contained defoliation levels less than 1%.

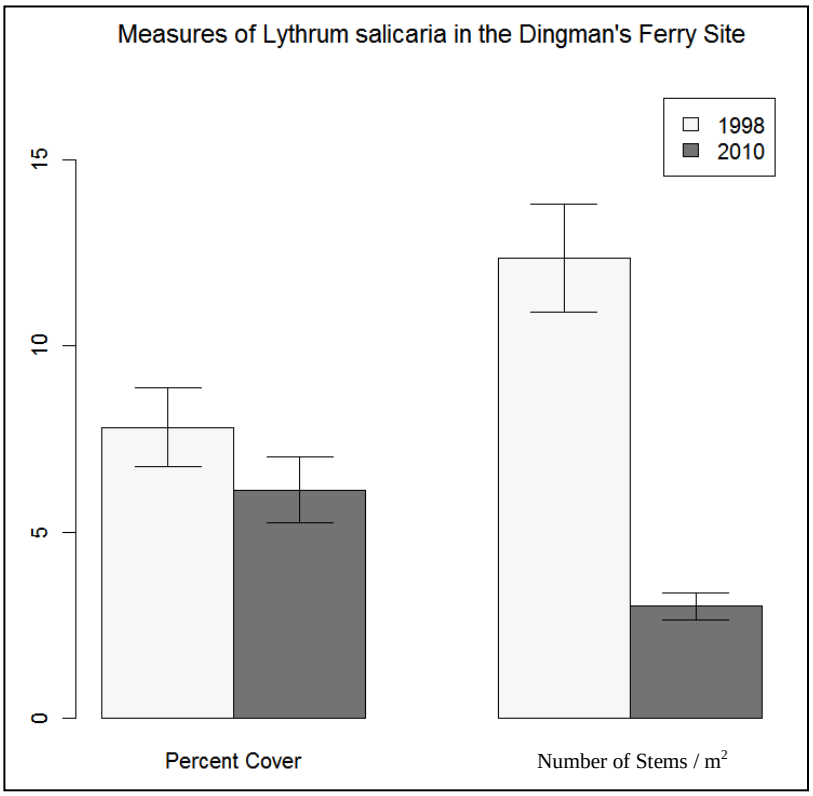

Figure 4. Change in average percent cover (+/- standard error) and average number of stems per square meter (+/- standard error) of *Lythrum salicaria* across 150 plots in the Dingmans Ferry site between 1998 and 2010.

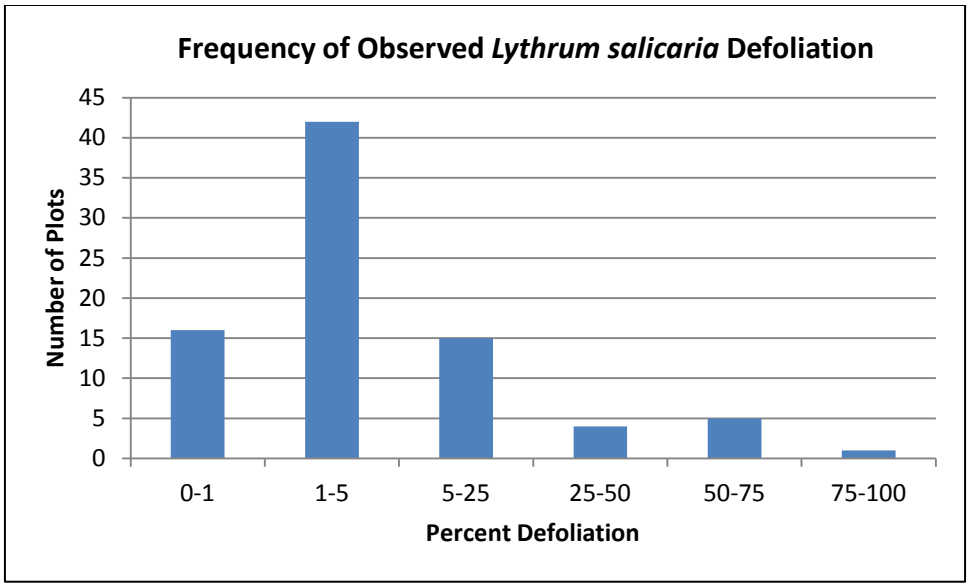

Figure 5. Frequency distribution of defoliation categories observed on *Lythrum salicaria* in 150 plots in the Dingmans Ferry site in 2010.

Other Invasive Exotic Plant Species

Numerous important changes were observed in invasive exotic plant species abundance and distribution between 1998 and 2010 (Table 2). Three invasive exotic species, mile-a-minute (*Polygonum perfoliatum*), narrowleaf bittercress (*Cardamine impatiens*), and Oriental bittersweet (*Celastrus orbiculatus*), were observed in 2010 but had not been previously documented at the Dingmans Ferry site. Three additional invasive exotic species, multiflora rose (*Rosa multiflora*), dame's rocket (*Hesperis matronalis*), and Japanese knotweed (*Polygonum cuspidatum*), were not captured by the plot sampling in 1998, but were known to occur at the Dingmans Ferry site in 1997 or 1998. These three species were captured in the 2010 plot sampling.

Autumn olive (*Elaeagnus umbellata*) showed the largest increase in relative importance value between the two sampling periods (Table 2). In 1998, *Elaeagnus* sp. was only identified to genus and was observed in 4 plots, with a total percent cover of 18% from those plots, and a relative importance value of 0.168. In 2010, *Elaeagnus umbellata* was observed in 21 plots, with a total percent cover of 636% from those plots, and a relative importance value of 3.148. Ignoring the differences in taxonomic specificity between the sampling periods, and analyzing only those plots that contained *Elaeagnus* spp. in either one of the sampling periods, there was a significant ($p=0.0008$) increase of 28% on average in *Elaeagnus* spp. cover at the Dingmans Ferry site. *Elaeagnus umbellata* now occurs in dense thickets on the upper slopes of the Calcareous Riverside Outcrop near the woodland edge. Locations 7 and 10 contain the worst infestations of *Elaeagnus umbellata.*

Table 2. Total percent cover, total frequency (number of plots), and relative importance values for key invasive exotic plant species observed across 150 plots at the Dingmans Ferry site in 1998 or 2010.

	Total Percent Cover		Total Frequency		Relative Importance Value	
Scientific Name	**1998**	**2010**	**1998**	**2010**	**1998**	**2010**
Alliaria petiolata	9	7	7	6	0.2011	0.2018
Artemisia sp.	2	0	2	0	0.0551	0.0000
Artemisia vulgaris	0	291	0	34	0.0000	2.1471
Berberis thunbergii	6	40	1	2	0.0481	0.2177
Cardamine impatiens	0	17	0	2	0.0000	0.1258
Celastrus orbiculatus	0	2	0	1	0.0000	0.0370
Elaeagnus sp.	18	0	4	0	0.1679	0.0000
Elaeagnus umbellata	0	636	0	21	0.0000	3.1483
Glechoma hederacea	71	280	13	27	0.5970	1.9004
Hemerocallis fulva	0	12	0	3	0.0000	0.1348
Hesperis matronalis	0	4	0	2	0.0000	0.0739
Lonicera japonica	1	0	1	0	0.0276	0.0000
Lonicera morrowii	0	265	0	17	0.0000	1.5508
Lonicera sp.	3	0	1	0	0.0358	0.0000
Lychnis flos-cuculi	206	30	35	19	1.6685	0.6702
Silene sp.	0	88	0	30	0.0000	1.2205
Lysimachia nummularia	4	29	3	2	0.0868	0.1738
Lythrum salicaria	1172	920	105	89	7.2860	6.2523
Melilotus alba	90	3	23	1	0.9096	0.0409
Microstegium vimineum	524	250	59	61	3.5401	2.7655
Myosotis scorpioides	19	94	1	15	0.1017	0.8099
Myosotis sp.	5	0	4	0	0.1143	0.0000
Polygonum caespitosum	0	6	0	4	0.0000	0.1398
Polygonum persicaria	12	0	10	0	0.2838	0.0000
Polygonum cuspidatum	0	3	0	1	0.0000	0.0409
Rosa multiflora	0	66	0	7	0.0000	0.4664
Sedum sarmentosum	29	171	3	10	0.1897	0.9726

An identical trend was observed with Morrow's honeysuckle (*Lonicera morrowii*) (Table 2). In 1998, exotic bush honeysuckles were identified only as *Lonicera* sp. and were recorded only in 1 plot with a cover of 3%. In 2010, *Lonicera morrowii* was observed in 17 plots, with a total percent cover of 265% from those plots, and a relative importance value of 1.55 (compared to 0.0358 for *Lonicera* sp. in 1998). *Lonicera morrowii* also commonly occurs on the upper slopes of the Calcareous Riverside Outcrop near the woodland edge.

Although common wormwood (*Artemisia vulgaris*) and true forget-me-not (*Myosotis scorpioides*) have not been identified as invasive exotic plant species in DEWA before, these two species are acting invasively at the Dingmans Ferry site. They were not documented in 1998 but were the dominant species in several sections of the site in 2010. Even if the generic *Artemisia* sp. and *Myosotis* sp. records from 1998 are assumed to be *A. vulgaris* and *M. scorpioides*, these two species have shown marked increases over the 12 years (Table 2). *A. vulgaris* is common in the drier, upper-slope sections of the Calcareous Riverside Outcrop, while *M. scorpioides* is common in Calcareous Riverside Seeps and other mesic crevices throughout the site.

Stringy stonecrop (*Sedum sarmentosum*) showed marked increases between 1998 and 2010, primarily in the plots closest to the woodland. The total percent cover for this species increased

from 29% to 171% between the sampling periods (Table 2). This species grows vigorously over open rock outcrops. Ground ivy (*Glechoma hederacea*) also increased in cover, frequency, and relative importance value between 1998 and 2010 (Table 2). This species is now common in the mid- and upper-slopes of the shoreline.

Although the observed total cover, total frequency, and relative importance value of ragged robin (*Lychnis flos-cuculi*) decreased sharply between 1998 and 2010 (Table 2), the true abundance and distribution of this species has probably not changed significantly between the two sampling years. During the 2010 sampling, *L. flos-cuculi* had already senesced and was identified to species by the dried capsules that were remaining. Some of these dried capsules were attached to basal rosettes which were common throughout the site. However, basal rosettes that were not attached to stalks with dried capsules could not be positively identified as *L. flos-cuculi*. These rosettes were labeled as *Silene* sp., because they could have been other species in that genus (The Flora of Pennsylvania now uses *Silene flos-cuculi* for *L. flos-cuculi*). If the *Silene* sp. records from 2010 are included as *L. flos-cuculi* records, then the cover, frequency, and relative importance values for *L. flos-cuculi* have not changed greatly between 1998 and 2010.

White sweetclover (*Melilotus alba*) showed marked decreases in cover, frequency, and relative importance value between 1998 and 2010. However, this biennial species often is abundant only in alternate years. Shank (1999) reported that in 1997, *M. alba* formed robust, dense stands at all three calcareous rivershore sites in DEWA. In 1998, very few scraggly plants were found at the Dingmans Ferry site during the community sampling, making *M. alba* one of the least abundant species that year. If *M. alba* has maintained this biennial cycle, we would have expected very low abundance of *M. alba* in 2010, even though preceding and subsequent years may contain *M. alba* in high abundance.

Japanese stilt grass (*Microstegium vimineum*) was one of the few invasive exotic plant species for which declines were observed between 1998 and 2010, predominantly in Plots 1 and 2, those closest to the woodland and those in the middle of the shoreline. The total percent cover for this species in 2010 is less than half of that observed in 1998; though the frequency was relatively stable (Table 2).

Another invasive exotic species that may have declined between the two sampling periods is Oriental lady's thumb (*Polygonum caespitosum*). This species is easily confused with spotted lady's thumb (*P. persicaria*). *P. caespitosum* was observed only in 2010, while *P. persicaria* was recorded only in 1998. If we assume that these plants are actually the same species identified differently in the two sampling periods, then lady's thumb has shown decreases in total percent cover and total frequency by about half (Table 2), though its relative importance value was not large in either sampling period.

Reed canary grass (*Phalaris arundinacea*) has not been identified as an invasive exotic species in DEWA. This species is native to the United States and Canada but is now more widely distributed and abundant because of introductions from both local and European populations. The introduced strains ability to aggressively colonize and form near monotypic stands may reduce biodiversity within the riparian zone (Barnes 1999, Lavergne and Molofsky 2004). In the Dingmans Ferry site, the total cover of reed canary grass in all sampled plots has doubled from

567% in 1998 to 1019% in 2010. This species forms dense colonies in the mid- and lower-slopes of the shoreline, with few other species persisting in those areas.

Environmental Conditions

Changes in groundcover substrate categories of rock, soil, litter, moss, water, and garbage were assessed at the Dingmans Ferry site. Percent cover of bare soil significantly increased between 1998 and 2010 ($p<0.0001$), an average of 15% increase (Figure 6). Increases in average soil percent cover were observed in every Location except Location 3. However, in 2010, the amount of bare soil resulting from earthworm activity was particularly noticeable in the northern part of the site. Earthworm casts and burrows were abundant on bare soil north of Location 10. A significant ($p=0.01$) increase of 7% on average was observed in the percent cover of litter between 1998 and 2010 (Figure 6).

The percent cover of bare rock increased slightly from 1998 to 2010, but this change was not significant (Figure 6). No significant changes in percent cover of moss were observed (Figure 6). Water cover was recorded in only nine plots (6% of plots) in 1998 and 18 plots in 2010 (12% of plots). These 2010 plots tended to contain higher cover of water since the river level during the

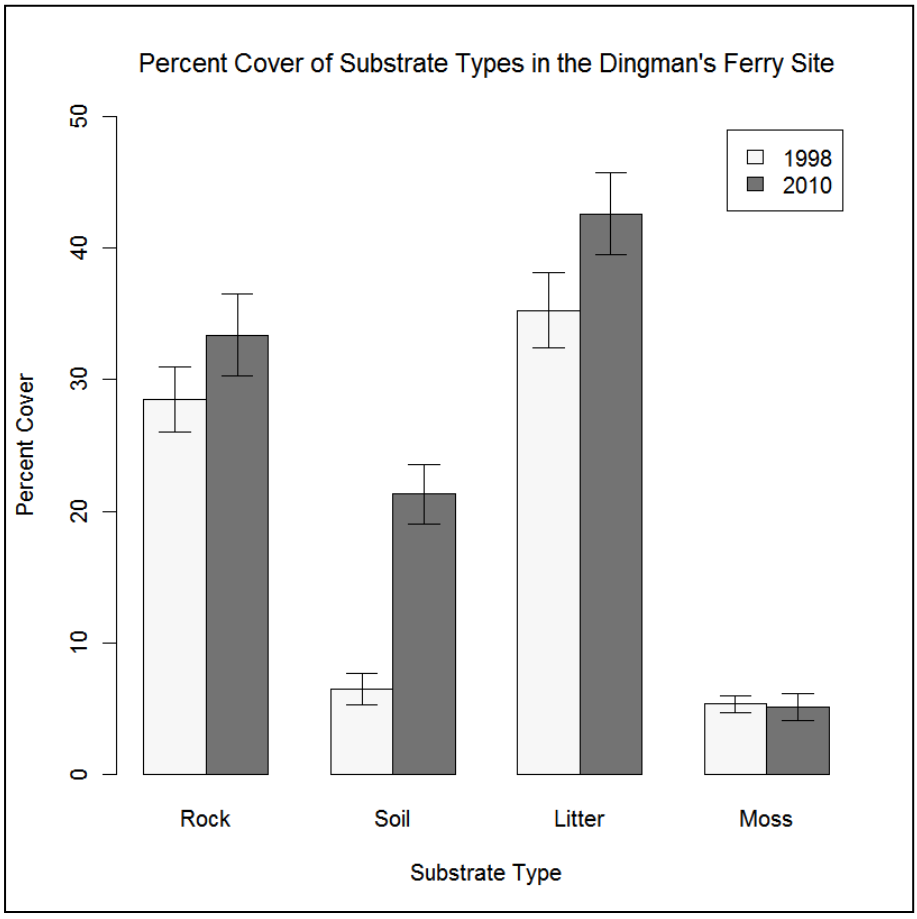

Figure 6. Average percent cover (+/- standard error) of substrate types across 150 plots at the Dingmans Ferry site in 1998 and 2010.

