Microclimatic effects on Spring Ephemeral Flower species at Black Rock Forest in the Hudson Highlands, NY

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Abstract:

A study was done in May of 1997 to determine different microclimatic effects on spring flower diversity. This study was conducted on three long-term ecological research sites in The Black Rock forest in Cornwall, New York. Each site contained numerous microenvironments, including flatland, stream valley, hillside, and hilltop. The abiotic factors examined were soil moisture, soil content, LAI, and slope. All flower species in each of the microenvironments were identified. Ten-meter square samples were taken to determine how many individual plants of each species were present. Furthermore, light readings were recorded at each site.

Of greatest importance was the large range of flower density observed in the different microenvironments. The stream valley microenvironments with moist soil and 0-5% slope had the greatest species abundance and richness. The hillsides and hilltops, which represented most plots in the interior of the forest, had few species and few individual plants of each species. Dry flatlands, which tended to be near the edge of the sites, had more species than hillsides and hilltops but less than the stream valley microenvironments.

Light and water are the primary factors governing flower diversity and abundance. The findings of this study suggest that flower diversity on lower lying plots is influenced by the increased

influx of light and water at the sites' edges. This increased diversity in the plots on the sites' edges may be a direct result of their proximity to the roads, which run parallel to all three sites, since the abiotic forces present along the edges promote diversity.

Introduction:

A spring ephemeral flower is an inflorescence that blooms in early spring and dies during canopy formation. The lack of solar radiation caused by leaf formation on the upper layers of the forest cause the demise of these species later in the season.

Light and water are the primary resources that influence plant growth. When water is plentiful, plants are able to use most of their energy in the production of shoots. However, when water is a limiting resource, plants expend most of their energy developing their root system to seek more water. Since all flowers are using their energy for growth in areas where water is not in limited supply, the competition for light increases. However, in areas where water is a limiting resource, there is great competition for water and little competition for light because all flowers are expending their energy on the production of roots (Huston, 1994).

Many species of plants have a variety of ways of adapting to conditions of limited light or water, such as closing stomata or augmenting leaf size. Woody plant species are more dependent on a variety of resources than annual spring flowers and are thus more likely to survive among limiting conditions (Huston, 1994). Since spring flowers are especially sensitive to environmental stress, they are a key group to study in terms of the effects of abiotic factors on vegetative growth.

Herbaceous understory is the first pioneers to take root immediately following a disturbance and during spring regeneration. At this time there is no competition for light since there is no overstory to shade species at the bottom of the forest. Moreover, there is less competition for water which, except in cases of drought, is also readily accessible to the lower lying herbaceous species. Soil moisture is directly affected by tree cover; without tree cover more water reaches the soil at a quicker rate than by drip, stemflow and evaporation off the leaves of the upper strata (Moore and Vankaat, 1986). Disturbance disproportionately affects the emergent canopy, therefore a direct result of disturbance is greater availability of both light and water, which in turn leads to greater diversity on the surface layer of the upset area.

The number of times that a disturbance occurs within a particular time period is called disturbance frequency. The time between disturbances governs how much the area can recover before another disturbance takes place. Disturbance has three primary effects on resource availability: 1. Converting necromass into nutrients useable by and essential to the standing crop; 2. Eliminating predominate species that previously manipulated or excluded a considerable amount of a particular resource; and 3. the loss or alteration of resources. Often the removal of biomass from a system leads to increased resource availability since the resources are no longer being used by individuals that formerly occupied the area (Huston, 1994).

Disturbances create an edge separating the area, which has been disturbed, from the interior of the forest. Studies have found that edges contain more photosynthetically active radiation, non-native, weedy, and shade intolerant understory with greater species richness and abundance than in the forest interior. These differences have been termed edge effects. The herb layer is an important indicator of edge effects, since the primary inhabitants are those species which are most sensitive to edge microclimates (Thomson, 1995).

