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Comparisons of Four Riparian Plant Communities on the Little Chazy River, Northern New York

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ABSTRACT

Riparian zones are transitional plant communities that are important for the protection of stream water quality and biota and they often have high biological diversity within small geographical areas. This study characterized the vegetation and several physical site features within four riparian zones in the Little Chazy River watershed located in Clinton County, NY. A total of 110 plant species were sampled in the overstory, understory, and groundcover at these study sites. Average species richness in the 1m^2 groundcover plots ranged between 7.0 at the agricultural riparian zone to 17.8 at one of the forested riparian zones. Species diversity values ranged between 1.23 at the agricultural riparian zone to 2.32 at one of the forested riparian zones. In this study, the riparian zone with active agricultural activity had no overstory or understory and the least diverse groundcover. Ordination of groundcover data showed both between-site and within-site separations, indicating large differences in species composition can occur on a small spatial scale. No relationship was found between nutrient availabilty and disturbance intensity of the riparian zones. The abundance of non-indigenous plant species was directly related to disturbance history of the riparian zones. Best management practices (BMP's) for agriculture and forestry in the Lake Champlain Valley should include guidelines for the preservation of natural riparian ecosystems without producing severe economic consequences for landowners. BMP's should be specific to each type of riparian ecosystem found in northeastern New York.

Key Words: Riparian, plant communities, Little Chazy River.

INTRODUCTION

Riparian ecosystems can generally be described as transitional zones in which water, soil and vegetation interact within three-dimensional (vertical, lateral, and longitudinal) corridors (Gregory et al., 1991). Riparian zones are direct interfaces between terrestrial and fluvial ecosystems (Naiman et al., 1993; NRC, 2002). Moreover, riparian systems are unique with regard to upland ecosystems in that they are noted for gradients in physical site conditions, ecological processes, and biota (NRC, 2002). While characteristics of riparian plant communities vary according to the nature and frequency of disturbances (e.g., inundation, drought, sedimentation, etc.), the extent and function of riparian systems can be further distinguished from adjacent upland areas by defining the ecological characteristics and processes (Salo and Cundy, 1987).

Excluding Alaska, riparian corridors comprise only 2-11 percent of the landscape found within the United States (Salo and Cundy, 1987). In addition to being spatially restricted, multi-gradient features of riparian zones result in high biodiversity/habitat area ratios, in comparison with small ecological communities found in other comparatively sized landscape types (NRC, 2002). As such, the study of riparian corridors should provide a better understanding of related fluvial biodiversity and community dynamics (Naiman et al., 1993). Consequently, there is an increased need for recommended best management practices (BMP's) for modern agricultural and silvicultural actions in riparian zones. These BMP's should be based upon scientific studies of riparian corridors.

In the summer of 2004, the plant ecology group of Plattsburgh State University's Research Experiences for Undergraduates (REU) completed a study of four riparian sites on the Little Chazy River in Northeastern New York. The objectives of this study were to make comparisons between four riparian zones on the Little Chazy River for:

1. Plant communities including ground-cover, understory, and overstory species;
2. Nitrogen [N] and phosphorus [P] in jewelweed (*Impatiens capensis*), the only herbaceous species present at all study sites; and
3. Total nitrogen and total phosphorus in streamside soils;

METHODS

Vegetation Sampling

Vegetation sampling occurred during June, 2004. Sample plots were contained within 100 m long riparian zone transects that extended ten meters perpendicular to the stream channel (Fig. 1). Due to stream meandering, transects were positioned two meters from the channel at the point of closest approach (Fig. 1). Each 10x100 m transect was subdivided into 10x20 m plots. Two plots were sampled systematically for each stratum of vegetation (Fig. 1).

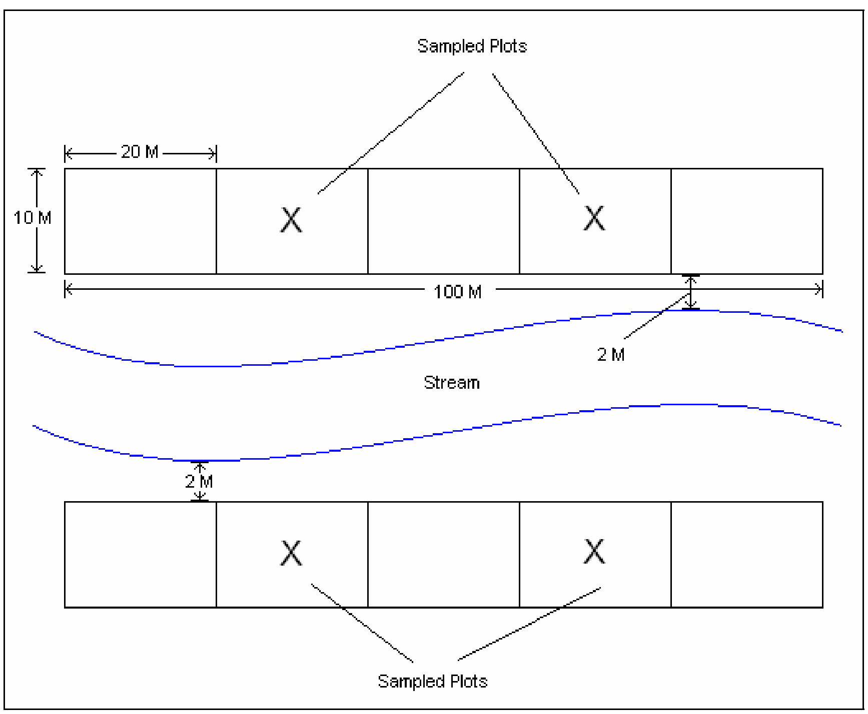

Figure 1. Sampled riparian plots (not drawn to scale).

Overstory Trees

Overstory trees were sampled in the 10x20 m plots. All trees with a diameter at breast height (DBH) greater than or equal to 15 cm were identified, and the DBH was recorded to the nearest 0.1 cm. Dead trees were sampled in the same manner, but there were too few of these trees in the plots for them to be included in further analyses.

Understory Woody Plants

Multiple-stemmed shrubs and saplings > 2 m in height and less than 15 cm in DBH were considered understory. Understory plants were sampled in an 8x10 m plot centered within each larger 10x20 m plot (Fig. 4). Living understory plants were identified and stems were tallied for each species.

Groundcover Plants

Herbaceous plants and all tree seedlings > 10cm in height were sampled in four 1x1 m plots located at the corners of the 10x20 m overstory plots (Fig. 2). Plants were identified, and stem counts were recorded for each species. In the case of grasses and sedges, percent coverage rather than a stem count was recorded for all species that comprised over 5 percent of the plot.