2010 sampling was higher than its level during the 1998 sampling. Very little garbage was recorded in the plots in either year. Only three plots in 1998 and two plots in 2010 contained garbage, all with cover of 2% or less.

Significant differences (p=0.002) were observed between the proportions of plots classified in the different hydrology categories in the two sampling periods (Figure 7). More plots were classified as seeps or dried seeps in 1998 than in 2010, whereas more plots were classified as dry or shoreline in 2010 than in 1998. These results are not surprising, given that the Palmer Drought Severity Index for Sussex County, New Jersey, was mid-range in August 1998 (neither wetter nor drier than average) but showed moderate drought in August 2010 (USGS 2010).

No significant differences between 1998 and 2010 were found in tree canopy cover for Plots 1 and 2, those closest to the woodland and those in the middle of the shoreline. The vast majority of Plots 3, those closest to the river, had no canopy cover in either 1998 and 2010.

Taxa Richness and Nativity

During plot sampling, there were 270 taxa recorded in 1998 and 256 taxa recorded in 2010. Taxa richness per plot decreased significantly (p=0.0001), from an average of 14.2 taxa in 1998 to an average of 11.5 taxa in 2010. Out of the 397 total taxa observed between both sampling years, only one third (130 taxa, 33% of total) were observed in both 1998 and 2010, with 140 taxa (35% of total) observed only in 1998 and 127 taxa (32% of total) observed only in 2010. Similarly, 93 species (34.7% of total) were observed in both 1998 and 2010, with 75 species recorded only in 1998 and 103 species recorded only in 2010.

We calculated the total cover per plot and the taxa richness per plot for native species, nonnative species, and generic taxa. The percent of each plot's total cover and the percent of each plot's total taxa richness attributed to each of these groups were also calculated. However, it was determined that any changes observed between 1998 and 2010 in these variables were a result of

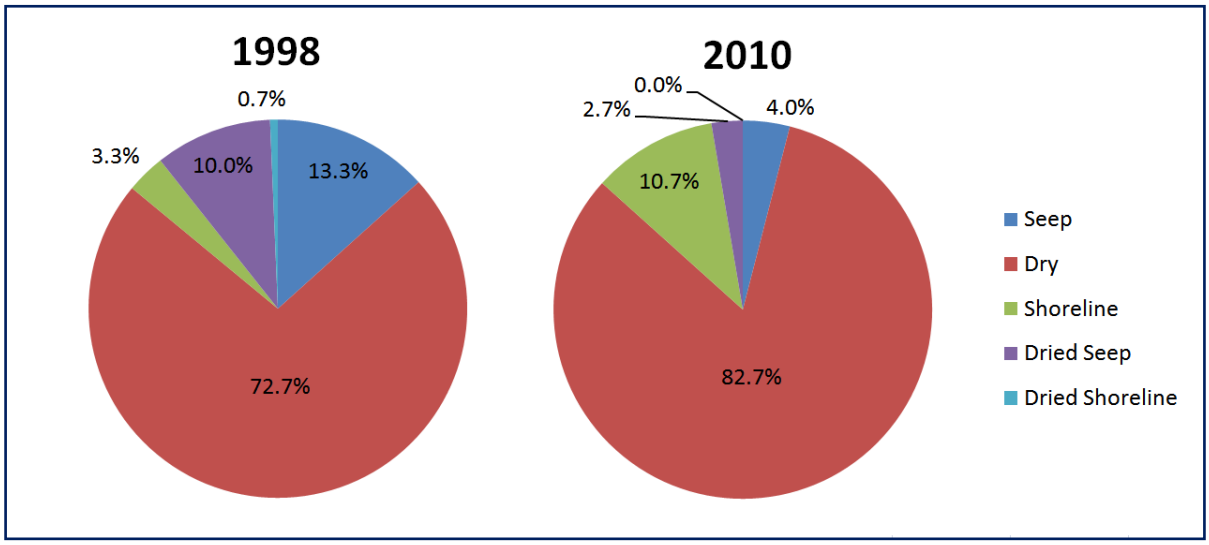

Figure 7. Proportion of 150 plots classified by hydrology categories at the Dingmans Ferry Site in 1998 and 2010.

differences in the specificity of taxa identification between the two sampling periods. We were not able to document real changes to the cover or richness of native or nonnative species between 1998 and 2010.

Community Composition

The NMS analysis recommended a three-dimensional ordination. For each axis, p = 0.0196 in which p is equal to the proportion of randomized runs in which the stress is less than or equal to the observed stress. Stress in NMS analysis is calculated based on the distances between data points in the ordination space as compared to the same distances in higher-dimensionality space (McCune and Grace 2002). The cumulative r^2 for the three axes was 0.431.

The position of the plots along the shoreline strongly influences the species composition within the plots. Plots along the shoreline (Plots 3) tend to occur in the upper left side of the ordination diagram, while plots near the woodland (Plots 1) tend to occur in the lower right side of the diagram (Figure 8). Since bare rock is more common near the shoreline and litter is more common near the woodland, Axis 1 showed strong correlations with percent cover of bare rock, litter, and water (Table 3). Although the correlations with substrate cover are not as strong for Axis 3, plot position within the shoreline appears to be a strong factor along Axis 3 (Figure 8). Axis 2 appears to be associated with sampling year (Figure 9).

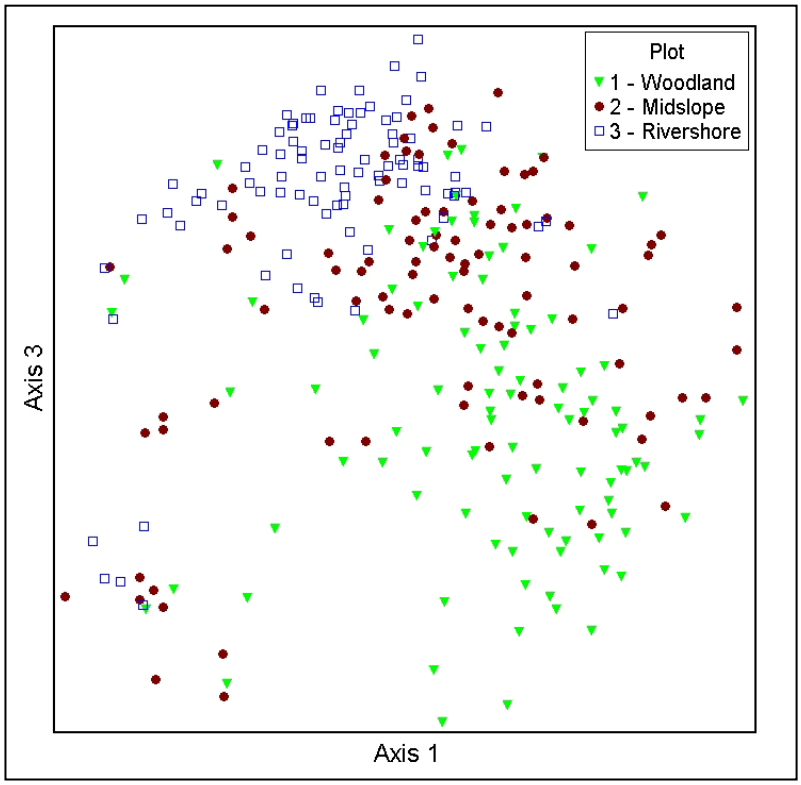

Figure 8. Ordination diagram from the non-metric multidimensional ordination analysis (NMS) showing grouping of plots in the Dingmans Ferry site based on the plots' position on the shoreline.

Table 3. Correlations (r values) between percent cover of substrate types and the axes calculated in the non-metric multidimensional ordination analyses (NMS) for all sampled plots, only woodland plots (Plots 1), and only mid-slope plots (Plots 2). Important correlations are highlighted in bold.

Substrate Percent Cover	**Axis**		
ALL PLOTS	**1**	**2**	**3**
Rock	**-0.581**	0.207	0.121
Litter	**0.641**	-0.196	-0.289
Moss	-0.074	0.290	-0.092
Water	**-0.301**	-0.144	-0.008
PLOTS 1 ONLY	**1**	**2**	**3**
Rock	**-0.321**	-0.420	0.132
Litter	0.286	**0.471**	-0.209
Moss	**-0.395**	**-0.405**	0.203
PLOTS 2 ONLY	**1**	**2**	**3**
Rock	**0.440**	**-0.447**	-0.178
Soil	**-0.306**	0.210	0.262
Litter	**-0.516**	**0.401**	0.107

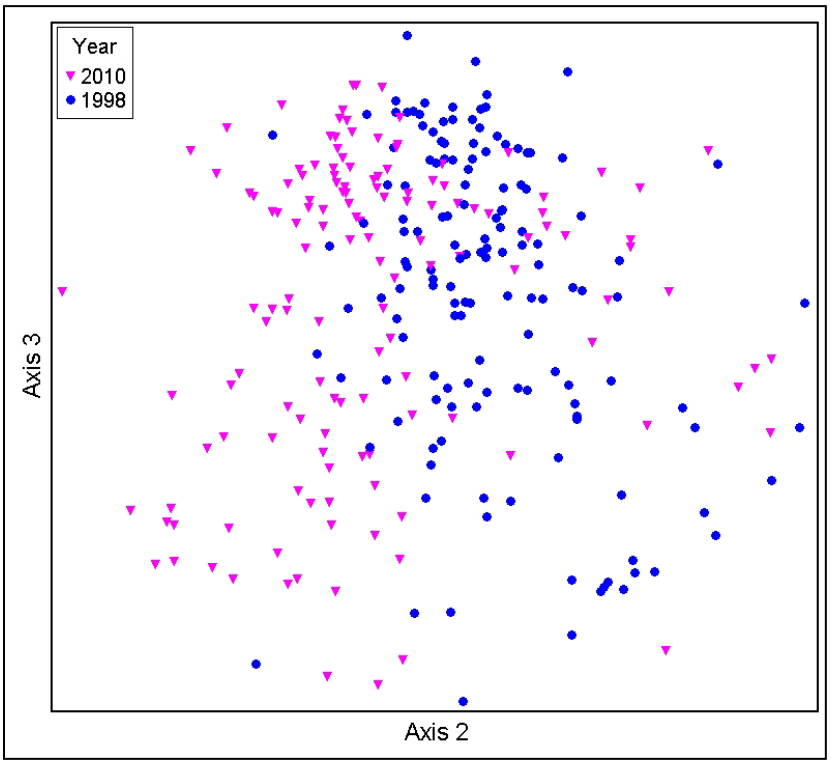

Figure 9. Ordination diagram from the non-metric multidimensional ordination analysis (NMS) showing grouping of plots in the Dingmans Ferry site by sampling year.

The type of substrate also influences species composition within the plots closest to the woodland (Plots 1), as well as mid-slope plots (Plots 2). When NMS analyses were run separately for data from Plots 1 and 2, percent cover of bare rock, litter, bare soil, and moss showed strong correlations with one or more axes in the ordinations (Table 3). The NMS analyses for data from shoreline plots (Plots 3) yielded a one-dimensional solution, indicating no patterns in species composition between sampling years or in relation to the measured environmental variables.

The hydrology categories group more coherently in NMS ordinations that used only 1998 data, as compared to ordinations that included both 1998 and 2010 data (Appendix C). This may be a result of the drier year in 2010, when very few seeps were present. The predominance of the dry hydrology category in 2010 likely masks the groupings by hydrology seen in the 1998 data.

The ordination for all sampled plots also shows shifts in species composition between years (Figure 9). Plots sampled in 2010 tend to fall on the left side of Axis 2, while plots sampled in 1998 tend to fall on the right side of Axis 2. These groupings by year indicate that the species composition of the plots differed between the two sampling years.

The shift in species composition between sampling years can be examined through relative importance values. Comparing a species' relative importance value in the two sampling years provides information on the shifts in species dominance and abundance within the site. Tables 4, 5, 6, and 7 list those species for which marked changes in relative importance value were observed between the two sampling periods. ["Marked change" was considered a difference in relative importance value greater than 0.5.] Changes that appeared to be a result of taxonomic specificity (e.g., *Oxalis* sp. versus *Oxalis stricta*) or differences in nomenclature between the two sampling periods were removed. The results presented in Table 4 used all sampled plots to calculate relative importance values for the entire site. Tables 5, 6, and 7 included only Plots 1 (woodland), Plots 2 (mid-slope), and Plots 3 (shoreline), respectively, to calculate relative importance value.

Species listed in these tables highlight several types of species shifts occurring in the Calcareous Riverside Outcrop and Calcareous Riverside Seep communities:

a) species migration within the Dingmans site. For example, *Myosoton aquaticum* showed marked decreases in Plots 1 and 2 (woodland plots and mid-slope plots, respectively), but showed marked increases in Plots 3 (rivershore plots) between the two sampling years.

b) composition changes in response to varying hydrologic conditions. The moisture content of microhabitats within the outcrops and the seeps varies with the amount of rainfall, groundwater, and river levels. Species respond to the seasonal and annual variation in available moisture. For example, algae had high relative importance in 1998, primarily recorded in the seeps and other wet crevices in the rocks, but this taxon was not recorded in 2010.

c) species shift between riverine sites within the park. *Spartina pectinata* had high relative importance in 2010 in rivershore and mid-slope plots. However, this species was not previously documented at the Dingmans Ferry site. Given its distinctive growth form and inflorescence, it is unlikely that this species was overlooked or not identified to species in previous surveys of the Dingmans Ferry site. In 1997 and 1998, *S. pectinata* was known to occur on the other two Calcareous Riverside Outcrop and Calcareous Riverside Seep sites in DEWA. This suggests that this species has strongly colonized the Dingmans Ferry site in the last 12 years.