Another local factor that seems to have a considerable effect on local diversity is competition. This is evident especially under conditions that allow concentrated competition or the existence of many species in the same microenvironment sharing similar resources. A species may inhibit the growth of an individual or other species directly through competition for essential resources or indirectly by hindering the species ability to acquire or use a particular resource (Ball et al, 1997).

However, past studies have shown that there is no one factor to explain all patterns of diversity. Instead, flower species diversity is governed by a variety of factors, such as light, soil moisture, slope and competition, all of which vary in importance from one microenvironment to another (Huston, 1994).

Hypothesis tested

This study on spring flowers compared different microenvironments and their abiotic effects on species richness and diversity. The question being asked by this study is whether there is a difference in flower diversity among distinct microenvironments. The four microenvironments compared in this study are dry flatland, hillside, hilltop, and stream valley. The abiotic factors examined were Leaf area index (LAI), photosynthetically active radiation (PAR), soil moisture, soil content and slope.

The purpose of this study is to identify different microenvironments in the three long-term sites and determine if there is a significant difference in diversity of spring flowers among these microenvironments. Once the microenvironments were designated, abiotic factors were examined to determine which ones primarily affected plant growth and diversity. The aims of this study are to identify the different microclimatic effects governing flower diversity, determine which of these effects plays a primary role in the different microenvironments, and lastly to identify what alternative elements may control flower diversity.