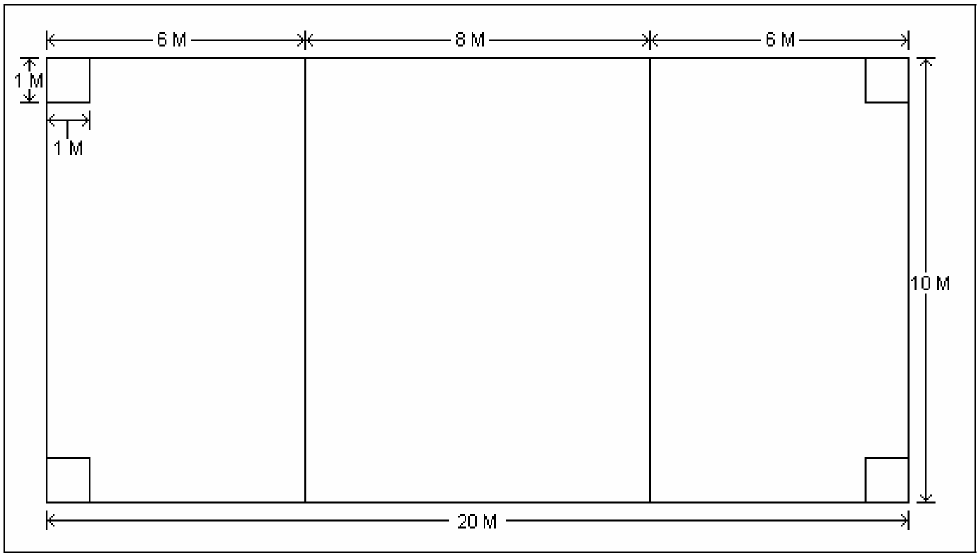

Figure 2. Nested plots (drawn to scale).

Species Recording

All plant species within the overstory, understory, and groundcover plots were recorded using a 6-letter code. This code consisted of the first three letters of the genus name and the first three letters of the species name (Appendix 1). Field identification was accomplished using Newcomb's Wildflower Guide (Newcomb, 1977), Peterson's Guide to Ferns (Cobb, 1963), and Peterson's Guide to Trees and Shrubs (Petrides, 1972). Nomenclature for plant species followed Fernald (1970). Species were also described as native or non-indigenous to New York State, referencing Mitchell and Tucker (1997).

Nutrient Analysis

At each of the 16 vegetation sampling plots, samples of jewelweed and soil samples around the rooting zone of each plant were taken in order to complete an analysis of nitrogen and phosphorus concentrations. All sampled jewelweed stems were between 10 and 50 cm in height; none of the plants were in flower.

Vegetation and soil samples were placed in a drying oven at 60 C and then weighed. Between 0.15 and 0.20 g of the sixteen soil and jewelweed samples were analyzed for total nitrogen using a Leco FP428 Nitrogen Analyzer. Plant samples were analyzed for total phosphorus using Ascorbic Acid/Molybdate method. Soil samples were also analyzed for available phosphorus using the methodology described in SSSA (1996).

ANOVA was used to test for differences in soil and foliar nitrogen and phosphorus concentrations between the four study sites.

Vegetation Data Analysis

All data were separated by overstory, understory and groundcover for each of the 16 vegetation plots. The following were calculated for each stratum:

Density = number of stems per hectare (ha)

Dominance (trees) = basal area (m^2) = $(dbh_{cm})^2 * 0.00007854$, converted to basal area per ha

Relative Density = density of a species/ total density of all species * 100

Relative Dominance (trees) = basal area of a species/ total basal area of all species * 100

Importance Value = relative density + relative dominance

Relative Importance (RIV) = IV for a species/ total importance for all species * 100

Species Diversity = Shannon-Wiener Index (H^1) based on relative density

$$H^1 = -\Sigma \ln Pi * Pi$$

Where Pi = decimal fraction of relative density for each species

Pielou Evenness Index = H^1/H^1 max * 100

Where H^1 max = ln S

S = number of species (species richness)

Bray-Curtis ordinations were performed using Pcord (McCune and Mefford, 1999; McCune and Grace, 2002) for each of the three levels of vegetation. A Shannon-Wiener Diversity Index (Cox, 2002) was calculated for each plot.

RESULTS

Vegetation

A total of 110 plant species were sampled in the study, representing 39 plant families. Sixty-one herbaceous species were native to New York State and 18 species were nonindigenous; five shrubs were native species and three were nonindigenous species; all 23 tree species were native (Appendix 1).

Table 1 shows the Shannon diversity, evenness and richness data for all the sites and strata. The Barnaby Spring site had the highest overstory diversity (1.01) and the highest understory diversity (1.43). The highest groundcover diversity index was at the I87 site (2.32).

Table 1. Species richness and diversity values at each study site.

Site	Overstory Species Richness	Overstory Diversity Index	Overstory Evenness Percent	Understory Species Richness	Understory Diversity Index	Understory Evenness Percent	Groundcover Species Richness	Groundcover Diversity Index	Groundcover Evenness Percent
BS	3.5	1.01	88.6	5.8	1.43	84.3	15.5	2.03	74.1
BM	1.8	0.41	84.2	3.5	0.83	66.8	16.8	2.03	72.5
I87	2.3	0.68	96.3	6.3	1.28	67.9	17.8	2.32	81.0
WA	None	None	None	None	None	None	7.0	1.23	63.0

Overstory

Table 2 shows that sugar maple was the most important overstory species on each side of the stream at the Barnaby main site. The most important overstory species at the Barnaby Spring Site were sugar maple, red maple and basswood (Table 2). Green Ash was the most important overstory species at the I87 site (Table 2). The Wood Ag site had no overstory trees.

Table 2. Relative importance values for overstory species at the study sites.

Barnaby Main South

Species	Stems/ha	Basal Area (m^2/ha)	RIV (%)
Acesac	150	41.7	64.9
Acerub	75	3.5	26.7
Faggra	50	1.8	8.4
Total	275	47.0	100.0

Barnaby Main North

Species	Stems/ha	Basal Area (m^2/ha)	RIV (%)
Acesac	175	24.8	90.1
Faggra	25	0.5	9.9
Total	200	25.3	100.0

Barnaby Spring SE

Species	Stems/ha	Basal Area (m^2/ha)	RIV (%)
Acesac	250	14.1	53.3
Tilame	150	11.1	31.0
Tsucan	25	3.5	6.3
Acerub	25	1.2	3.6
Ostvir	25	0.9	3.2
Fraame	25	0.4	2.6
Total	500	31.2	100.0

Barnaby Spring NW

Species	Stems/ha	Basal Area (m^2/ha)	RIV (%)
Acerub	125	8.1	39.4
Acesac	175	6.3	22.7
Pinstr	25	5.4	20.2
Tilame	50	4.9	11.0
Pruser	50	1.9	6.7
Total	425	26.6	100.0

I-87 Southeast

Species	Stems/ha	Basal Area (m^2/ha)	RIV (%)
Frapen	75	9.3	62.6
Acesac	25	5.3	20.7
Tilame	25	3.6	16.7
Total	125	18.2	100.0

I-87 Northwest

Species	Stems/ha	Basal Area (m^2/ha)	RIV (%)
Frapen	75	3.3	54.3
Carcor	50	0.9	34.2
Ulmrub	25	0.9	11.5
Total	150	5.1	100.0

Overstory Ordination

Ordination of overstory species showed community differences between each of the three study sites possessing overstory (Figure 3).