Table 4. Summary of key changes in species' relative importance values between 1998 and 2010, as calculated from all sampled plots.

LOSERS		WINNERS	
Species whose relative importance showed marked *decrease* between 1998 and 2010	**Species of high relative importance in 1998 not observed in 2010**	**Species whose relative importance showed marked *increase* between 1998 and 2010**	**Species of high relative importance in 2010 not observed in 1998**
Andropogon gerardii	*Algae*	*Phalaris arundinacea*	*Elaeagnus umbellata*
Physocarpus opulifolius	*Solidago canadensis*	*Solidago gigantea*	*Artemisia vulgaris*
Galium boreale	*Poa compressa*	*Glechoma hederacea*	*Impatiens capensis*
Lythrum salicaria	*Symphyotrichum puniceum*	*Thelypteris palustris*	*Lonicera morrowii*
Ageratina altissima	*Leucanthemum vulgare*	*Sedum sarmentosum*	*Spartina pectinata*
Symphyotrichum lanceolatum		*Myosotis scorpioides*	*Calamagrostis canadensis*
Melilotus alba		*Solidago rugosa*	*Poa palustris*
Microstegium vimineum		*Acer rubrum*	*Leersia oryzoides*
Poa compressa		*Hypericum mutilum*	*Leersia virginica*
Euthamnia graminifolia			*Polygonum hydropiper*
			Stellaria longifolia

Table 5. Summary of key changes in species' relative importance values between 1998 and 2010, as calculated only from woodland plots (Plots 1).

LOSERS		WINNERS	
Species whose relative importance showed marked *decrease* between 1998 and 2010	**Species of high relative importance in 1998 not observed in 2010**	**Species whose relative importance showed marked *increase* between 1998 and 2010**	**Species of high relative importance in 2010 not observed in 1998**
Microstegium vimineum	*Algae*	*Sedum sarmentosum*	*Elaeagnus umbellata*
Physocarpus opulifolius	*Symphyotrichum puniceum*	*Solidago rugosa*	*Lonicera morrowii*
Ageratina altissima	*Prunella vulgaris*	*Elymus* sp.	*Artemisia vulgaris*
Phalaris arundinacea	*Poa compressa*	*Glechoma hederacea*	*Impatiens capensis*
Desmodium glutinosum	*Hypericum punctatum*	*Solidago gigantea*	*Leersia virginica*
Agrostis sp.	*Solidago canadensis*	*Toxicodendron radicans*	*Galium tinctorium*
Hypericum perforatum	*Geum laciniatum*	*Helianthus tuberosus*	*Polygonum perfoliatum*
Galium boreale	*Galium palustre*	*Hamamelis virginiana*	*Rosa multiflora*
Polygonum virginianum	*Actaea racemosa*	*Ostrya virginiana*	*Poa palustris*
Myosoton aquaticum	*Poa pratensis*		*Myosotis scorpioides*
	Thalictrum dioicum		*Equisetum arvense*
	Leucanthemum vulgare		
	Carex granularis		
	Elaeagnus angustifolia		

Table 6. Summary of key changes in species' relative importance values between 1998 and 2010, as calculated only from midslope plots (Plots 2).

LOSERS		WINNERS	
Species whose relative importance showed marked *decrease* between 1998 and 2010	**Species of high relative importance in 1998 not observed in 2010**	**Species whose relative importance showed marked *increase* between 1998 and 2010**	**Species of high relative importance in 2010 not observed in 1998**
Microstegium vimineum	*Algae*	*Solidago gigantea*	*Galium tinctorium*
Galium boreale	*Melilotus alba*	*Aster* sp.	*Impatiens capensis*
Andropogon gerardii	*Solidago canadensis*	*Glechoma hederacea*	*Elaeagnus umbellata*
Euthamia graminifolia	*Leucanthemum vulgare*	*Myosotis scorpioides*	*Artemisia vulgaris*
Helianthus tuberosus	*Poa compressa*	*Symphyotrichum lanceolatum*	*Spartina pectinata*
Amphicarpaea bracteata	*Physocarpus opulifolius*	*Boehmeria cylindrica*	*Poa palustris*
Viola sp.	*Bidens coronata*	*Campanula aparinoides*	*Leersia oryzoides*
Eupatorium perfoliatum	*Ageratina altissima*	*Hypericum mutilum*	*Thelypteris palustris*
Juncus tenuis	*Carex granularis*	*Onoclea sensibilis*	
Myosoton aquaticum			

Table 7. Summary of key changes in species' relative importance values between 1998 and 2010, as calculated only from rivershore plots (Plots 3).

LOSERS		WINNERS	
Species whose relative importance showed marked *decrease* between 1998 and 2010	**Species of high relative importance in 1998 not observed in 2010**	**Species whose relative importance showed marked *increase* between 1998 and 2010**	**Species of high relative importance in 2010 not observed in 1998**
Symphyotrichum lanceolatum	*Andropogon gerardii*	*Phalaris arundinacea*	*Spartina pectinata*
Lythrum salicaria	*Euthamia graminifolia*	*Microstegium vimineum*	*Calamagrostis canadensis*
Eleocharis sp.	*Salix exigua*	*Acer rubrum*	*Galium tinctorium*
Mentha arvensis	*Polygonum persicaria*	*Thelypteris palustris*	*Ludwigia palustris*
	Ranunculus hispidus	*Polygonum pensylvanicum*	*Polygonum hydropiper*
		Hypericum mutilum	*Lindernia dubia*
		Rorippa sylvestris	*Leersia oryzoides*
			Panicum virgatum
			Acalypha rhomboidea

Woody Species

Another important change in community composition between 1998 and 2010 was the cover of woody species. The percent of each plot's total cover attributed to woody species showed a significant increase ($p=0.0004$) between the two sampling years, on average a 7% increase. The percent of total frequency attributed to woody species showed no significant differences between 1998 and 2010. Given that the frequency of woody species did not increase, but that the percent cover of woody species showed significant increases, it is likely that native shrubs are being replaced by aggressive invasive exotic shrubs. Native shrubs such as narrowleaf willow (*Salix exigua*) and common ninebark (*Physocarpus opulifolius*) are listed as showing marked declines, whereas invasive exotic shrubs such as autumn olive (*Elaeagnus umbellata*), Morrow's honeysuckle (*Lonicera morrowii*), and multiflora rose (*Rosa multiflora*) showed marked increases.

Comparison of Sampling Methods

A comparison of the results from the 2010 plot and point-intercept samplings are shown in Table 8. Transects took longer to sample in the plot method than in the point-intercept method. However, in the plot method, the permanent sampling unit from which data from two points in time would be compared is the plot, not the transect. On average, sampling time for one plot was approximately 25 minutes, whereas sampling time for one point-intercept transect was approximately 55 minutes.

Species Diversity and Richness

The point-intercept method captured 22% fewer species than the plot method and average species richness per transect was significantly lower ($p<0.0001$) for the point-intercept method (average of 18.9 species) versus the plot method (average of 34.5 species). Numerous other studies have documented that intercept sampling captures fewer species than plot sampling (Floyd and Anderson 1987, Stohlgren et al. 1998, Kercher et al. 2003, Leis et al. 2003). Symstad et al (2006) also reported that the plot method captured significantly more (approximately half again as many) species than the point-intercept method. However, the vast majority of species missed by the point-intercept method had a cover of less than 0.5% (Symstad et al 2006). In the current study, only 20% of the species missed by the point-intercept method had a cover of less than 1%. However, nearly 60% of the species missed by the point-intercept method were observed in only one plot.

Percent Cover of Species and Substrate Types

The two methods yielded similar results in some of the measures that would be of most importance to a long-term monitoring program (Table 8). Both methods yielded nearly identical values for average percent of total cover occupied by native and nonnative species per transect. Similar results were observed for percent cover of substrate type (e.g. percent cover of rock, soil, and litter).

Table 8. Summary of results from the plot and point-intercept sampling at the Dingmans Ferry site in 2010.

Measurement	Plot Sampling	Point-Intercept Sampling
Average Sampling Time per Transect	~ 72 minutes	~ 53 minutes
Total Species Captured	249	193
Average Species Richness per Transect	34.5	18.9
Percent of Total Cover occupied by Nonnative Species	30.60%	29.02%
Percent of Total Cover occupied by Native Species	51.20%	51.39%
Percent Cover of Rock	33.40%	25.37%
Percent Cover of Soil	21.28%	18.01%
Percent Cover of Litter	42.60%	49.39%
Percent Cover of *Lythrum salicaria*	6.13%	8.84%
Percent Cover of *Phalaris arundinacea*	6.79%	11.77%
Percent Cover of Elaeagnus umbellata	4.24%	5.98%
Percent Cover of *Solidago gigantea*	2.79%	9.24%

Average cover values for four of the most common species were similar between the two methods (Table 8), though the plot method yielded lower cover values than the point intercept method. Kercher et al. (2003) and Miller et al. (2006) found that cover values were consistently lower when measured by the plot method than when measured with an intercept method. Because the point-intercept method assumes that the sampling point is infinitesimally small, but actual sample points have a diameter, the point-intercept method inevitably over-estimates cover compared to the true value (Winkworth 1955). Despite the differences found between the two methods, Symstad et al. (2006) reported that the values from the two methods were highly correlated with each other. Thus, either method could be used for long-term monitoring, as long as the method was applied consistently.

Power of Sampling Method

The number of transects needed to detect 20% change in the response variables varied by sampling method and response variable (Figure 10). In general, the point-intercept sampling required fewer transects for the same level of precision than plot sampling. The coefficients of variation for these six variables showed identical trends. Though these results seems to favor point-intercept sampling, two important caveats need to be considered. First, in the plot method, the permanent sampling unit from which data from two points in time would be compared is the plot, not the transect. Second, these power analyses were conducted using spatial variability among transects, not temporal variability which is crucial in long term monitoring. Spatial variability is a poor surrogate for temporal variability, since the former is much more variable than the latter. Urquhart et al. (1998) posit that variability among sites has no influence on the sampling designs' ability to detect trends in parameters of interest over time. This is illustrated by power analyses conducted on the average cover of autumn olive (*Elaeagnus umbellata*) at the Dingmans Ferry site. The power analyses using spatial variation indicated that 1,698 transects would be needed to detect 20% change in autumn olive cover using the plot method, while only 1,301 transects would be needed using the point intercept method. However, the current study detected a significant (p=0.0008) increase of 28% cover in autumn olive using only 50 transects (150 plots).

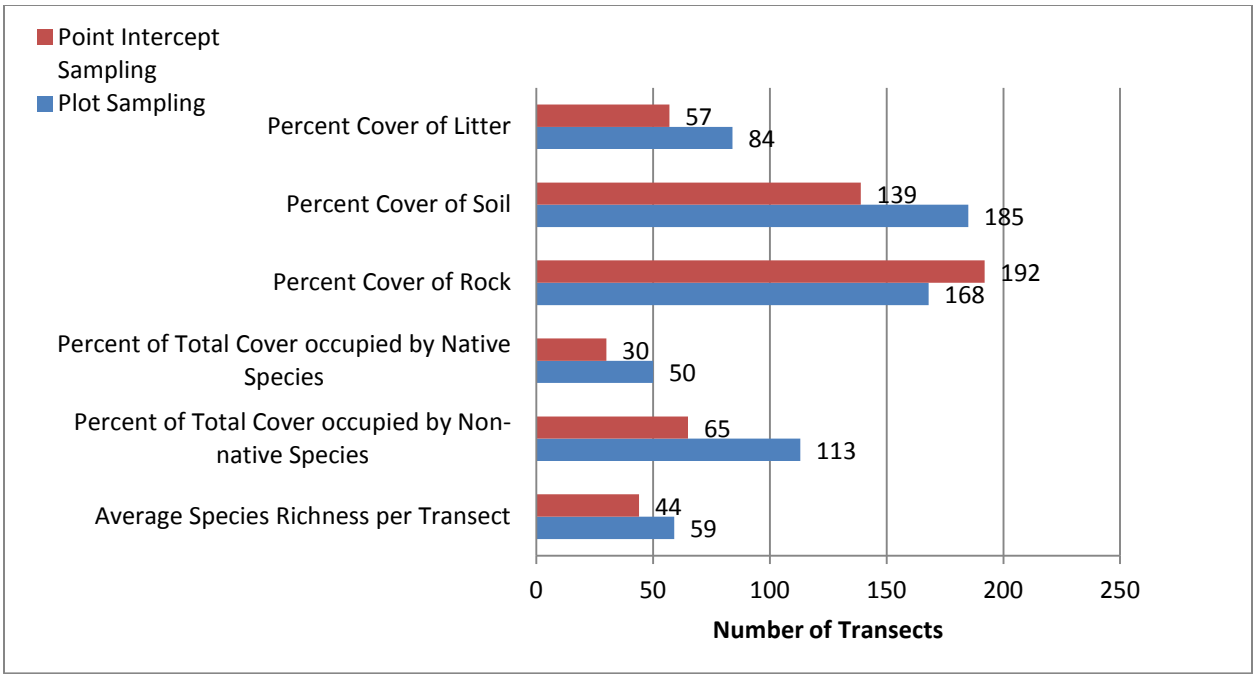

Figure 10. Number of transects needed to detect 20% change in the listed variables with alpha = 0.1 and power = 0.8. For reference, the 2010 plot sampling included 50 transects of 3 plots each, while the point intercept sampling included 67 transects with a point intercept every 0.5 meters for the length of the transect.

Discussion

This study documented changes in the distribution, abundance, and composition of plant species within the Calcareous Riverside Outcrop and Calcareous Riverside Seep at the Dingmans Ferry site since 1998. According to these data, the park's management objective of purple loosestrife (*Lythrum salicaria)* cover less than 25% (Shreiner 2008) has been maintained. It is unclear whether the 75% reduction in the number of *L. salicaria* stems observed between the two sampling periods can be attributed to the biocontrol beetles. Defoliation of *L. salicaria* was observed at low levels throughout the site, confirming that the leaf-eating *Galerucella* beetles are feeding at the Dingmans Ferry site. Parkwide, *L. salicaria* cover has rebounded in recent years after dramatic declines in *L. salicaria* cover observed between 2001 and 2008. It is likely that the biocontrol beetles and *L. salicaria* are exhibiting the classic cyclical pattern of abundance observed in many predator-prey relationships (Huffaker 1958). The frequent scour from the Delaware River likely further affects the abundance of *L. salicaria* and the biocontrol beetles at the Dingmans Ferry site.