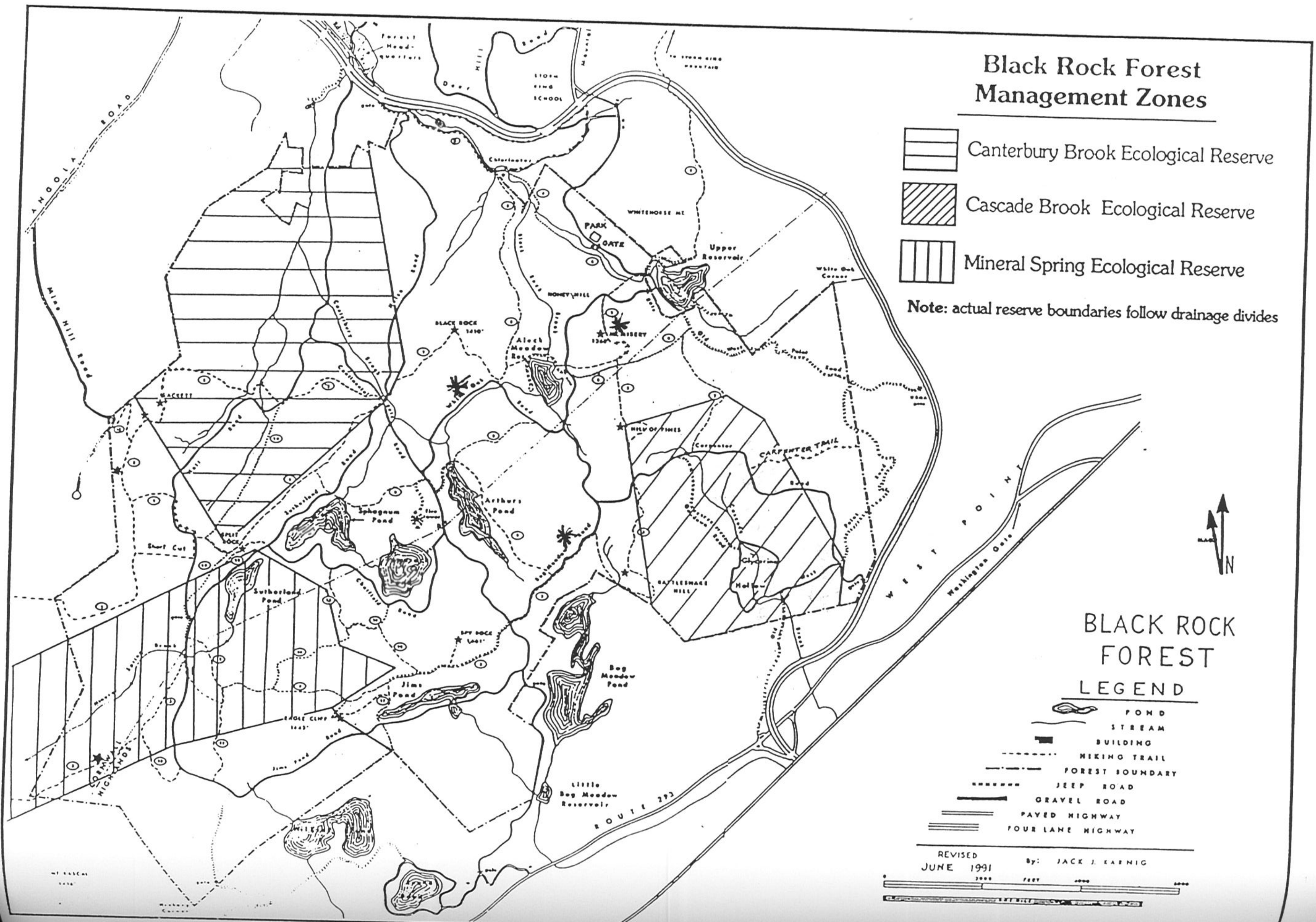
Methods

Background on experimental sites

About one and a half miles west of the Hudson River, located in the towns of Cornwall and Highlands, in the Hudson Highlands of New York, are 3,750 acres (1500ha) that comprise The Black Rock Forest. Between 1927 and 1949, three different sites were established in various locations within the designated experimental area. The three sites were partitioned into sections designated for one of three types of activities: clearcutting, selective logging or no treatment. Well -preserved management records from this time show that since their treatment in the 1930's these three sites, Bog Meadow, Arthur's Brook, and Mount Misery have remained relatively undisturbed (figure 1). Old photographs and recorded compass readings were used to determine the precise lines dividing these sites.

Soil Type

Six soil samples were collected from two general areas within each of the three sites in August of 1995. The samples were mixed and composites of the soil were examined. These soils were tested for organic content by loss of ignition method. Only a few differences have been observed among the different soils at the three sites which all have soils of relatively poor quality. In the analysis and



Black Rock Forest
Management Zones
Canterbury Brook Ecological Reserve
Cascade Brook Ecological Reserve
Mineral Spring Ecological Reserve
Note: actual reserve boundaries follow drainage divides
BLACK ROCK
FOREST
LEGEND
POND
STREAM
BUILDING
HIKING TRAIL
FOREST BOUNDARY
JEEP ROAD
GRAVEL ROAD
PAVED HIGHWAY
FOUR LANE HIGHWAY
REVISED
JUNE 1991
By: JACK J. KARNIG
N
ANGOLA ROAD
Mine Hill Road
WEST POINT
Washington Gate
ROUTE 293
PARK
GATE
Upper Reservoir
WHITEHORSE MT.
HONEY HILL
BLACK ROCK
Aleck Meadow Res.
Arthurs Pond
Sphagnum Pond
Sutherland Pond
Jims Pond
Bog Meadow Pond
Little Bog Meadow Reservoir
RATTLESNAKE HILL
HILL OF PINES
CARPENTER TRAIL
SPY ROCK
EAGLE CLIFF
SPLIT ROCK
Short Cut
STORM KING SCHOOL
Upper Reservoir

discussion sections the soils at each site will be examined at length (Farrell, 1997).

Climate

The mean annual temperature at Black Rock Forest is about 50 degrees Fahrenheit with the minimum temperature reaching 15 degrees and the maximum 103. The mean annual precipitation is 126cm per year (West Point precipitation data, 1980-1995). The predominate season of vegetational growth is approximately 160-180 days long starting in the beginning of May and lasting through late September, and 13 out of the 46 inches of rainfall generally occur during the summer months (Raup, 1938).