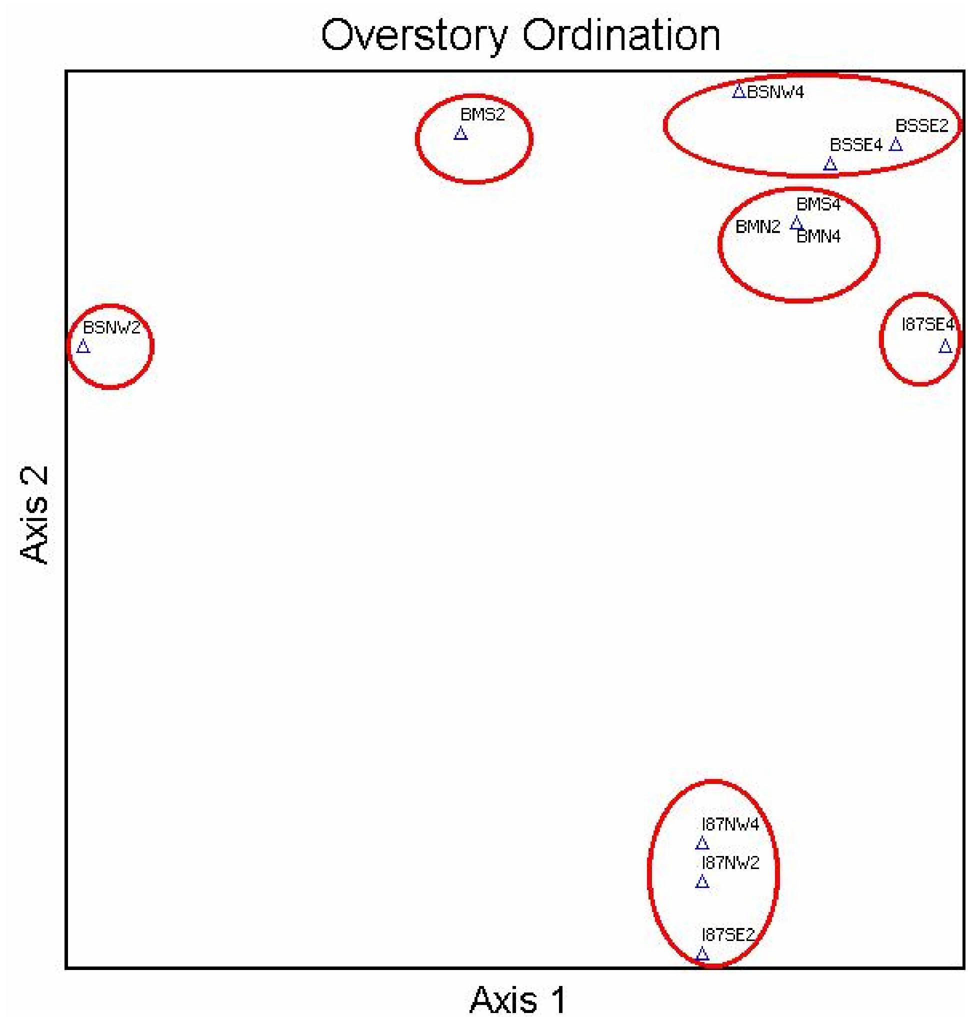

Figure 3. Ordination of overstory plots.

Figure 3 shows the Bray-Curtis ordination of overstory tree sample plots (12 total). The widest plot separations occurred for the three I87 plots that were dominated by green ash. Generally, the ordination shows a clustering of plots from the same site. However, three plots showed exceptions to this trend. I87SE4 ordinated close to the BM main groups due to the presence of sugar maple and basswood; BMS2 was separated because it contained red maple; BSNW2 was separated because it was the only plot with white pine and black cherry present in the overstory.

Understory

The three most important understory species at the Barnaby Main site were sugar maple, red elderberry, and hophornbeam (Table 3). American beech, Witch-hazel, and hophornbeam were the three most important understory species at Barnaby Spring. At the I-87 site the three most important understory species were buckthorn, speckled alder, and nannyberry.

Table 3. Relative importance and density values for understory woody species at the study sites on the Little Chazy River.

Barnaby Main South

Species	Stems/ha	RIV (%)
Acesac	1000	36.7
Samcan	750	27.2
Ostvir	563	20.4
Ulmrub	250	9.0
Fraame	125	4.5
Tilame	63	2.2
Total	2751	100.0

Barnaby Main North

Species	Stems/ha	RIV (%)
Acesac	1000	50.1
Ostvir	625	31.2
Fraame	187	9.3
Faggra	125	6.2
Acepen	63	3.1
Total	2000	100.0

Barnaby Spring Southwest

Species	Stems/ha	RIV (%)
Ostvir	1500	24.8
Faggra	1375	22.4
Acesac	1250	20.4
Amearb	938	15.3
Fraame	500	8.1
Pinstr	250	4.0
Poptre	250	4.0
Tilame	63	1.0
Total	6126	100.0

Barnaby Spring Northeast

Species	Stems/ha	RIV (%)
Hamvir	2000	35.8
Faggra	1625	28.8
Acesac	875	15.5
Fraame	500	8.8
Amearb	250	4.4
Ostvir	250	4.4
Querub	125	2.2
Acerub	63	1.1
Total	5687	100.0

I-87 Southeast

Species	Stems/ha	RIV (%)
Rhacat	3875	64.4
Viblen	1125	18.5
Vitspp	312	5.1
Lonspp	188	3.0
Pruvir	188	3.0
Quemac	125	2.0
Aceneg	63	1.0
Frapen	63	1.0
Salspp	63	1.0
Tilame	63	1.0
Total	6065	100.0

I-87 Northwest

Species	Stems/ha	RIV (%)
Alnrug	2000	39.5
Rhacat	1001	19.8
Ulmrub	688	13.6
Pruvir	375	7.5
Lanser	313	6.2
Jugcin	313	6.2
Frapen	125	2.4
Craspp	125	2.4
Carcor	125	2.4
Total	5065	100.0

Understory Ordination

Figure 4 shows the Bray-Curtis ordination of the twelve understory sample plots. The understory plots for Barnaby Main and Barnaby Spring clustered together. The I-87 plots were clearly distinct from the other two study sites with regard to understory vegetation.