Other important changes in the community composition with the Calcareous Riverside Outcrop and Calcareous Riverside Seep at the Dingmans Ferry site include the appearance of three new invasive exotic plant species and the spread of eight other previously documented invasive exotic species. Only two invasive exotic plant species showed any substantial declines between the two sampling periods. Data from this pilot study also suggest that native shrubs are being replaced by aggressive invasive exotic shrubs. This underscores the importance of monitoring and managing invasive exotic species at high priority natural resource sites such as Calcareous Riverside Outcrop and Calcareous Riverside Seep. Without intervention, species such as autumn olive (*Elaeagnus umbellata*), Morrow's honeysuckle (*Lonicera morrowii*), mile-a-minute (*Polygonum perfoliatum*), narrowleaf bittercress (*Cardamine impatiens*), common wormwood (*Artemisia vulgaris*), and true forget-me-not (*Myosotis scorpioides*) will likely continue to spread in the Dingmans Ferry site.

Species composition in plots in both 1998 and 2010 was strongly influenced by the location along the shoreline (i.e. proximity to the woodland versus the water) and the type of substrate (i.e. bare rock, litter, bare soil, and water). Hydrology strongly influenced the species composition in 1998, but not in 2010, probably due to the drier year in 2010 in which few seeps were present in August.

We were not able to document changes to the cover or richness of native or nonnative species between 1998 and 2010. However, changes in abundance for many individual species were documented. These changes highlight three processes occurring in the Calcareous Riverside Outcrop and Calcareous Riverside Seep communities: a) species migration within the site; b) inter-annual variation in composition due to varying hydrologic conditions; and c) species migration among riverine sites within the park. The migration of species among sites underscores the importance of maintaining all three Calcareous Riverside Outcrop and Calcareous Riverside Seep sites in DEWA. Maintaining multiple separate populations of rare plants that are within the dispersal distance for the species helps maintain genetic diversity and provides refugia for species when sites are disturbed. This is especially important in the dynamic riparian environment where disturbance is common.

This study also compared the original plot-based sampling methodology to a point-intercept sampling methodology. Though both methods yielded similar results, the plot method was clearly better at capturing more species and was more efficient per sampling unit. Similar results have been documented by numerous other studies (Floyd and Anderson 1987, Stohlgren et al. 1998, Symstad et al 2006).

Helm and Mead (2004) compared five methods of evaluating forest understory composition for reproducibility among observers, including the plot and point-intercept methods discussed here. They found that observer variances were generally similar among techniques and that observer variance was significant in most cases. No sampling method stood out as being more reproducible than others (Helm and Mead 2004). Similarly, Symstad et al (2006) found that both the plot and point-intercept methods are highly repeatable for most community-level variables and abundant species. However, species richness and cover for species of low abundance were not as repeatable with the point-intercept method when compared to the plot method. They concluded that there was no clear-cut advantage of using one method over the other (Symstad et al 2006).

Given these findings, the original plot method should be retained for future monitoring at the Dingmans Ferry site and other Calcareous Riverside Outcrop and Calcareous Riverside Seep sites in DEWA so that direct comparisons can be made with the 1998 data. Repeat sampling of these plots will increase the statistical power to detect trends over time. The arrangement of the three plots per transect also captures the diversity in species composition and environmental conditions from woodland to river and facilitates separate analyses for each zone of the site.

The point-intercept method could be appropriate for other rare riparian communities in the ERMN that do not exhibit strong environmental or species gradients from woodland to river. Such communities include the Riverscour Prairie in New River Gorge National River and Gauley River National Recreation Area, and the Northern Riverside Outcrop in the Upper Delaware Scenic and Recreational River. However, the plot method will likely be more cost-effective given that each sampling unit requires less time, and that more species are captured by the plot method. In addition, if woody species encroachment is a concern in these communities, line-intercept sampling could be employed on the same transects to monitor change in woody species cover.

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Appendix A. Plot Sampling Standard Operating Procedures.

Plot Sampling Standard Operating Procedures for the Dingmans Ferry site in the Delaware Water Gap National Recreation Area

The plot sampling consists of 50 transects stratified along the length of the site. Each transect contains three 1 m^2 plots, one each in the upper, middle, and lower sections of the transect, for a total of 150 plots throughout the site. Plant species and groundcover within the plot are characterized by percent cover.

Transect Set-Up

1) Locate the southern boundary point for the Location. Use previously documented GPS coordinates, tree tags, and location descriptions to locate the tagged trees that mark the Location Boundary. In general, the boundary location is directly in line with the marked tree, unless otherwise noted. The location boundary along the shoreline can be located by running a tape from the marked tree (or other noted location) directly towards the shoreline.

2) Potential Transect Positions occur every two meters along the baseline tape, beginning at 0 meters (the southern Location Boundary). Possible transect locations along the baseline tape are: 0 meters, 2 meters, 4 meters, and so forth to the final position which corresponds to the total length of the Location minus 2 meters. From a random number generator/table, an even number between 0 and (total Location length – 2) was selected in 1998. This randomly generated number is the Transect Position, in meters as measured from the southern Location Boundary.

3) Along the shoreline (where it is much easier to walk), place a surveyor's stake at the southern Location Boundary. Attach the zero end of the baseline tape to the surveyor's stake. Stretch the baseline tape to distance specified by the Transect Position along the baseline tape.

4) Transects are aligned perpendicular to the river shoreline at the Transect Position along the baseline tape. At the Transect Position, stretch a measuring tape that will serve as the transect upslope towards the woods. The crew member walking towards the woods should have the zero end of the tape and a non-declinated compass. At the edge of the woods, determine the location of the upper end of the transect. Since the upper end of the transect is not permanently marked, the location of the transect end will be subjectively determined based on these three criteria:

a) lower edge of a small rock ledge
b) break in slope from a steeper slope in the woods to a shallower slope on the shoreline
c) a line of small-trunked trees and saplings

5) Once the upper end of the transect has been determined, use the compass to sight the crew member standing at the Transect Position along the shoreline. A compass heading, in uncorrected magnetic degrees north, is taken from woodland edge looking toward the river. Move left or right until the crew member is sighted in the compass at the appropriate Transect Azimuth that was used in 1998. Secure the zero end of the tape with a surveyor's stakes at this point.

[Note on recording azimuths: For Latitude 41.218182 N and Longitude -74.86000 W, on Aug 15, 1998, the declination was 12º 54'W. On August 15, 2010, the declination was 12º 46'W. Given the similarity between these declinations, compasses were not declinated in 2010 in order to replicate the 1998 transect set up.]

6) Once the upper end of the transect is secured at the appropriate azimuth, stretch the tape to the water's edge. The distance to the water's edge is the Transect Length. Record the Transect Length on the datasheet. This may be different than the Transect Length recorded in 1998. Record the Transect Number, Transect Position, and Transect Azimuth on the datasheet. These should be the same as those recorded in 1998.

7) Crew members should walk only on the south side of the transect tape to avoid trampling vegetation. Put the tape in your left hand when walking away from the river to ensure that you are on the south side of the transect.

8) In 1998, the transect length was divided by 3, creating three sections of equal length in the transect: upper (closest to the woods), middle, and lower (closest to the water). When the resulting length of a section had a fraction other than 0.5, they rounded to the nearest whole or half number for the upper and middle sections. The length of the lower section was the remaining length of shoreline. For example: a Sample Transect of 11 meters long was divided into an upper and middle section each 3.5 meters long, and one lower section that was 4 meters long.

9) One plot is placed in each section, with Plot #1 in the upper section closest to the woods, Plot #2 in the middle section, and Plot #3 in the lower section closest to the river. Potential plot positions occur every 0.5 meters along the transect, beginning at 0 meters at the top of the transect closest to the woods. Possible plot locations along the transect are: 0 meters, 0.5 meters, 1 meters, 1.5 meters, and so forth to the final position which corresponds to the total transect length – 0.5 meters. For each section, a whole or half number between 0 and (section length – 0.5) was selected from a random number generator/table in 1998. The randomly generated number is the Plot Position, in meters as measured from the upper end of the transect. Plot position is recorded as total distance from the upper end of the transect, not the distance within a section. Record the Plot Position on the datasheet, using the values created in 1998. If the plot position in 2010 is the same as it was in 1998, record a "N" in the "New Position?" section on the datasheet.

10) If the current transect is shorter than the transect length specified in 1998, and the 1998 plot position for Plot #3 exceeds the current transect length, then place Plot #3 as close to the current water level as possible, such that:

a) the plot is located at a whole or 0.5 meter distance along the transect, and
b) the majority of the plot does not contain river water.

Record the new distance as the Plot Position for Plot #3 and record an "Y" in the "New Position?" section on the datasheet.

11) Place the plot on the up-river side (to the north) of the transect, with the up-slope, 2-meter long edge of the plot was aligned on the randomly selected Plot Position point. Place the plot as

close to perpendicular with the transect as possible. Align the outer edge of the short side of the quadrat with the outer edge of the transect tape.

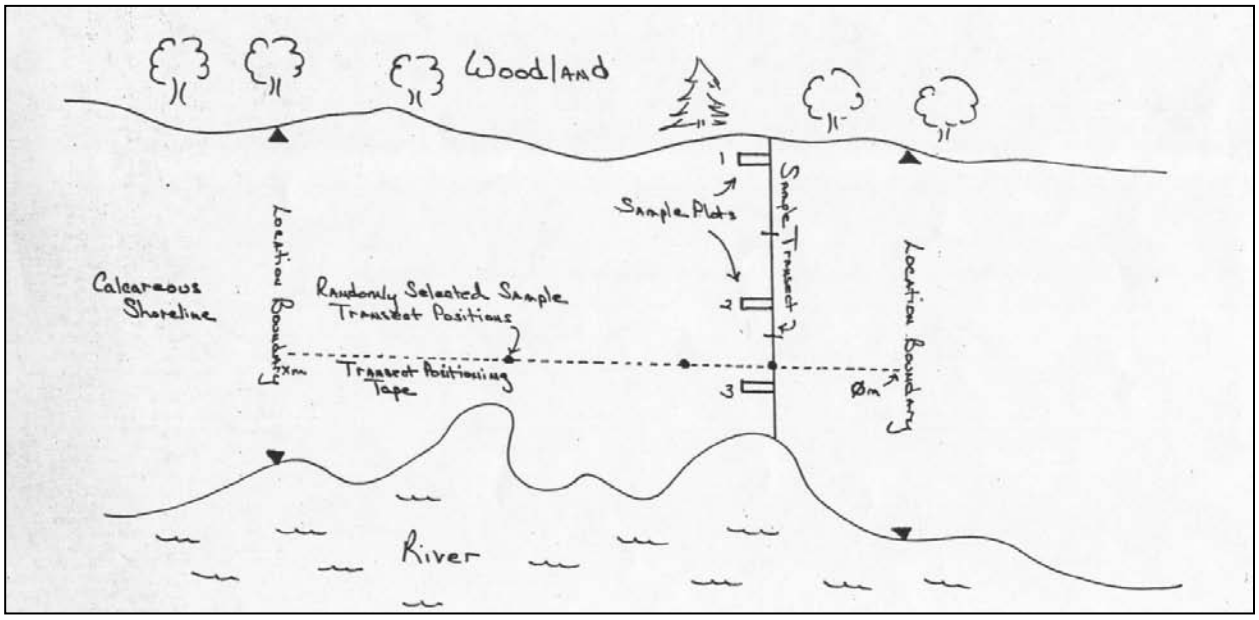

Figure A1. Diagram of transect and plot positions at Digman's Ferry monitoring site.

<u>Data Collection</u>
The following fields are recorded on the datasheet:

1) <u>Date:</u> month, day and year sampling occurred.

2) <u>Observers</u>: first and last name of all crew members.

3) <u>Location Number:</u> number assigned in 1998 to that Substrate Location within the site.

4) <u>Transect Number:</u> number assigned to that transect within the Location. Transects are numbered sequentially from south to north within a Location. Use the transect number assigned in 1998 to that transect within the Location.

5) <u>Transect Position:</u> position of the transect within the Location. This number is the distance in meter from the southern Location Boundary. This number was randomly generated in 1998. Use the position assigned in 1998 to that transect.

6) <u>Transect Azimuth:</u> A compass heading, in uncorrected magnetic degrees north, taken from woodland edge looking toward the river. Use the azimuth assigned in 1998 to that transect.

8) <u>Transect Length:</u> Length in meters of transect stretched perpendicular to the river shoreline. See Transect Set-up above for criteria on determining the location of the upper end of the

transect. The lower end of the transect is the current water's edge. The transect length will be different than that recorded in 1998.

Plot Characterization

Plot #1 is located in the upper section of the transect, closest to the woods. Plot #2 is in the middle section, and Plot #3 is located in the lower section of the transect, closest to the river. For each of the three plots within a transect, record:

1) Plot Position: position of the plot along the transect. This number is the distance in meters as measured from the upper end of the transect closest to the woods. This number was randomly generated in 1998. Use the plot position specified in 1998 unless the water level prohibits it. See Transect Set-Up above for directions if the 1998 plot position is under water.

2) New Plot Position: Record "N" if the 2010 plot position is the same as the 1998 position. Record "Y" is the 2010 plot position is different than the 1998 plot position. "Y" should be recorded only for Plot 3 in cases where the 1998 plot position is under water.

3) Hydrology: Use the following codes:

1 – seep: water or damp areas in rivulets, cracks or drainages down the slope of the shoreline, typically originating from the edge of the wooded slope or cracks in the bedrock. Dampness from rain does not count as a seep.

2 – dry: no current evidence of water seeping from or over the ground.

3 – shoreline: plots that contain water from the current level of the Delaware River, including any Plot #3 that had to be moved to due higher current water levels.

4 – seep, now dry: obvious evidence that seeps occurred in the plot earlier in the year. Drainage patterns from rainfall do not count as seeps.

5 – combination of seep and dry within the plot

6 – combination of dry and shoreline within the plot

4) Plot Characterization: Estimate to the nearest percent the percent cover within the plot for the following categories:

Bare rock
Bare soil
Litter (all dried plant material and fallen leaves resting on the ground)
Garbage
Moss

The percent cover values for the first four categories (excluding Moss) should add up to 100%.

5) Canopy Cover: Estimate to the nearest percent the percent cover of canopy over the plot. Canopy cover includes any woody species greater than 2 meters in height that is overhanging the edges of the plot.

Species Sampling

1) To facilitate more accurate and consistent sampling, each plot was sampled ¼ meter at a time by placing additional 0.5 meter poles across the plot at 0.5 meter intervals. In extremely dense

vegetation, each quarter meter was further divided into four sections with crossed 0.5 meter poles.

2) Identify each plant within the plot to the most specific taxonomy possible. Species names follow the Master Plant List in the ERMN Vegetation and Soil Monitoring Database, which is based on the USDA PLANTS Database. If neither species nor genus can be determined due to the immaturity of the plant, damage or senescence, assign the plant an unknown morphotype number or place it in one of the categories of unknowns: dicot, monocot, grass, or sedge. All vascular plant species that have any living part overhanging or rooted within the plot, within 2 meters of the ground, should be recorded.