Site Locations

Arthur's Brook is situated on the southern hillside of a valley, which lies approximately 2.5 miles east-south-east of the Hudson River. The elevation ranges from 1100 feet at Arthur's Brook to about 1250 feet in the southern most end of the experimental section. The actual brook runs through the northern most end of the experimental zone primarily affecting five of the plots (Farrell, 1997).

Bog Meadow is located on a hillside that faces east-north east, around 2.3 miles east-south-east of the Hudson River. "The section ranges in elevation from about 1200 feet, in the northwest corner to about 1300 feet, in the southeast corner" (Farrell, 1997).

Mount Misery is located in a small valley between Honey Hill (1135 feet) and Mount Misery (1268 feet), around 2.0 miles from the Hudson. The site is divided by White Oak Road, which runs through the center of the valley. Part of the site lies southeast of the road partly on a hillside that faces northwest. The other half of the site is located partly on a hillside that faces southeast, northwest of the road (figure 1) (Farrell, 1997).

Re-establishing sites

Surveying began in mid-May and continued until the end of the month. During the preliminary visits, the sites were carefully examined. This included looking for 48 stakes, 18 stakes in two of the larger sites, Bog Meadow and Arthur's Brook and 12 in the smaller site, Mount Misery, that were plotted the previous summer in each of the sites. They were placed strategically to get a precise representation of the entire areas.

Each stake was plotted at least 10 feet from the boundaries and at least 10 feet from the other plots to avoid side effects and overlapping. Stakes were distributed on similar elevation ranges, and were placed in the mid-points of the plots. These plots, 74 feet in diameter, were each categorized into one of four different microenvironments: flat, hillside, stream valley, or hilltop (table 1).

Site analysis

In the summer of 1997, each plot was characterized geographically using Farrell's (1997) technique. Plots were classified into one of four microenvironments based on the moisture of the soil and the slope of the plot. All the stream valleys were on flatland areas with a slope of 0-5%. The dry flatland microenvironments had dry soils and slopes of 0-5%. Therefore the only distinction between flatland and stream valley is the presence of a water source. The hillside microenvironments had a slope greater than 5%.

Table 1. Separation of plots into microenvironments: Each of the 48 plots were designated to one of the four microenvironments: flatland, hillside, stream valley or hilltop. The numbers represent the number of plots within each microenvironment. 15 plots were dry flatland microenvironments, 23 were hillside, 5 were hilltop and 5 were stream valley.

	Mount Misery		Bog Mead			Arth's Brook		
Flat	3	4	2	3			1	2
Hillside	3	2	2	3	5	3	3	2
Hilltop			2		1	1	1	
Stream						2	1	2

Surveying of Spring Flowers

There were a total of 48 plots: 18 at both Bog Meadow and Arthur's brook and 12 at Mount Misery. A stake was placed at the center of each plot. A 37' rope was attached to each stake to form a 37' radius in which a plant survey was performed. All species that were present were recorded.

Samples were also taken by using a hula-hoop, which is approximately the size of a one square meter quadrant. Ten sample segments were established at each plot. In each of these 10 sample segments, the different species and number of individuals of each species were recorded. These samples were arbitrary representations of the plot. However, enough samples were taken to ensure that the whole 37-foot radius was represented.

Light Recordings

PAR (photosynthetically active radiation) and LAI (Leaf area index) recordings were taken with a ceptometer at each site in order to assess the correlation between amount of light and flower growth (table 2). Six readings were recorded at each plot during the last week of May. The average of 108 light readings was taken at both Bog Meadow and Arthur's Brook and the average of 72 light readings were taken at Mount Misery. The ceptometer used was a LiCOR ceptometer, which reads PAR in units of micromoles per square meter. It can only obtain wavelengths between 400-600 nanometers. By comparing subcanopy PAR readings to open light readings the ceptometer can estimate the leaf area index.