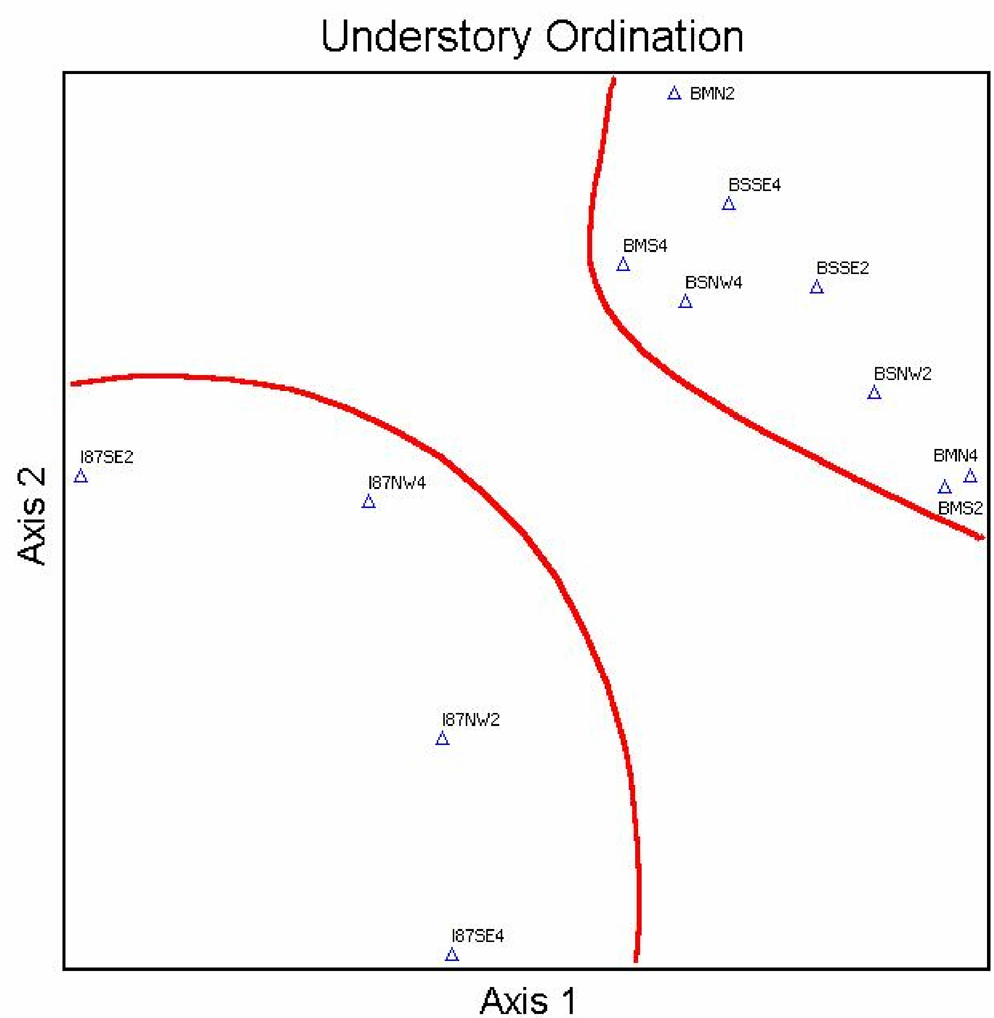

Figure 4. Ordination of understory plots.

Groundcover

Relative importance values were determined for all groundcover species.

Table 4. Relative importance values for groundcover species at the four study sites.

Barnaby Main South

Species	RIV (%)
Impcap	27.7
Carspp	18.0
Gerrob	8.5
Poaspp	8.5
Urtdio	7.8
Hydvir	4.8
Cirqua	3.9
Aritir	3.9
Acesac	3.0
Poaspp	1.9
Santir	1.6
Bowcyl	1.4
Brymar	1.4
Oxaspp	1.2
Ruball	1.2
Denpun	1.2
Ostvir	0.7
Astspp	0.7
Arcmin	0.7
Uvuses	0.5
Jugcin	0.3
Viospp	0.3
Ampbra	0.3
Galspp	0.1
Tilame	0.1
Samcan	0.1
Trispp	0.1
Solspp	0.1
Total	1

Barnaby Main North

Species	RIV (%)
Acesac	25.8
Uvuses	20.5
Carspp	11.2
Carspp2	11.2
Aranud	4.6
Ampbra	3.3
Denpun	3.3
Lycobs	3.3
Drymar	2.6
Solspp	1.9
Urtdio	1.9
Poaspp	1.3
Ruball	1.3
Arerac	0.6
Aritri	0.6
Epihel	0.6
Fraame	0.6
Impcap	0.6
Jugcin	0.6
Ostvir	0.6
Rahcat	0.6
Samcan	0.6
Thadio	0.6
Tribor	0.6
Trispp	0.6
Ulmrub	0.6
Total	100.0

Barnaby Spring Southwest

Species	RIV (%)
Athfil	13.7
Acesac	11.7
Astspp	9.3
Onosen	9.3
Dryspi	7.8
Osmcin	7.8
Fraame	6.2
Euprug	5.8
Aranud	5.4
Impcap	3.9
Poaspp	3.9
Miacan	3.5
Osmcla	2.7
Acerub	1.9
Amearb	1.9
Eryame	1.1
Strros	1.1
Apoand	0.7
Pinstr	0.7
Trigra	0.7
Epihel	0.3
Ostvir	0.3
Pruser	0.3
Total	100.0

Barnaby Spring Northeast

Species	RIV (%)
Impcap	39.6
Maican	12.0
Athfil	10.0
Osmcla	7.9
Copgro	6.0
Onosen	5.6
Osmcin	4.2
Dendip	3.7
Galspp	3.6
Fraves	2.4
Tiacor	1.0
Aranud	0.7
Solspp	0.7
Poaspp	0.5
Ariame	0.4
Thadio	0.4
Acesac	0.2
Ampbra	0.2
Equpar	0.2
Ostvir	0.2
Eryame	0.1
Fraame	0.1
Tribor	0.1
Trispp	0.1
Viospp	0.1
Total	100.0

Table 4, continued.