3) Record your level of confidence in the species identification for each plant. Your confidence in the identification is independent of the level of taxonomic specificity. You could be very confident in a plant identified only to family, (e.g. Species = Orchidacea; Confidence = 1) because you are sure that it is in that family, but have no idea which genus it is. Similarly, you could be not very confident in a genus- or species-level identification (e.g. Species = Dryopteris sp.; Confidence = 3) for obscure, small, or un-collectable individuals. Use the following codes:

1 = confident
2 = somewhat confident
3 = not very confident

4) After identifying all species within the plot, estimate the percent cover of each species to the nearest 1 percent. Consider all living plant parts overhanging or rooted within the plot, within 2 meters of the ground. To facilitate quick, accurate, and consistent estimates, use the scale of one fist, held no more than one foot (30 cm) above the vegetation, equal to 1 percent cover. The purple and white squares painted on the plot poles each represent 1%. These should be used to help visualize the percent cover of species. If a species covers significantly less than 1%, but is present in the plot, record 1% for percent cover. In 1998, "P" was used to record cover for these "present" or "trace" species. Total percent vegetation cover greater than 100% is possible due to the structural complexity of the vegetation. Total percent cover less than 100% is also possible in sparse vegetation.

Purple Loosestrife Sampling

If purple loosestrife (*Lythrum salicaria*) occurs in the plot, two additional values are recorded.

1) Number of Stems: Record the number of stems of purple loosestrife contained within the plot. Number of stems is a unit of identification that is clearly defined, easy to identify, and is a reproducible measure between individual surveyors and different years of sampling. It also does not require a distinction between ramets and genets.

2) Average Percent Foliar Damage: Consider all purple loosestrife leaves that are overhanging or within the plot. Estimate the average percent defoliation or visible damage among all the leaves. Use the following percent categories: 0-1; 1-5; 5-25; 25-50; 50-75; and 75-100%.

Equipment List

GPS unit

Surveyors stakes

Flagging

Baseline measuring tape (100-m)

Transect measuring tape (30-m)

Compass

1-m^2 plot (pvc or wooden)

The Sample Plot is 1 $meter^2$ and measures 2 meters by 0.5 meter. In 1998, four narrow (1.25 cm in diameter) wooden poles were used to demarcate the four sides of each plot. They recommended using square rather than round poles so that the poles stay in position and do not roll down the shoreline slope. Poles also can have eye hooks screwed into the ends, which enable the surveyor to anchor two sides of the plot together with surveyor's stakes. In 2010, 1.25 cm PVC pipe with elbow joints was used to construct the plot. Purple squares were painted with PVC primer on the plot poles to represent 1% to the plot area.

Clipboard

Pencils

Datasheets on plain and Rite-in-the-Rain paper

Appendix B. Location Boundary Descriptions.

Description of Substrate Locations and Placement of Location Boundary Markers (Tree Tags) at the Dingman's Ferry Site

(Adapted from Shank and Shreiner (1999), updated by S. Perles and J. Shreiner in 2010)

SITE ACCESS: The northern quarter mile of the site is heavily used by fishermen and there was occasional evidence of use in the form of litter and trampled vegetation. Fortunately, the remainder of the site was relatively free of all but occasional anthropogenic disturbance.

Northern End: Just east of the Digman's Ferry Bridge, park in the small pull-out on the south side of Route 560. Walk down the heavily used fisherman's trail to the river. You will enter Location 18 at the river.

Middle(ish): From Route 560, east of the Digman's Ferry Bridge, turn south onto Old Mine Road. Drive approximately 550 meters and park in a small pull-out on the west side of the road. Just upslope from the pull-out, there is an old woods road that will lead you down slope, paralleling the river, approximately 600 meters to Location Boundary 10/11 (Tree Tag #10).

Southern End: From Route 560, east of the Digman's Ferry Bridge, turn south onto Old Mine Road. Continue to the stop sign in Peters Valley. Turn right to stay on Old Mine Road. When Old Mine Road comes to a T at the Lennington Farm, park there in the old farm driveway. Hike 850 meters through the farm fields and then downslope through the woods to Location 1. In a 4WD vehicle with clearance, you can drive through the fields (generally staying to the right (north) of the wooded fence row) to within 200-300 meters of Location 1.

TAG NUMBERS: Tag numbers correspond to the assigned Location number immediately to the south of the substrate boundary that is marked. In general, the boundary location is directly in line with the marked tree, unless otherwise noted. The location boundary along the shoreline can be located by running a tape from the marked tree (or other noted location) directly towards the shoreline.

SOUTHERN BOUNDARY OF SITE: Tag #0 - Tag placed at a height of approximately 6 and ½ feet on the down-river side of a white ash (*Fraxinus americana*). The tree has a crack at its base and is growing over three rock slags that are as wide as the base of the trunk.

Location 1 - Substrate 1: solid outcrop with few crevices. The total length of this location is approximately 30 meters.

LOCATION BOUNDARY 1/3: Tag #1 - Tag placed at a height of approximately 6 and ½ feet on the down-river side of a sugar maple (*Acer saccharum*). Tree is about 10 meters above the woodland edge bank. Numerous small trees are between the *A. saccharum* and the river shoreline.

Location 3 - Substrate 2: latticed outcrop. This Location (7/30/97) includes two previously designated Locations, 2 and 3. The southern 15 meters are fissured with a near perfect lattice pattern and dense vegetation in the crevices. The northern part of Location 3 has large open rock areas with predominantly diagonal crevices and several horizontally oriented crevices. The total length of this location is approximately 44 meters.
NOTE: There is no Location 2.

LOCATION BOUNDARY 3/4: Tag #3 - Tag placed at a height of approximately 6 and ½ feet on the down-river side of a sugar maple (*Acer saccharum*). NOTE: The tree is approximately 4 meters up-river from the actual boundary. The tree is immediately above a 2 foot high rock ledge.

Location 4 - Substrate 1: solid outcrop with few crevices. This location is very long, continuous, and sparsely vegetated with occasional clusters of *Melilotus alba* dominated vegetation in heavily creviced areas. The southern end of the location is delineated by a 2 foot ledge running northeast to southwest across the slope. There are two seep areas within this location. The most southern seep is extensive and appears to have a less variable flow rate. The upper slope of Location 4 has a 0.5 meter ledge at the woodland edge. The total length of this location is approximately 278 meters.

LOCATION BOUNDARY 4/5: Tag #4 - Tag placed at a height of approximately 6 and ½ feet on the down-river side of a white pine (*Pinus strobus*).

Location 5 - Substrate 2: latticed outcrop. The vegetation and substrate in this location are very variable. The southern end of the location contains large flat outcrop areas that are several meters wide. These open areas are dwarfed by wide, dense bands of vegetation growing between the rocks. Some areas contain very dense stands of *Phalaris arundinacea* and fine cobbles, while other sections within this location have small (less than 20 meters wide), solid limestone outcrops. The total length of this location is approximately 158 meters.

LOCATION BOUNDARY 5/6: Tag #5 - Tag placed at a height of approximately 6 and ½ feet on the down-river side of a very large hemlock (*Tsuga canadensis*). Hemlock has two main trunks.

Location 6 - Substrate 1: solid outcrop. Location 6 begins (southern end) with a 50 to 70 meter wide section of solid outcrop, followed by a short (<15 meter) cobbled section and then a seep on ledged bedrock. A band of dense vegetation in a finely cobbled area, which is less than 20 meters wide, is adjacent to the seep area. As one moves north through the site, one will encounter a dry barren outcrop, a second band of dense vegetation, and a final seep that extends over approximately 20 meters. The total length of this location is approximately 157 meters.

LOCATION BOUNDARY 6/7: Tag #6 - Tag placed at a height of approximately 6 and ½ feet on the down-river side of a large chestnut oak (*Quercus prinus*). The tree has a gracefully curved trunk and is up a small bank approximately 10 meters from the woodland edge. In 2010, this tree appeared to be approximately 6 meters from the woodland edge and was tagged with a **new tag #7**.

Location 7 - Substrate 3: cobbled substrate. This location has very dense vegetation (*Melilotus alba* dominated in 1997 but not in 1998) cover. There are significant alluvial deposits between medium to fine cobbles and an occasional large rock. The substrate becomes more cobbled as one moves north through the site and includes sections of large flat boulders. The composition and density of the vegetation is constant throughout the location. Seeps in open, cobbled areas are interspersed throughout the northern half of Location 7. This is a very long location (approximately 0.34 miles long). The total length of this location is approximately 500 meters.

LOCATION BOUNDARY 7/8: Tag #7 - Tag placed at a height of approximately 6 and ½ feet on the down-river side of a red oak (*Quercus rubra*). Tree is atop a small, 1 meter high, bank and is among a cluster of 5 red oak trees. The tagged tree is the most southern of the three trees located on the edge of the bank. In 2010, a **new tag #100** was placed adjacent to the old tag.

Location 8 - Substrate 1: solid outcrop. Location is about 70 meters long and disrupted by several areas of dense vegetation. The southern end is ledged and contains a seep. All crevices are densely vegetated with *Lythrum salicaria, Asclepias* species, and *Melilotus alba*.

LOCATION BOUNDARY 8/9: Tag #8 - Tag placed at a height of approximately 6 and ½ feet on the down-river side of a red oak (*Quercus rubra*). The tree is rooted in the middle of a 3 meter high bank and has a radius of approximately 10 inches. A basswood tree (*Tilia americana*) is down slope and about 1 meter north of the tagged oak tree.

Location 9 - Substrate 3: cobbled substrate. Area is very finely cobbled and very densely vegetated. The total length of this location is approximately 79 meters.

LOCATION BOUNDARY; 9/10: Tag #9 - Tag placed at a height of approximately 6 and ½ feet on the down-river side of a white ash (*Fraxinus americana*). The tree is at the top of a 3 meter woodland bank. A small sugar maple (*Acer saccharum*) is immediately in front of the ash, but below the bank and on the sloping shoreline. In 2010, the original ash tagged with #9 was located, however, the tree was dead. A new white ash was marked with tag #9, approximately 6.5 feet up on the downriver side of the bole. The new ash is 6.8 meters downriver from the original white ash, and therefore is 6.8 meters downriver from the Location Boundary. The new ash is on the top of the slope directly behind a large black birch that is heavily leaning over the river. The new ash is 11 meters downriver from a 10" DBH American chestnut.

Location 10 - Substrate 2: latticed outcrop. Location 10 is very long (approximately 0.2 miles; estimated length is approximately 367 meters) and highly variable. It has large expanses of solid, rock outcrop fissured by horizontal and vertical crevices that are 10 to 20 cm wide. Dense vegetation grows in these crevices. The northern section of Location 10 becomes very densely vegetated, but the large, flat expanses of rock are still evident and not of the cobbled type. A band of small cobbles develops in the mid-slope of this northern area but is bounded by large rock slabs on the upper and lower slopes.

LOCATION BOUNDARY 10/11: Tag #10 - Tag placed at a height of approximately 6 and ½ feet on the down-river side of a white ash (*Fraxinus americana*). The tree has a split trunk and is growing in the middle of a rocky, gently sloped bank. There is a second larger white ash 3 meters up-slope and slightly up-river from the tagged tree.

Location 11 - Substrate 3: cobbled substrate. The southern part of Location 11 contains fairly large stones, but greater than 50% of the surface area is covered with alluvial deposits and soil. The location is primarily coarsely cobbled. The vegetation is dense, primarily *Phalaris arundinacea*, in the open cobbled areas. The estimated length of Location 11 is approximately 85 meters long.

LOCATION BOUNDARY 11/12: Tag # 11 - Tag placed at a height of approximately 6 and ½ feet on the down-river side of a tulip-tree (*Liriodendron tulipifera*). There is a dense stand of *Physocarpus opulifolius* at the woodland edge. The tagged tree is one of 6 clustered tulip-trees, and is the middle tree of the three that are closest to the river.

Location 12 (H) - Substrate 1: solid outcrop. This is a very large expanse (estimated length is 100 meters) of solid rock outcrop about 0.5 miles south of the Dingman's Ferry Bridge. The southern half has numerous fissures with very low vegetation in the crevices. The northern section of Location 12 is a seep on solid bedrock with few fissures.

LOCATION BOUNDARY 12/13: Tag #12 - Tag placed at a height of approximately 6 and ½ feet on the down-river side of an American basswood (*Tilia americana*). The tree is at the base of the woodland bank and is approximately 4 meters north of the actual boundary.

Location 13 (G) - Substrate 2: latticed outcrop. This area begins with a short (0.5 meter), gradual transition from of cobbled substrate, which then becomes heavily latticed substrate. The remainder of Location 13 is latticed bedrock with horizontally and vertically oriented crevices. The total length of this location is approximately 100 meters.

LOCATION BOUNDARY 13/14: Tag #13 - Tag placed at a height of approximately 6 and ½ feet on the down-river side of a red oak (*Quercus rubra*). Tree is large: DBH approximately 1.5 to 2 feet. A second red oak is down slope from the tagged tree. A cluster of young hemlocks, *Tsuga canadensis*, is on the down-river side of the two oak trees.

Location 14 (F) - Substrate 1: solid outcrop. This location is very long (approximately 374 meters) and consists of a fairly continuous solid outcrop that is only sporadically broken by short (< 10 meter), cobbled sections and dense vegetation. A seep occurs on the southern end adjacent to a small ledge. This is followed by a wide dry section which is near the 'natural steps' that lead up to the large *Carex deweyana* population. There are occasional seeps in the next ledged and basically dry area, which becomes more heavily 'ledged' as one moves north. This is followed by a seep that extends through geometric ledges and a 0.5 meter ledge, which is adjacent to and a few meters south of 'Triangle Spring'. 'Triangle Spring' is a shallow spring pool that is contained by what looks like a manmade, concrete berm. This is at the base of a 3 to 5 meter high rocky bank that looks like 'stacked' outcrop ledges. There are additional small pools downslope from 'Triangle Spring' and *Lythrum salicaria* is prevalent throughout the downslope area. This seep is very extensive (total length 45 to 50 meters) and continues north for an additional 30 meters where it ends near the most southern set of cinder block steps. Sections of the seep are periodically dry during the summer. The lower third of the slope in the next section is cobbled substrate with dense *Lythrum salicaria*. A dry area lies between the very large, second seep area and the third, 20 to 30 meter wide, seep. The mid- and lower-slopes are cobbled and moderately vegetated. The location ends at the north with large (> 1 meter wide) rock slabs that are interspersed with 20 to 50 cm wide crevices and dense vegetation. The lower half of the slope in this area also is cobbled. This last section is too short to be considered a new location. *Lythrum salicaria* is present throughout this Location in cobbled lower slope areas.

LOCATION BOUNDARY 14/15: Tag #14 - Tag placed at a height of approximately 6 and ½ feet on the down-river side of a young red oak (*Quercus rubra*). DBH of tagged tree estimated at 6 to 8 inches. Tree is located at the woodland edge.