Table 2: Light Readings at each site: average PAR (photosynthetically active radiation) and LAI (leaf area Index) readings for each site. Six readings were taken at each plot.

	PAR	LAI	Avg. R	Avg. I
Arthur's Brook, 1-6	0.231	0.007	0.187	0.008
Arthur's B, 7-12	0.146	0.009		
Arthur's B, 13-18	0.185	0.008		
Bog Meadow, 1-6	0.349	0.005	0.235	0.007
Bog M, 7-12	0.169	0.008		
Bog M, 13-18	0.187	0.008		
Mount Misery, 1-6	0.128	0.009	0.119	0.009
Mount Misery, 7-12	0.111	0.010		
MEAN	0.188	0.008		
Sq. deviation	0.040	0.000		

Hypothesis testing

The microenvironments were considered the independent variable and the number of species and number of individuals within each microclimatic zone the dependent variable. The null hypothesis stated that there is no variance in total abundance among sites or treatment (microenvironment). The data from the 480 sample plots (10 at each 48 microenvironments) was used for all analyses.

The data was analyzed by MANOVA (SPSS, 5.0). The analysis compared the number of individuals, the site (Mount Misery, Bog Meadow and Arthur's Brook) and the treatment or type of microenvironment. Microenvironments were divided into four groups (table 1).

Alternative hypotheses testing

The general observation that the plots closest to the roads, which run parallel to the sites, had higher species richness than those in the forest interior led to the formulation of an alternative hypothesis. This hypothesis examined the effects that the road has on flower species diversity. This was also tested by MANOVA with the road as the independent variable and the number of species and number of individuals as the dependent variables. The null hypothesis tested was that the road would not affect the diversity of the microenvironments within close proximity.

The contents of the soil at each site were examined from soil samples taken in the summer of 1995. The effect that soil content has on flower diversity at each site was another hypothesis analyzed. Since the data on soil at each plot was limited, there was no statistical test for this hypothesis.

A hypothesis was conceived pertaining to the relationship between *Kalmia latifolia* and flower growth. Two observations supported the hypothesis. The first observation made was that in plots where the *Rhododendron* was prevalent, few to no flower species were identified. The second observation was that *Streptopus amplexifolius* remained prevalent despite the presence of *Kalmia* *latifolia* and in many plots where the *Rhododendron* was present the only species that was identified was *Streptopus amplexifolius.*

It was hypothesized that either *Kalmia latifolia* affects flower growth and diversity by emitting a chemical compound, which inhibits the growth of flower species, or that the presence of the shrub prevents the flowers from receiving sufficient light. Other hypotheses that correlates to this observation is that *Streptopus amplexifolius* has adapted to low light influx, that the this species may be immune to the *Kalmia latifolia's* chemicals, or that the species is dependent on one or both for its success. In order to test the allelopathic relationship between spring flowers and *Rhododendron*, the number of individuals of *Streptopus amplexifolius* was compared to the amount of Kalmia *latifolia* at each plot.

In 1996, Dan Farrell recorded the shrub coverage at each microenvironment using the Brown-Blanket cover scales. The scale varies from 1 to 5 with 1 representing 0-5%, 2 representing 6-25%, 3 representing 26-50%, 4 representing 51-75% and 5 representing 76-100% (Farrell, 1997). These results for soil and shrub coverage were used to test these two alternative hypotheses. Since Dan Farrell's data was used to correlate the abundance of *Kalmia latifolia* present at each microenvironment, there is no raw data for the abundance of *Kalmia latifolia* at the sample plots within each treatment area. Therefore, in order to analyze this data it was necessary to establish two categories.