Wood Ag West

Species	RIV (%)
Poacom	68.5
Fesrub	9.3
Stadal	8.1
Phlpra	6.2
Brolne	3.7
Equarv	1.2
Sedgea	1.2
Ptepen	0.6
Ascsyr	0.6
Conarv	0.6
Total	100.0

Wood Ag East

Species	RIV (%)
Tripra	39.7
Agrrep	33.1
Phaaru	15.6
Poacom	3.7
Viccar	3.7
Phlpra	1.8
Cirarv	0.6
Equarv	0.6
Rorisl	0.6
Teroff	0.6
Total	100.0

I-87 Southeast

Species	RIV (%)
Poacom	13.8
Lysnum	10.0
Urtdio	9.3
Solcan	8.1
Ptepen	7.5
Clevir	5.6
Ranrac	5.6
Carspp	5.0
Impcap	5.0
Rubocc	5.0
Vervir	3.7
Polsag	3.1
Galpal	2.5
Geucan	2.5
Menspi	2.5
Anecan	1.8
Phaaru	1.8
Rhacat	1.8
Viospp	1.8
Aceneg	0.6
Parqui	0.6
Poaspp	0.6
Ribspp	0.6
Solnig	0.6
Viblen	0.6
Total	100.0

I-87 Northwest

Species	RIV (%)
Carspp	22.6
Lysnum	17.3
Vervir	10.0
Ptepen	7.9
Viospp	6.1
Viblen	5.6
Poaspp	4.3
Solcan	4.1
Galrup	2.5
Sedpur	2.5
Impcap	2.4
Onosen	1.8
Clevir	1.3
Agrstr	1.2
Rhacat	1.2
Pruvir	1.2
Ribspp	1.2
Solspp	1.0
Galasp	1.0
Anecan	0.8
Polsag	0.6
Rubocc	0.6
Solnig	0.6
Thapol	0.5
Astspp	0.5
Athfil	0.5
Cirspp	0.2
Teroff	0.2
Parqui	0.1
Equspp	0.1
Ostvir	0.1
Total	100.0

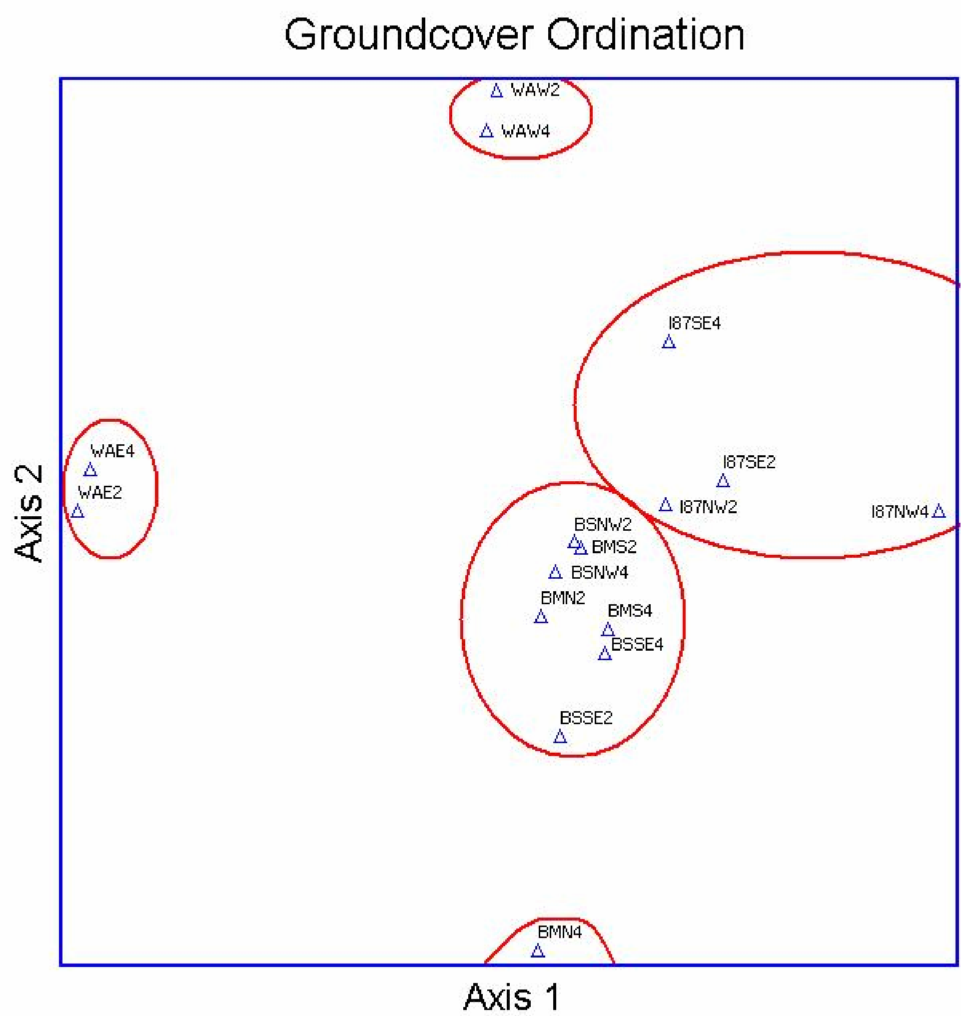

Figure 5. Ordination of groundcover plots.

Figure 5 shows the Bray-Curtis ordination of the twelve groundcover plots. Generally, both sides of the stream at each site clustered together. The exception to this pattern was WA, the site with the most intensive agriculture and the most non-indigenous species.

Figure 6 shows the groundcover species richness of all forested sites (Barnaby Main, Barnaby Spring, and I-87) were significantly larger than the open field site (Wood Ag).