Location 15 (E) - Substrate 2: latticed outcrop. The total length of Location 15 is about 50 meters. The location is interspersed with heavily creviced areas. These heavily creviced areas have narrow (< 5 cm) cracks and greater than 90% coverage of bedrock. The southern end of Location 15 is finely cobbled but the spaces between cobbles are very narrow, and hence considered part of the same substrate. There is a 2 meter high rock ledge on the upper slope. A seep occurs in the middle of the location where the midslope area is solid bedrock and the up-slope area is cobbled.

LOCATION BOUNDARY 15/16: Tag #15 - Tag placed at a height of approximately 6 and ½ feet on the down-river side of a red oak (*Quercus rubra*). The tagged tree is located in the middle of the woodland bank and has a split trunk at the base. The smaller of the two trunks wraps around the east side of the larger trunk. A young *Ulmus rubra* is at the base of the bank below the tagged oak.

Location 16 (D) - Substrate 1: solid outcrop. A seep extends over the most northern 5 to 10 meters of cobbled substrate in Location 16. The rest of the location is solid bedrock. Half of the area is seep and half is dry. The area below the solid outcrop and along the river's edge is cobbled with alluvial deposits. The total length of this location is approximately 55 meters.

LOCATION BOUNDARY 16/17: Tag #16 - Tag placed at a height of approximately 6 and ½ feet on the down-river side of a very tall, and straight *Fraxinus americana*. Tree is along the woodland edge but is not on the bank.

Location 17 (C) - Substrate 2: latticed outcrop of large solid bedrock slabs with horizontal and vertical cracks. Location includes a dense band of *Lythrum salicaria* about 2 to 3 meters from the water's edge. A small 10 meter section of dense vegetation on cobbled substrate occurs in the middle of the location. The total length of this location is approximately 42 meters.

LOCATION BOUNDARY 17/18: Tag #17 - Tag placed at a height of approximately 6 and ½ feet on the down-river side of a silver maple (*Acer saccharinum*). The tagged tree is heavily ice scoured and is at the edge of a flat wooded 'plateau' in front of a steep 15m high bank. In 2010, this tree was heavily covered in poison ivy vines.

Location 18 (B) - Substrate 3: cobbled substrate. This location is approximately 30 meters long and supports a moderately dense cover of vegetation. There is a 10 to 15 meter wide area of relatively rock free, alluvial deposit within this location. *Lythrum salicaria* is the most dominant species in this location.

LOCATION BOUNDARY 18/19: Tag #18 - Tag placed at a height of approximately 6 and ½ feet on the down-river side of a sugar maple (*Acer saccharum*). The tagged tree is set back from the rivershore on the top of a steep woodland bank. It is about 18m up-slope from the access path leading to the river from the parking area near the bridge.

Location 19 (A) - Substrate 4: alluvial shoreline. The surface is covered with thick alluvial deposits and very little bedrock. Many well-worn paths bisect this area and are testimony to the heavy recreational use of this northern part of the site. The northern boundary of this Location was arbitrarily designated as the bridge. This substrate continues north of the bridge. However, since we did not find any elements in this Location and substrate class we did not expend the effort to search north of the bridge. We made an initial exploration of the area north of the bridge, which did not produce any elements. The total length of this location is approximately 43 meters.

Appendix C. Analysis of 1998 Plot Data.

Analysis of the 1998 Plot Data from the Dingmans Ferry site in the Delaware Water Gap National Recreation Area

The 1998 plot data from the Dingmans Ferry Calcareous Rock Outcrop and Calcareous Seep were analyzed in spring of 2010 while planning for the 2010 sampling. The objective of this analysis was to determine if the 1998 sampling design adequately captured the variation in the site's vegetation. In particular, we examined whether substrate, the sampling Locations, plot position, and hydrology had detectable influences on the vegetation.

A non-metric multidimensional scaling analysis was run in the software package R 2.8.0 (R Development Core Team, 2008) on the 1998 plot data from the Digman's Ferry site. The resulting ordination diagram from this analysis shows each plot graphed in two-dimensional space based on the similarity (or dissimilarity) in species composition among the plots. Plots in these diagrams tend to group by several environmental factors. Groupings are shown in two ways: 1) a `spider' diagram in which each plot is connected to the group centroid, and 2) a 'hull' diagram in which lines for the convex hulls encircle the plots in the groups.

As shown in the graphs below, plot position and hydrology seem to be influential on species composition, since plots of similar position and hydrology tend to group together. There does not appear to be distinct groupings among the substrate types or among the Locations. Since the Locations were defined subjectively according to the substrate type, and substrate type does not seem to greatly influence species composition, future sampling need not be stratified by substrate type. In addition, the two community types described from the 1998 data rely more heavily on hydrology and species composition than on substrate type. Furthermore, several different substrate types are listed in each community description.

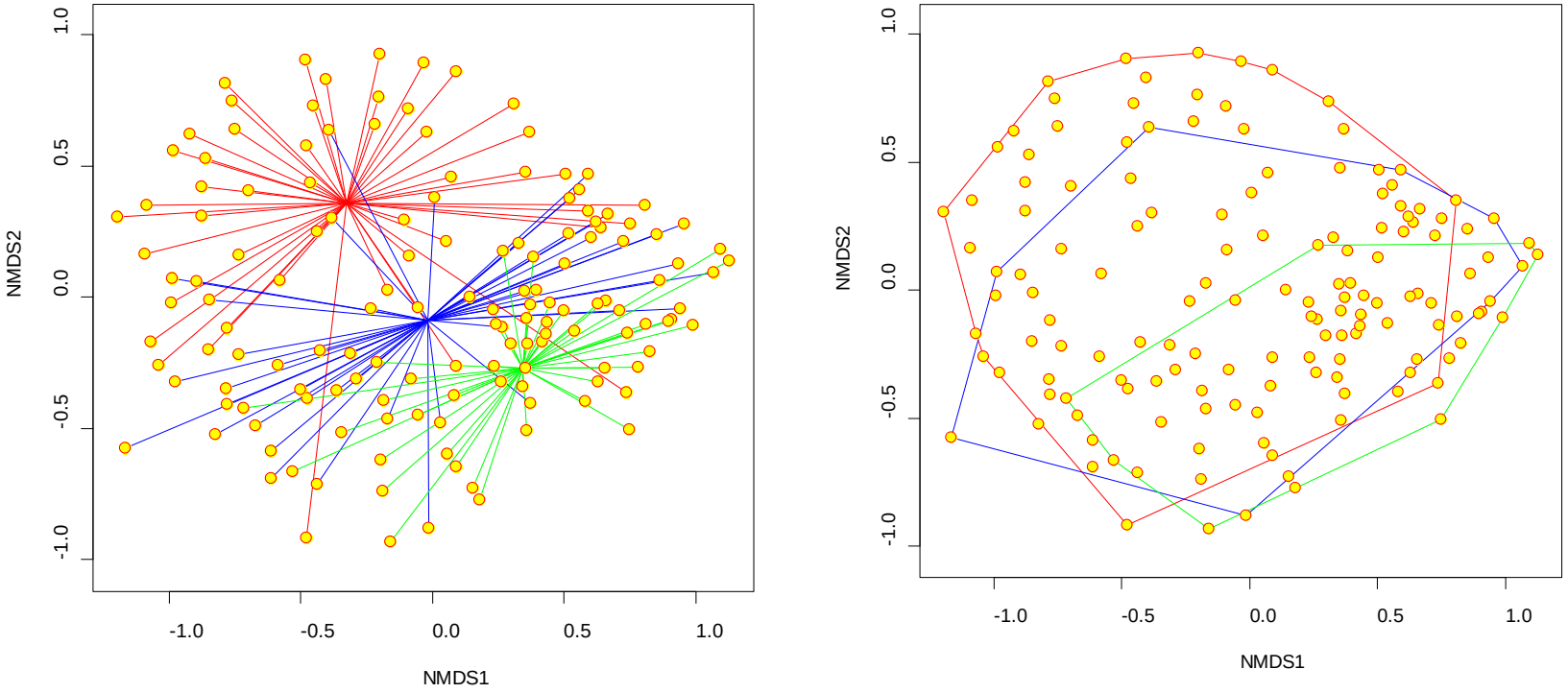

Figure C1. Ordination diagram from the non-metric multidimensional ordination analysis (NMS) showing plots grouped by plot position. Red indicates Plots 1 (plots closest to woods). Blue indicates Plots 2 (midslope plots). Green indicates Plots 3 (plots closest to river).

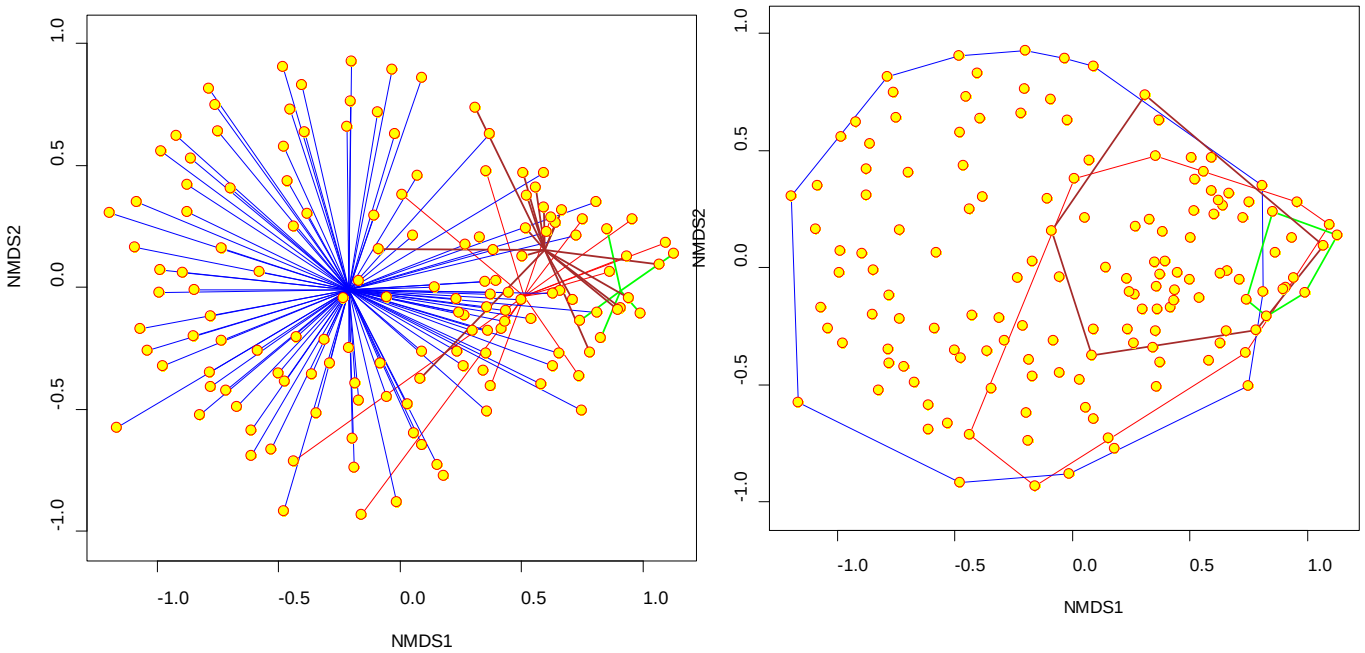

Figure C2. Ordination diagram from the non-metric multidimensional ordination analysis (NMS) showing plots grouped by hydrology. Red indicates seeps. Blue indicates dry plots. Green indicates shoreline. Brown indicates a seep that dried later in the year.

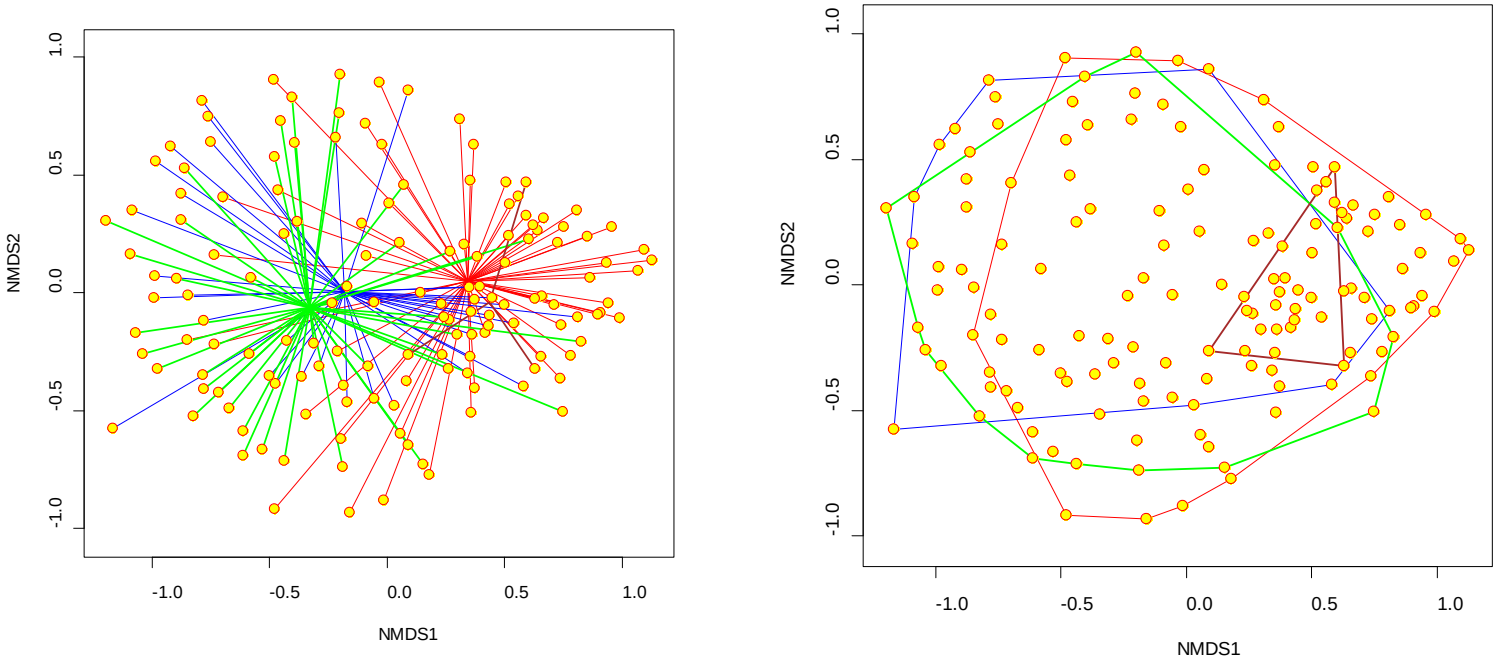

Figure C3. Ordination diagram from the non-metric multidimensional ordination analysis (NMS) showing plots grouped by substrate. Red indicates solid rock outcrop. Blue indicates latticed rock outcrop. Green indicates cobble. Brown indicates a alluvial substrate.