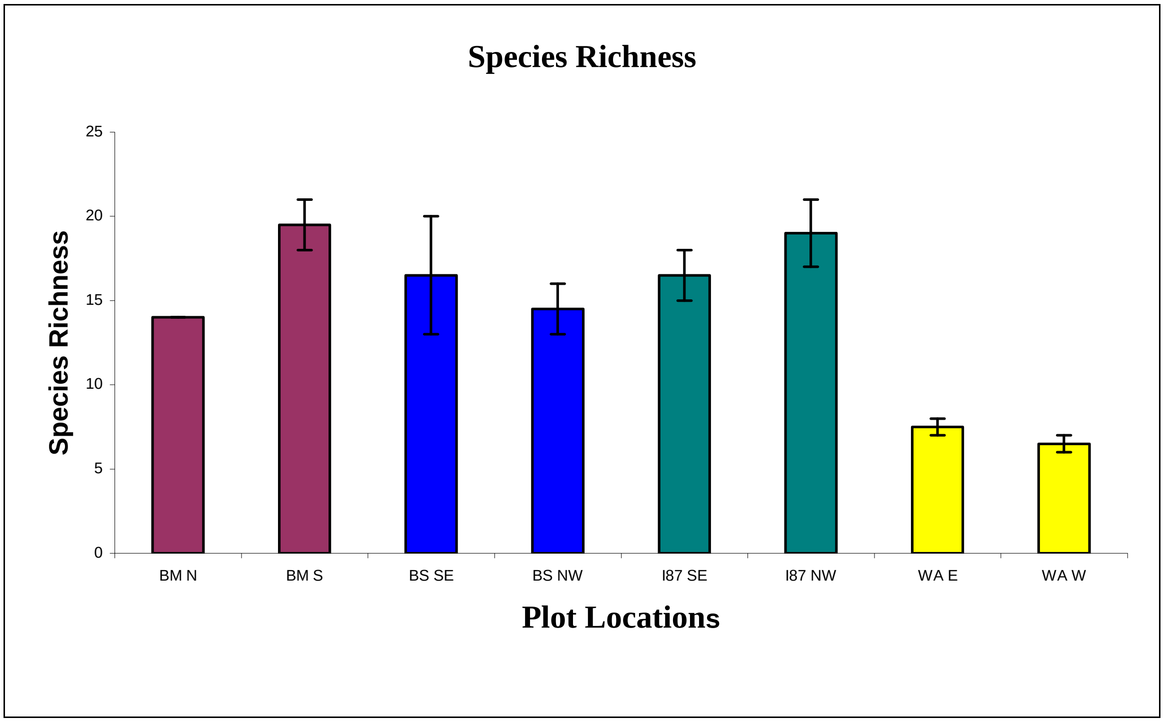

Figure 6. Histogram of groundcover species richness at each sample site.

Non-indigenous Species

The percentage of groundcover species that are not indigenous to New York ranged from 4.0% at Barnaby Spring Northeast to 70.0% at Wood Ag East (Table 5). ANOVA comparison of non-indigenous species presence for each sample site showed significant differences (f-value= 17.34, p value= 0.0093). The Wood Ag site had significantly larger non-indigenous species presence than either Barnaby Main or Barnaby Spring.

Table 5. Proportion of non-indigenous species at each sample site.

Sample Site	Percent
Barnaby Main North	15.3
Barnaby Main South	14.2
Barnaby Spring Northeast	4.0
Barnaby Spring Southwest	8.7
I-87 Northwest	22.5
I-87 Southeast	32.0
Wood Ag East	70.0
Wood Ag West	50.0

Chemical Analyses

Soil Nitrogen:

Nitrogen concentrations ranged between 0.01% at Wood Ag East A and 1.29% at Barnaby Spring Southeast 2 (Table 6). ANOVA comparisons of soil nitrogen for each streamside at each sample site showed significant differences (f-value=10.450, p value=0.002). The Southeast Barnaby Spring soil had significantly greater nitrogen concentrations than all other sites (Figure 7).

Table 6. Soil chemical analyses for nitrogen and phosphorus.

Sample Site	Phosphorus (%)	Nitrogen (%)
Barnaby Main, N, A	0.030	0.084
Barnaby Main, N, B	0.076	0.106
Barnaby Main, S, 2	0.001	0.021
Barnaby Main, S, 4	0.068	0.482
Barnaby Spring, NW, A	0.062	0.329
Barnaby Spring, NW,B	0.064	0.357
Barnaby Spring, SE,2	0.123	1.295
Barnaby Spring, SE,4	0.078	0.955
I87, NW, 4	0.077	0.115
I87, NW, 2	0.078	0.162
I87, SE, A	0.031	0.235
I87, SE, B	0.061	0.280
Wood Ag, E, B	0.082	0.166
Wood Ag, E, A	0.047	0.012
Wood Ag, W, 2	0.031	0.168
Wood Ag, W, 4	0.016	0.106

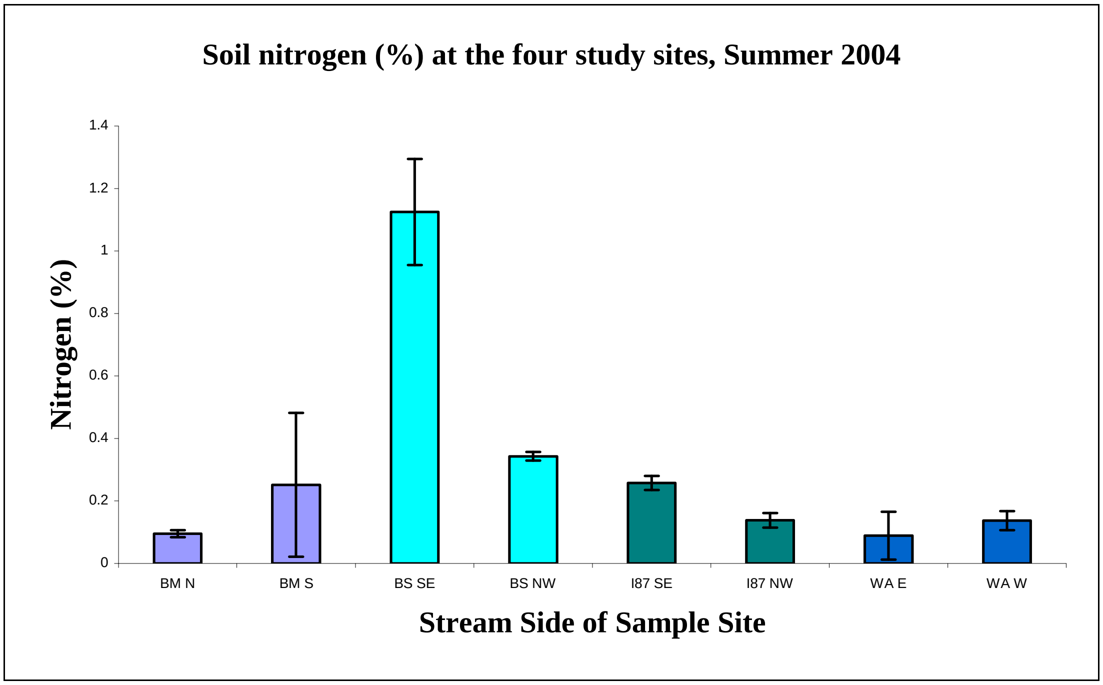

Figure 7. Comparison of soil nitrogen concentrations at the study sites.

Soil Phosphorus:

Total phosphorus concentrations ranged between 0.001% at Barnaby Main South 2 and 0.123% at Barnaby Spring Southeast 2 (Table 6). Comparisons of soil phosphorus concentrations between the study sites by ANOVA showed no significant differences (f-value= 1.630, p value= 0.254).

Plant (jewelweed) Nitrogen:

Nitrogen concentrations of jewelweed ranged between 1.952% at Wood Ag East A and 4.779% at Barnaby Main South 2 (Table 7). Comparisons of plant nitrogen concentrations between the study sites by ANOVA showed no significant differences (f-value= 2.506, p value= 0.111).

Table 7. Plant chemical analyses for nitrogen and phosphorus.

Sample Site	Phosphorus (%)	Nitrogen (%)
Wood Ag, E, A	0.255	1.952
Wood Ag, E, B	0.400	2.592
Wood Ag, W, 2	0.329	3.328
Wood Ag, W, 4	0.223	2.635
I87, SE, A	0.368	4.661
I87, SE, B	0.348	4.222
I87, NW, 2	0.223	3.250
I87, NW, 4	0.358	2.392
Barnaby Spring, NW, B	0.279	2.979
Barnaby Spring, NW, A	0.352	2.421
Barnaby Spring, SE, 2	0.258	3.297
Barnaby Spring, SE, 4	0.162	2.341
Barnaby Main, S, 2	0.247	4.779
Barnaby Main, S, 4	0.210	2.931
Barnaby Main, N, A	0.392	3.851
Barnaby Main, N, B	0.290	4.779

Plant (jewelweed) Phosphorus:

Phosphorus concentrations of jewelweed ranged between 0.162% at Barnaby Spring Southeast 4 and 0.400% at Wood Ag East B (Table 7). Comparisons of plant phosphorus concentrations by ANOVA showed no significant differences (f-value= 1.161, p value= 0.415).

DISCUSSION

The four riparian ecosystems in this study represented a wide range of disturbance types and intensities. The sites identified as Barnaby Main and Barnaby Spring had low-intensity tree removal within the past 50 years (K. Adams, pers. commun.). The site designated as I87 showed evidence of moderate-intensity timber harvest and pasturing within the past century (K. Adams, pers. commun.). The Wood-Ag site was categorized as a high-intensity agricultural site. The high-intensity and prolonged agricultural disturbances at the Wood-Ag site resulted in the loss of all overstory and understory vegetation and the replacement of native groundcover species by non-native grasses for the purpose of hay production.

Defining and delineating the spatial extent of riparian zones is difficult, as the boundaries associated with related stream systems are inherently variable and are dependent on what aspect is being studied within a riparian system, i.e., hydrologic, topographic, edaphic, ecological, etc. (Naiman et al., 1988). For examples, riparian landscapes have been defined by high water marks (Naiman and Decamps, 1997), fluvial processes and fluvial geomorphology (Gregory et al., 1991), plant species indicators (Quinby and Lee, 2001) avian communities (Spackman and Hughes, 1995), and fluvial biota (Naiman et al., 1988). Additionally, it is often essential to integrate definitions that offer practical descriptions of riparian zones in terms of public and private land usages (e.g., road construction and maintenance, agriculture, and forestry) when developing economically feasible riparian buffer restoration practices and policies (Palone and Todd, 1997). As with any ecosystem, preserving the ecological integrity of riparian zones requires the consideration of many variables (Karr, 1993).

From an ecological perspective, studies suggest that the width of riparian zones should be evaluated on a stream by stream basis when studying species biodiversity, richness, and conservation (Naiman et al., 1988, 1993; Naiman and Decamps, 1997; Spackman and Hughes, 1995). We observed differences in plant species composition between stream sides were observed within the same riparian zone. This study supports the recommendation to define riparian zone width on a stream by stream basis rather than applying an arbitrary riparian zone width for all streams across a wide geographical area.

Species richness and equitability within riparian corridors, when considered by separate layers (i.e., overstory, understory, and groundcover), appear to benefit from endogenous disturbances (e.g., small canopy openings, woody debris, flooding) and increased resource availability (Bormann and Likens, 1979). Conversely, human disturbances such as clearcutting or the removal of riparian forest cover for agriculture (Naiman et al., 1988; NRC, 2002), as well as pesticide contamination and nutrient runoff from crop fertilization, can result in the loss of native plant species (Naiman and Decamp, 1997; NRC, 2002). This study did not find a relationship between riparian zone disturbance history and nutrient (nitrogen and phosphorus) availability. However, the results of this study show that the proportions of non-indigenous plant species in the understory and groundcover increased as the level of disturbance increased from low-intensity tree removal to clearcutting and conversion to agriculture. Additionally, the most intensely disturbed riparian zone in this study, the agricultural site, had the lowest species richness and lowest species diversity.

In general, the ecological attributes of riparian ecosystems have not been adequately documented in order to develop best management practices (BMPs); (NRC, 2002). The "three-zone concept", however, that was developed to guide riparian zone management in forests (Palone and Todd, 1997) has been found to be an effective methodology for delineation of many riparian zone types.

The "three-zone" riparian management guidelines developed in the Chesapeake Bay Riparian Handbook (CBRH) offer a flexible classification system for defining the width of riparian zones and are intended to achieve both water quality and landowner objectives (Palone and Todd, 1997). Zone One is the area ranging from the stream's edge to an upland slope position. Zone One provides both stream bank stabilization and an equitable habitat for fluvial organisms. Zone Two is located immediately upslope of Zone One and serves to chemically alter and store nutrients, sediment, and other chemical pollutants that flow overland and through groundwater (Palone and Todd, 1997). Zone Three is located immediately upslope of Zone Two and includes control measures (such as grass strips) that serve to minimize nutrient runoff, filter chemicals associated with sediment, and provide a means for water to infiltrate the soil (Palone and Todd, 1997).

The CBRH is based on extensive collaborative research between organizations such as the US Forest Service, the Virginia Dept. of Forestry, Maryland Forest, Wildlife and Heritage Service, and the Metropolitan Washington Council of Governments. As defined within its body, the purpose of the CBRH is to "provide information on the function, design, establishment, and management of riparian buffer forests" and to offer detailed site and disturbance-specific suggestions concerning restoration." The CBRH focuses on riparian zone management to reduce nonpoint source pollution and to restore riparian landscapes that have deteriorated due to high intensity human disturbance from agriculture, pasturing, and commercial timber harvesting (Palone and Todd, 1997). The methodology described in the CBRH is functionally applicable to the riparian landscapes examined for this study. As such, the CBRH offers a valuable model for implementation of BMPs and restoration practices for riparian buffer zones in the Little Chazy River watershed.