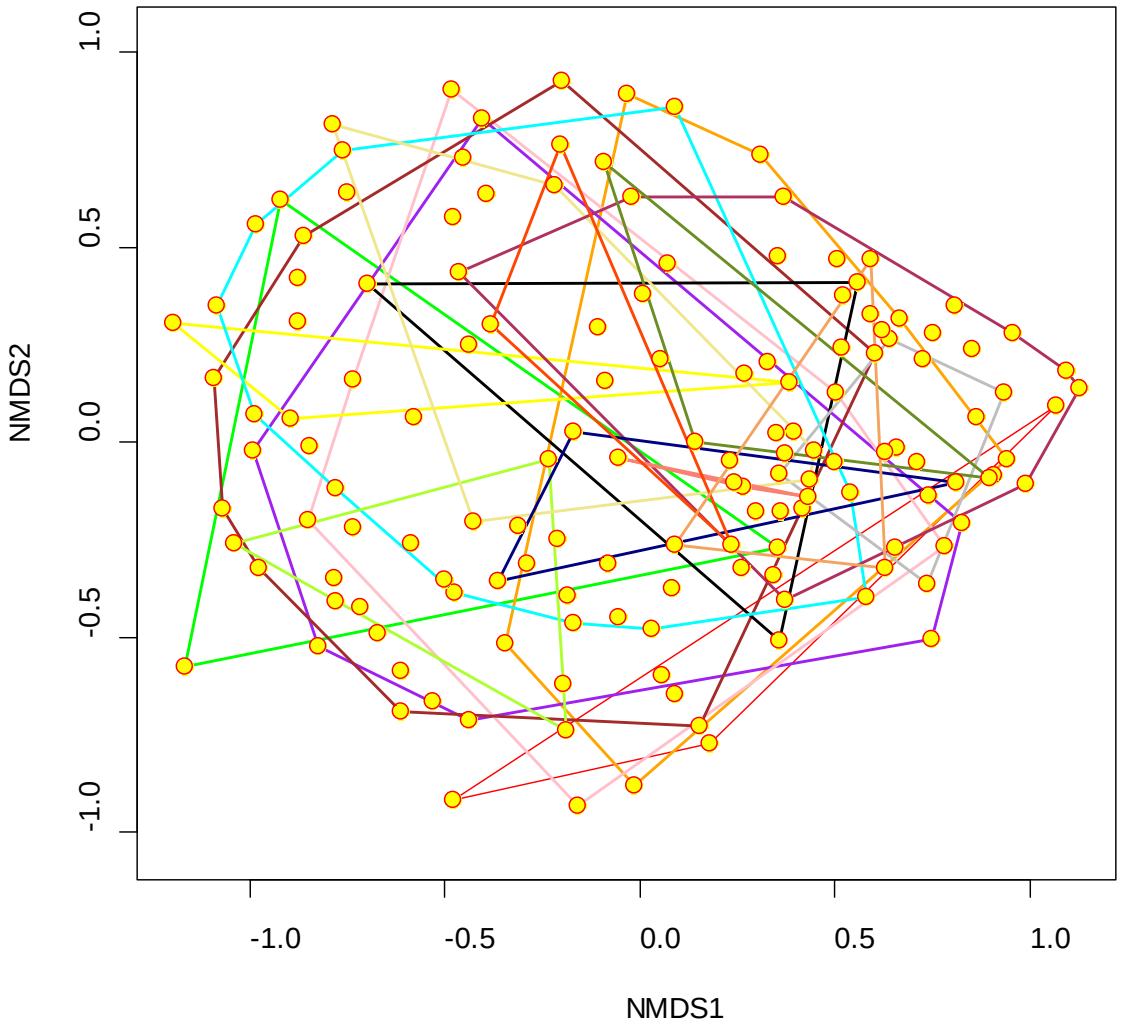

Figure C4. Ordination diagram from the non-metric multidimensional ordination analysis (NMS) showing plots grouped by Location. Each of the 19 locations is shown in a different color.

Appendix D. Transect and Plot Position Information for Plot Sampling.

Location	Transect	Transect Position (m)	Transect Azimuth	1998 Transect Length (m)	2010 Transect Length (m)	Plot Number	1998 Plot Position (m)	2010 Plot Position (m)	Plot Position Different?
1	1	4	319	15	13.5	1	3	3	No
						2	7.5	7.5	No
						3	11	11	No
3	1	8	312	14.5	13.5	1	2	2	No
						2	5.5	5.5	No
						3	12	12	No
4	1	26	309	17.5	17	1	1	1	No
						2	7	7	No
						3	12.5	12.5	No
4	2	118	306	16	14	1	2.5	2.5	No
						2	5.5	5.5	No
						3	14	13.5	Yes
4	3	148	308	16	16	1	3	3	No
						2	6	6	No
						3	12	12	No
4	4	176	308	18.5	18	1	2	2	No
						2	10	10	No
						3	14.5	14.5	No
4	5	180	310	18	18	1	5.5	5.5	No
						2	8.5	8.5	No
						3	14.5	14.5	No
4	6	222	312	16.5	16.5	1	3	3	No
						2	5.5	5.5	No
						3	16	16	No
5	1	24	315	17.5	15.5	1	4	4	No
						2	10.5	10.5	No
						3	15.5	15	Yes
5	2	26	313	15	13.5	1	4.5	4.5	No
						2	6.5	6.5	No
						3	12.5	12.5	No
5	3	66	313	15	14	1	0	0	No
						2	5.5	5.5	No
						3	14.5	13.5	Yes
6	1	54	313	15.5	14	1	1.5	1.5	No
						2	7	7	No
						3	13	13	No
6	2	70	310	12.5	11	1	3.5	3.5	No
						2	5.5	5.5	No
						3	10	10	No
6	3	100	308	13.5	13.5	1	2	2	No
						2	4.5	4.5	No
						3	10	10	No
7	1	30	310	12	8.5	1	3.5	3.5	No
						2	5.5	5.5	No
						3	10	8	Yes
7	2	118	314	12.5	11	1	0.5	0.5	No
						2	7	7	No
						3	9	9	No
7	3	138	313	14.5	12.5	1	2	2	No
						2	7.5	7.5	No
						3	12.5	12	Yes

Location	Transect	Transect Position (m)	Transect Azimuth	1998 Transect Length (m)	2010 Transect Length (m)	Plot Number	1998 Plot Position (m)	2010 Plot Position (m)	Plot Position Different?
7	4	150	315	14.5	13	1	4	4	No
						2	8.5	8.5	No
						3	13	13	No
7	5	224	315	15	12	1	2	2	No
						2	9	9	No
						3	11.5	11	Yes
7	6	234	315	13.5	12.5	1	1.5	1.5	No
						2	6.5	6.5	No
						3	11.5	11.5	No
7	7	258	315	15	13.5	1	0	0	No
						2	9	9	No
						3	13.5	13	Yes
7	8	316	315	15.5	15.5	1	3	3	No
						2	7.5	7.5	No
						3	12	12	No
7	9	402	315	13	12	1	3	3	No
						2	8.5	8.5	No
						3	10	10	No
7	10	454	315	12.5	12	1	3	3	No
						2	4	4	No
						3	8.5	8.5	No
8	1	6	315	15	15	1	2.5	2.5	No
						2	5	5	No
						3	13.5	13.5	No
9	1	24	307	12.5	12	1	2	2	No
						2	5	5	No
						3	10.5	10.5	No
10	1	0	307	17	17	1	0	0	No
						2	6	6	No
						3	15.5	15.5	No
10	2	90	310	20.5	18.5	1	2.5	2.5	No
						2	11	11	No
						3	15	15	No
10	3	114	311	20	19.5	1	0.5	0.5	No
						2	11	11	No
						3	18.5	18.5	No
10	4	136	312	18.5	18	1	2.5	2.5	No
						2	6.5	6.5	No
						3	15.5	15.5	No
10	5	152	312	19	19	1	2	2	No
						2	10.5	10.5	No
						3	14.5	14.5	No
10	6	176	315	20.5	19.5	1	0	0	No
						2	13.5	13.5	No
						3	15	15	No
10	7	234	314	18.5	18.5	1	3	3	No
						2	9	9	No
						3	14.5	14.5	No
11	1	28	310	18	18	1	1	1	No
						2	6	6	No
						3	12	12	No
12	1	20	308	16.5	17	1	5	5	No
						2	8.5	8.5	No
						3	15.5	15.5	No

Location	Transect	Transect Position (m)	Transect Azimuth	1998 Transect Length (m)	2010 Transect Length (m)	Plot Number	1998 Plot Position (m)	2010 Plot Position (m)	Plot Position Different?
12	2	24	310	17	17.5	1	4	4	No
						2	10.5	10.5	No
						3	15.5	15.5	No
13	1	68	309	27	26	1	1	1	No
						2	12	12	No
						3	19.5	19.5	No
13	2	86	308	21.5	21.5	1	2	2	No
						2	11	11	No
						3	16	16	No
14	1	90	307	21.5	21	1	4.5	4.5	No
						2	7	7	No
						3	21	20.5	Yes
14	2	142	308	19.5	18.5	1	6	6	No
						2	6.5	6.5	No
						3	14.5	14.5	No
14	3	154	302	18	15.5	1	1	1	No
						2	9.5	9.5	No
						3	12.5	12.5	No
14	4	200	321	17	19	1	4	4	No
						2	7.5	7.5	No
						3	16.5	16.5	No
14	5	234	314	15.5	14.5	1	1.5	1.5	No
						2	9.5	9.5	No
						3	13.5	13.5	No
14	6	250	311	21	21.5	1	1	1	No
						2	13	13	No
						3	20.5	20.5	No
14	7	286	314	17	19.5	1	5	5	No
						2	5.5	5.5	No
						3	13.5	13.5	No
15	1	12	303	21.5	21	1	5	5	No
						2	8.5	8.5	No
						3	19.5	15.5	Yes
16	1	6	299	21	21	1	1	1	No
						2	9	9	No
						3	15.5	15.5	No
17	1	36	290	16	15	1	2.5	2.5	No
						2	5.5	5.5	No
						3	14	14	No
18	1	2	297	17.5	18	1	4	4	No
						2	8	8	No
						3	15.5	15.5	No
19	1	26	283	5.5	5.5	1	0	0	No
						2	3	3	No
						3	4.5	4.5	No

Appendix E. Plot Sampling Data Sheet.

DINGMAN'S FERRY- COMMUNITY SAMPLING DATA SHEET

DATE ________________ OBSERVERS ______________________________

LOCATION #______ TRANSECT # ______

TRANSECT POSITION _______m TRANSECT AZIMUTH _______

TRANSECT LENGTH ________m

1=seep, 2=dry, 3=shoreline, 4=seep, now dry, 5=1 & 2, 6=2 & 3

Plot #	Plot Position	New	Hydrology	Bare Rock	Bare Soil	Litter	Garbage	Moss	Canopy Cover	*Lythrum* # Stems	*Lythrum* % Defol
1											
2											
3											

Defol: 0-1; 1-5; 5-25; 25-50; 50-75; 75-100

SPECIES	Percent Cover Plot 1	Plot 2	Plot 3	NOTES

Appendix F. Point Intercept Sampling Standard Operating Procedures.

Point Intercept Sampling Standard Operating Procedures for the Dingmans Ferry site in the Delaware Water Gap National Recreation Area

This sampling consists of 67 transects stratified along the length of the site. A sampling pole was systematically lowered along each transect at 0.5-m intervals and "hits" were tallied when contact was made with a plant species or groundcover class. Percent cover was calculated as the number of hits for each plant species or groundcover class divided by the total number of samples per transect.

Transect Set-Up

1) Locate the southern boundary point for the Section. Use previously documented GPS coordinates, tree tags, and location descriptions to locate the tagged trees that mark the Location Boundary. In general, the boundary location is directly in line with the marked tree, unless otherwise noted. The location boundary along the shoreline can be located by running a tape from the marked tree (or other noted location) directly towards the shoreline.

2) Potential Transect Positions occur every meter along the baseline tape, beginning at 0 meters (the southern Location Boundary). For each Section, random whole numbers were generated from 1 to the (length of Section - 1) using the website www.random.org. One random number was generated for each transect in the section. That number is the Transect Position, in meters, as measured from the southern Location Boundary.

3) Along the shoreline (where it is much easier to walk), place a surveyor's stake at the southern Location Boundary. Attach the zero end of the baseline tape to the surveyor's stake. Stretch the baseline tape to distance specified by the Transect Position along the baseline tape.

4) Transects are aligned perpendicular to the river shoreline at the Transect Position along the baseline tape. At the Transect Position, stretch a measuring tape that will serve as the transect upslope towards the woods. The crew member walking towards the woods should have the zero end of the tape and a non-declinated compass. Crew members should walk only on the south side of the transect tape to avoid trampling vegetation. Put the tape in your left hand when walking away from the river to ensure that you are on the south side of the transect.

5) At the edge of the woods, determine the location of the upper end of the transect using these three criteria:

a) lower edge of a small rock ledge
b) break in slope from a steeper slope in the woods to a shallower slope on the shoreline
c) a line of small-trunked trees and saplings

6) Determine and record the compass bearing of the transect from the zero point at the woodland edge to the rivershore. Record the length of the transect to the water's edge.

7) Permanently mark the location of the upper end of the transect by placing a 12" galvanized steel spike in the ground upslope of the transect end. Record the distance and azimuth from the spike to the transect end. The distance is measured as slope distance, in which the tape lays along

the slope on the ground, not horizontal distance in which the tape is held at the same height at both ends. Describe the location of the spike relative to the closest tree, shrub, or other distinctive feature.

Point Intercept Sampling

1) Points are sampled at 0.5 meter intervals along the length of the transect. The first point is 0.5 meters from the zero end of the transect near the woodland boundary.

2) Points are sampled on the north side of the transect tape. Crew members should always walk on the south side of the transect tape.

3) Points are sampled by lowering the 0.6 cm (0.236 in) diameter sampling pole vertically to the ground at a distance of 6.5 cm (2.5 in) away from the transect on the north side of the transect tape. An objective measure of 6.5 cm should be used to so that the distance from the transect tape is uniform for each sample. In 2010, the width of the bicycle flag on the sampling pole was 6.5 cm and was used to measure the distance from the transect tape.

[Note: In 2010, we tried three kinds of sampling poles: a recumbent bicycle flag, a plumb bob on a bright pink nylon string, and a water-proof red laser pointer mounted in a PVC holder attached to a thin fiberglass pole. The bicycle flag was chosen because it is the most stable while the botanist is inspecting the plants to see which are touching the pole. In addition, the bicycle pole broke down into three parts which was helpful in dense shrubs and for travelling between transects. It was very difficult to hold the laser still. Given the small size of the laser dot, it was difficult to assess which plants the laser touched. The plumb bob was easier to hold still than the laser, but not as stable as the bicycle flag. Winding and unwinding the plomb bob through the vegetation was also a disadvantage.]

4) The sampling pole should be lowered and held vertically to the ground, not perpendicular to the slope. It is important not to look at the vegetation itself when lowering the sampling pole as to not bias the placement of the pole. Focus on the transect tape, the distance from tape to pole, or the verticality of the pole, not what the pole is touching or not touching.