The preservation and management of healthy riparian zones in the Little Chazy River watershed will require extensive education initiatives for public and private land managers in the basin. Viable BMPs in this small watershed must include both ecological and economic perspectives. To achieve these objectives, we recommend following the guidelines described in the CBRH.

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Appendix 1. Species list of plants sampled in the riparian zones, Little Chazy River watershed, 2004.

Species Code	*Genus*	*Species*	NY Status	Species Code	*Genus*	*Species*	NY Status
Aceneg	*Acer*	*negundo*	Native	Dryspi	*Dryopteris*	*spinulosa*	Native
Acepen	*Acer*	*pensylvanicum*	Native	Epihel	*Epipactis*	*helleborine*	Alien
Acerub	*Acer*	*rubrum*	Native	Equarv	*Equisetum*	*arvense*	Native
Acesac	*Acer*	*saccharum*	Native	Equpar	*Equisetum*	*partense*	Native
Agrrep	*Agropyron*	*repens*	Alien	Equspp	*Equisetum*	*sp.*	Native
Agrstr	*Agrimonia*	*striata*	Native	Eryame	*Erythronium*	*americanum*	Native
Alnrug	*Alnus*	*rugosa*	Native	Euprug	*Eupatorium*	*rugosum*	Native
Amearb	*Amelanchier*	*arborea*	Native	Faggra	*Fagus*	*grandifolia*	Native
Ampbra	*Amphicarpa*	*bracteata*	Native	Fesrub	*Festuca*	*rubra*	Alien
Anecan	*Anemone*	*canadensis*	Native	Fraame	*Fraxinus*	*Americana*	Native
Apoand	*Apocynum*	*androsaemifolium*	Native	Frapen	*Fraxinus*	*pennsylvanica*	Native
Aranud	*Aralia*	*nudicaulis*	Native	Fraves	*Fragaria*	*virginiana*	Native
Ararac	*Aralia*	*racemosa*	Native	Galasp	*Galium*	*asprellum*	Native
Arcmin	*Arctium*	*minus*	Alien	Galpal	*Galium*	*palustre*	Native
Aritri	*Arisaema*	*triphyllum*	Native	Galspp	*Galium*	*sp.*	Native
Ascsyr	*Asclepias*	*syriaca*	Native	Gerrob	*Geranium*	*robertianum*	Native
Astspp	*Aster*	*sp.*	Native	Geucan	*Geum*	*canadense*	Native
Athfel	*Athyrium*	*felix-femina*	Native	Hamvir	*Hamamelis*	*virginiana*	Native
Boecyl	*Boehmeria*	*cylindrica*	Native	Hydvir	*Hydrophyllum*	*virginianum*	Native
Broine	*Bromus*	*inermis*	Alien	Impcap	*Impatiens*	*Capensis*	Native
Carcor	*Carya*	*cordiformis*	Native	Jugcin	*Juglans*	*cinerea*	Native
Carspp	*Carex*	*sp.*	Native	Lonspp	*Lonicera*	*sp.*	Alien
Cirarv	*Cirsium*	*arvense*	Alien	Lycobs	*Lycopodium*	*obscurum*	Native
Cirqua	*Circaea*	*quadrisulcata*	Native	Lysnum	*Lysimachia*	*nummularia*	Alien
Cirspp	*Circaea*	*sp.*	Native	Maican	*Maianthemum*	*canadense*	Native
Clevir	*Clematis*	*virginiana*	Native	Menspi	*Mentha*	*spicata*	Alien
Conarv	*Convolvulus*	*arvensis*	Alien	Onosen	*Onoclea*	*sensibilis*	Native
Copgro	*Coptis*	*groenlandica*	Native	Osmcin	*Osmunda*	*cinnamomea*	Native
Corrac	*Cornus*	*racemosa*	Native	Osmcla	*Osmunda*	*claytoniana*	Native
Craspp	*Crataegus*	*sp.*	Alien	Ostvir	*Ostrya*	*virginiana*	Native
Dendip	*Dentaria*	*diphylla*	Native	Oxaspp	*Oxalis*	*sp.*	Native
Denpun	*Dennstaedtia*	*punctilobula*	Native	Parqui	*Parthenocissus*	*quinquefolia*	Native
Drymar	*Dryopteris*	*marginalis*	Native	Phlpra	*Phleum*	*pratense*	Alien

Species Code	Genus	Species	NY Status	Species Code	Genus	Species	NY Status
Pinstr	*Pinus*	*strobus*	Native	Stapal	*Stachys*	*palustris*	Native
Poacom	*Poa*	*compressa*	Alien	Strros	*Streptopus*	*roseus*	Native
Poaspp	*Poa*	*sp.*	Alien	Taroff	*Taraxacum*	*officinale*	Alien
Polsag	*Polygonum*	*sagittatum*	Native	Thadio	*Thalictrum*	*dioicum*	Native
Popgra	*Populus*	*grandidentata*	Native	Thapol	*Thalictrum*	*polygamum*	Native
Poptre	*Populus*	*tremuloides*	Native	Tiacor	*Tiarella*	*cordifolia*	Native
Pruser	*Prunus*	*serotina*	Native	Tilame	*Tilia*	*americana*	Native
Pruvir	*Prunus*	*virginiana*	Native	Tribor	*Trientalis*	*borealis*	Native
Ptepen	*Pteretis*	*pensylvanica*	Native	Trigra	*Trillium*	*grandiflorum*	Native
Quemac	*Quercus*	*macrocarpa*	Native	Tripra	*Trifolium*	*pratense*	Alien
Querub	*Quercus*	*rubra*	Native	Trispp	*Trillium*	*sp.*	Native
Rhacat	*Rhamnus*	*cathartica*	Alien	Tsucan	*Tsuga*	*canadensis*	Native
Ribspp	*Ribes*	*sp.*	Native	Ulmame	*Ulmus*	*americana*	Native
Rorisl	*Rorippa*	*islandica*	Native	Ulmrub	*Ulmus*	*rubra*	Native
Ruball	*Rubus*	*allegheniensis*	Native	Urtdio	*Urtica*	*dioica*	Alien
Rubocc	*Rubus*	*occidentalis*	Native	Uvuses	*Uvularia*	*sessilifolia*	Native
Salser	*Salix*	*sericea*	Native	Vervir	*Veratrum*	*viride*	Native
Samcan	*Sambucus*	*canadensis*	Native	Viblen	*Viburnum*	*lentago*	Native
Sedpur	*Sedum*	*purpureum*	Alien	Viccra	*Vicia*	*cracca*	Native
Solcan	*Solidago*	*canadensis*	Native	Viospp	*Viola*	*sp.*	Native
Solnig	*Solanum*	*nigrum*	Alien	Vitspp	*Vitis*	*sp.*	Native