5) At each interval, once the pole is placed, record one hit for each plant species that touches the pole. Only record one hit for each plant species, even if the pole touches the same plant or plant species more than once. Record only species that touch the pole within 1.75 meters of the ground.

Data Collection

The following fields are recorded on the datasheet:

1) Date: month, day and year sampling occurred.

2) Observers: first and last name of all crew members.

3) Section: letter (A-E) assigned to that Section.

4) Distance along Baseline: position of the transect within the Section. This number is the distance in meters from the southern Location Boundary. This number was randomly generated.

5) Transect Number: number assigned to that transect within the Section.

6) Transect Azimuth: a compass heading, in uncorrected magnetic degrees north, taken from woodland edge looking toward the river.

7) Transect Length: length in meters of transect stretched perpendicular to the river shoreline. See Transect Set-up above for criteria on determining the location of the upper end of the transect. The lower end of the transect is the current water's edge.

8) Distance from spike to transect start: distance in meters from the spike to the transect end. Measure the distance as slope distance, in which the tape lays along the slope on the ground, not horizontal distance in which the tape is held at the same height at both ends.

9) Azimuth from spike to transect start: azimuth as determined with an undeclinated compass.

10) Description of the spike location: location of the spike relative to the closest tree, shrub, or other distinctive feature.

Species Sampling

1) Record the scientific name of each species that hits the sampling pole. Species names follow the Master Plant List in the ERMN Vegetation and Soil Monitoring Database, which is based on the USDA PLANTS Database. If neither species nor genus can be determined due to the immaturity of the plant, damage or senescence, assign the plant an unknown morphotype number or place it in one of the categories of unknowns: dicot, monocot, grass, or sedge. All vascular plant species that touch the sampling pole within 1.75 meters of the ground should be recorded.

2) If a plant touching the sampling pole has senesced, but it still identifiable to at least the family taxonomic level, record the plant. Plants or plant parts that have senesced and are not identifiable to the family level are considered litter and should not be recorded.

3) Record your level of confidence in the species identification for each plant. Your confidence in the identification is independent of the level of taxonomic specificity. You could be very confident in a plant identified only to family, (e.g. Species = Orchidacea; Confidence = 1) because you are sure that it is in that family, but have no idea which genus it is. Similarly, you could be not very confident in a genus- or species-level identification (e.g. Species = Dryopteris sp.; Confidence = 3) for obscure, small, or un-collectable individuals. Use the following codes:

1 = confident
2 = somewhat confident
3 = not very confident

4) For each point, record a hit ("X") for each species that hit the sampling pole. Record all unique species hits at each sampling point, but record each species only once per sampling point, regardless of the number of times the species contacts the sampling pole.

Ground Cover Characterization

1) For each point, record one tally in the appropriate category of ground cover. The possible ground covers are: litter, soil, rock, water, moss, or vascular plant. Record only the first ground cover intercepted, even if there is soil or rock under the litter that was first intercepted. Use vascular plant only was the basal portion of the plant is completely obscuring the substrate underneath and the plant parts cannot be moved gently aside to see the substrate below (Figure 1).

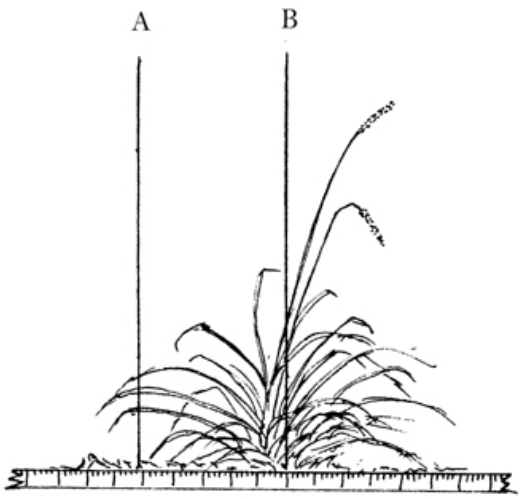

Figure F1. If the sampling pole eventually hits ground instead of the basal portion of the plant, then the appropriate ground cover code is recorded, even if it intercepts the aerial portion of the plant (A). Basal vegetation is recorded for ground cover when the pin hits the basal portion of the plant (B).

2) Hydrology: Record the hydrology at the sample point. Use the following codes:

1 – seep: water or damp areas in rivulets, cracks or drainages down the slope of the shoreline, typically originating from the edge of the wooded slope or cracks in the bedrock. Dampness from rain does not count as a seep.

2 – dry: no current evidence of water seeping from or over the ground.

3 – shoreline: plots that contain water from the current level of the Delaware River, including any Plot #3 that had to be moved to due higher current water levels.

4 – seep, now dry: obvious evidence that seeps occurred in the plot earlier in the year. Drainage patterns from rainfall do not count as seeps.

5 – combination of seep and dry within the plot

6 – combination of dry and shoreline within the plot

3) Last intercept: Circle on the datasheet the distance along the transect of the last intercept sampled before the transect ends at the water's edge.

Transect Information for Point Intercept Sampling

Section	Transect Number	Distance Along Baseline (m)	Transect Azimuth	Distance from Spike to Transect End	Azimuth from Spike to Transect End	Description of Spike Location
A	1	8	304	5.4	304	1 meter upstream from the base of a medium-sized white ash
A	2	16	304	6.2	291	0.5 meters downstream from the base of a smallish hemlock
A	3	26	304	5.5	304	15 cm upriver from the base of a Rhododendron maximum
A	4	56	304	4	304	In the middle between a medium-sized red oak and a sapling red maple. The transect starts just downslope of a sapling slippery elm.
A	5	80	304	5	310	30cm downriver from the base of a medium-sized chestnut oak
A	6	113	309	4.2	326	30cm downslope of a medium-large hemlock
A	7	236	318	3.2	318	1.3 meters downriver of the upslope edge of a medium-sized hemlock.
A	8	254	312	3.7	312	1.3 meters downriver of a Rhododendron maximum stump
A	9	284	307	3.2	307	1.1 meters downriver from the upslope edge of a medium-sized hemlock
A	10	309	316	1.9	316	5 cm from the upslope side of a large hemlock trunk
A	11	354	313	5.2	313	adjacent to the uphill and downriver side of a medium-sized hemlock. A large hemlock is downslope of the medium hemlock.
A	12	367	304	4.8	304	5 cm upriver of the up slope edge of a large hemlock trunk
A	13	373	313	4.3	313	in between a clump of three medium-large hemlock trees, aligned with the uphill side of the trunks
A	14	432	311	4	311	1 meter downriver from the upslope edge of a hemlock trunk
A	15	450	308	3.8	308	30 cm from the base of a medium-large chestnut oak on the upriver uphill side
A	16	465	306	5	306	50 cm up-river of a base of a large hemlock, aligned with the uphill edge of the trunk
A	17	495	312	6.4	312	10 cm up-river, upslope from a large Nyssa sylvatica(?) trunk
A	18	557	304	5.8	304	1 meter up-river of a large chestnut oak near the upslope side of the trunk
B	19	1	301	4.8	301	1 meter upriver from the gracefully curved chestnut oak that marks the Location 6-7 Boundary. The spike is aligned with the uphill side of the trunk.
B	20	62	309	4	284	30 cm up-river of a small Amelanchier arborea, 1 m upslope from the trunk base
B	21	90	301	2.4	301	0.5 m down-river of a small-ish white ash.
B	22	133	307	7.3	307	1 m down-river from a small hemlock
B	23	161	313	4.2	313	40 cm down-river and upslope from a small birch
B	24	237	310	8	310	2.3 m down-river from a large hemlock trunk, aligned with the upslope edge of the trunk. The spike is up a steep slope from the transect start.
B	25	266	313	4.4	313	the transect is in line with a large double trunked chestnut oak on top of a steep slope, leaning over the slope. The spike is just upslope of trunk center.
B	26	298	322	2.2	322	The spike is half way up a steep bank just beneath a rock outcrop under a large Rhododendron shrub. The transect starts on the upriver side of a medium-sized hickory.

Section	Transect Number	Distance Along Baseline (m)	Transect Azimuth	Distance from Spike to Transect End	Azimuth from Spike to Transect End	Description of Spike Location
B	27	323	310	7	310	40 cm down-river and upslope from a small red maple trunk
B	28	434	308	5.2	308	The spike is just upslope from a two trunk Rhododendron maximum, that is halfway up a moderately steep slope. The transect start is adjacent to a leaning small chestnut oak.
B	29	440	310	6.2	310	1.3 m down-river of a large black birch, aligned with the up-slope side of the trunk, which is halfway up a moderately steep slope
B	30	478	308	4.6	308	40 cm upslope from a large black birch, aligned with the downriver trunk edge
B	31	499	308	4.8	308	70 cm upriver from the upslope edge of a large red oak
C	32	5	306	9	306	40cm downriver from the upslope side of a small tulip poplar.
C	33	79	308	7	280	on the downriver, upslope side of a small Nyssa sylvatica trunk which is on the top of the short slope.
C	34	155	314	5.4	314	just upriver from a small American beech sapling, in between a medium-small sugar maple and a medium black gum.
C	35	161	313	5	313	40 cm up-river of a small tuliptree, aligned with the up-slope side of the trunk.
C	36	230	310	4	310	on the up-slope side of a medium-sized black birch, which is just down river from a medium slippery elm.
C	37	235	310	6.8	310	90 cm up-river from a large tuliptree. The tuliptree is the closest to the river and the farthest up-river within a clump of three tuliptrees.
C	38	261	317	2.5	317	just upslope of an 8 cm DBH sugar maple that is just downriver of a large red oak on the gentle slope.
C	39	275	314	8	314	40 cm downriver of a small sugar maple trunk, aligned ith the upslope trunk edge.
C	40	338	314	11.7	310	downriver and aligned with the downslope side of a small American Beech trunk.
C	41	379	312	5.6	312	30 cm downriver of a medium Amerian beech, aligned with the upslope side of the trunk
C	42	439	312	7.9	312	30 cm downriver of a medium black locust aligned with the downhill side of the trunk
C	43	444	309	5	309	50 cm downriver of a medium-sized tuliptree aligned with upslope side of the trunk
C	44	460	311	7.5	311	20 cm upriver of the base of a medium tuliptree, aligned with the upslope side of the trunk
C	45	468	311	5	311	2.0 m downriver of a smallish red oak, aligned with the upslope edge of the trunk. The spike is amongst an open Rhododendron maximum.
D	46	13	309	6.9	309	1.5m downriver of a small sugar maple, aligned with the upslope side of the trunk. The transect start is at the downriver side of a Tilia americana with three stems (1 main stem and two smaller stems).
D	47	45	310	4.2	310	2.2 m downriver of a medium-large tuliptree, aligned with the uphill side of the trunk. The spike is in barberry shrubs.
D	48	126	308	4.2	308	80 cm upriver of a small Tilia americana sapling, but on the same azimuth as a large (46cm DBH) sugar maple ~12 m transect start.
D	49	138	307	2.5	307	40 cm upslope from the downriver edge of a large sugar maple

Section	Transect Number	Distance Along Baseline (m)	Transect Azimuth	Distance from Spike to Transect End	Azimuth from Spike to Transect End	Description of Spike Location
D	50	199	312	6	312	1.5 m downriver from a 0.5 m uphill from the upslope edge of a large sugar maple. The transect starts adjacent to a dead Ulmus sp. on the upriver side.
D	51	219	310	4.3	310	80 cm upslope and 1 m downriver of a small sugar maple. The spike is in between (and upslope of) a small sugar maple and a medium hemlock
D	52	279	310	4.2	310	3.0 m upslope from the upriver edge of a medium sugar maple in the middle of the sloped bank.
D	53	331	310	6.9	310	1.1 m upriver of a medium sized white ash, aligned with the upslope side of the trunk.
D	54	340	314	6.5	314	1.8 m upslope from a small forked black birch, aligned with the upriver side of the trunk
D	55	354	311	7.1	311	1.2 m upslope and 0.5 m upriver of a small American elm. There is a second Americam elm just downslope from the first one.
D	56	408	317	9.6	317	1.4 m upslope and 20 cm upriver from an autumn olive clump/trunk.
D	57	439	305	10.3	305	50 cm upslope and 1.3 m upriver of a medium-large tuliptree
D	58	456	313	4.3	313	70 cm upslope and 30 cm upriver from a small black birch
D	59	486	309	6.5	309	1 m downriver of a medium black birch. The transect starts at the base of the rock wall.
D	60	595	304	7.2	304	10 cm upslope and aligned with the center of a hemlock trunk. The spike is in between two large hemlocks.
D	61	625	302	6.1	302	10 cm downslope of a scraggly, forked red maple, which is 1 m downriver of a very large tuliptree.
D	62	656	305	6.5	305	20 cm downriver of a small red oak (Tree Tag #14), aligned with the upslope side of the trunk. The transect was supposed to be 654 m along the baseline, but it is aligned with this tagged tree which is 656 m along the baseline.
E	63	38	305	7.9	305	1.7 m upslope of a large American beech, aligned with the downriver side of the trunk.
E	64	113	295	7.4	295	1.0 m upriver of a medium sized sugar maple, aligned with upslope side of the trunk.
E	65	122	294	8	294	1.8 m downriver of a medium red oak, which is halfway up the steepish slope
E	66	128	290	7.9	290	At the base of a steep slope, aligned with the downriver side of a large black oak that is at the top of the slope.
E	67	145	286	0		There is no spike marking this transect. The start of the transect is 50 cm downriver of the silver maple (Tree Tag #17), aligned with the upslope side of the trunk.

Appendix G. Point Intercept Sampling Data Sheet.

Site: _____ Date: _____ Observers: _____
Section: _____ Distance along Baseline: _____ Transect #: _____ Transect Azimuth: _____ Transect Length: _____
Distance from spike to transect start: _____ Azimuth from spike to transect start: _____ Description of spike location: _____

Circle last intercept

POINT INTERCEPTS	0.5	1	1.5	2	2.5	3	3.5	4	4.5	5	5.5	6	6.5	7	7.5	8	8.5	9	9.5	10	10.5	11	11.5	12	12.5	13	13.5	14	14.5	15	15.5	16	16.5	17	17.5	18	18.5	19	19.5	20
GROUND COVER																																								
Litter																																								
Soil																																								
Rock																																								
Water																																								
Moss																																								
Vascular Plant																																								
Hydrology																																								
POINT INTERCEPTS	0.5	1	1.5	2	2.5	3	3.5	4	4.5	5	5.5	6	6.5	7	7.5	8	8.5	9	9.5	10	10.5	11	11.5	12	12.5	13	13.5	14	14.5	15	15.5	16	16.5	17	17.5	18	18.5	19	19.5	20

The Department of the Interior protects and manages the nation's natural resources and cultural heritage; provides scientific and other information about those resources; and honors its special responsibilities to American Indians, Alaska Natives, and affiliated Island Communities.

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U.S. Department of the Interior

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