The first category represents plots with 0-50% coverage of *Kalmia latifolia.* The second category represents those plots with 50-100% coverage of the *Rhododendron.* These hypotheses were tested by MANOVA with *Kalmia latifolia* as the independent variable and the overall number of species, altogether number of individuals of all species and number of individuals of *Streptopus amplexifolius* were the dependent variables. The null hypothesis tested was that the abundance of *Streptopus amplexifolious*, number of individuals of all species and number of species, is not dependent on the presence of *Kalmia latifolia.*

Results

Results of flower survey

A total of 37 species were identified (table 3). Mount Misery had the fewest species with a total of 10 species, then Bog Meadow which had 12 species and finally Arthur's Brook with 35 (figure 2). The five most pervasive species were *Streptopus amplexifolius*, *Maianthemum canadense*, *Polygonatum canaliculatum*, *Lysimachia vulgaris* and *Aster*; these species appeared in all three of the sites (figure 3). The species with the highest number of individuals were *Maianthemum canadense*, which had 330 individuals, *Streptopus amplexifolius* with 236, *Anemonella thalictroides* with 167, *Medeola virginiana* with 126 and *Panax trifolius* with 99 individuals (figure 4). Out of the 48 plots, *Streptopus amplexifolius* appeared on 41, *Medeola virginiana* on 28, *Maianthemum canadense* was present on 26, and *Polygonatum canaliculatum* was present on 14 (figure 5). Some species appeared in bunches. This is evident from the approximate number of individuals of the species that appeared per plot (figure 6). This was obtained by dividing the number of individuals observed by the number of plots where the species was present. Although *Anemonella thalictroides* only appeared on one of the sites, Arthur's Brook, it had the highest average of individuals per plot with 41.8 individuals. Also, *Panax trifolius*, which was only present on two of the three sites, had the second highest number

Table 3: The Species identified on all plots: The common name, scientific binomal and family of each species identified on all three of the experimental sites; Bog Meadow, Mount Misery and Arthur's Brook (Peterson and Mckenny, 1986).

Common Name	Scientific Binomal	Family
rue-Anemone	*Anemonella thalictroides*	Ranunculaceae
spikenard	*Aralia racemosa*	Araliaceae **
dwarf ginseng	*Panax trifolius*	Araliaceae
Jack-in-the-pulpit	*Arisaema triphyllum*	Araceae
yellow wood sorrel	*Oxalis europaea*	Oxalidaceae
violets	*Viola ?*	Violaceae
white violets	*Viola* ?	Violaceae
bog violet	*Viola carspersa*	Violaceae
smooth Solomon's seal	*Polygonatum biflorum*	Liliaceae
Canada mayflower	*Maianthemum canadense*	Liliaceae
twisted stalk	*Streptopus amplexifolius*	Lilaceae
Indian cucumber root	*Medeola virginiana*	Lilaceae
jewelweed	*Impatiens pallida*	Lilaceae
wood lilly	*Lilium philadelphicum*	Lilaceae
pennsylvania bittercress	*Cardamine pensylvanica*	Cruciferae*
mountain watercress	*Cardamine rotundifolia*	Cruciferae*
blueflag iris	*Iris versicolor*	Iridaceae*
whorled loosestrife	*Lysimachia quadrifolia*	Primulaceae
Northern bedstraw	*Galium boreale*	Rubiaceae
water hemlock ???	*Cicuta maculata*	Umbelliferae*
ground ivy	*Glechoma hederacea*	Labiatae
lady slipper	*Cyprepedium*	Orchidaceae*
indian pipe	*Monotropa uniflora*	Pyrolaceae*
spotted wintergreen	*Chimaphila maculata*	Pyrolaceae
white lettuce	*Prenathes alba*	Compositae
aster	*Laevis*	Compositae

Unidentified species A-J

A	Opposite toothed leaves #1
B	Weed like thing # 1
C	Weed like thing #2
D	Opposite toothed leaves #2
E	Opposite toothed leaves A*
F	Opposite entire leaves A*
G	flagged at Mount Misery thinned
H	whorled leaves
I	Long Hairy weed like *
J	Long Weed like plant *
K	Possibly rose pagonia

*Only one species was identified in one plot

** Only one species was identified in two plots

Figure 2: Diversity of Plot The total number of species found on each plot.

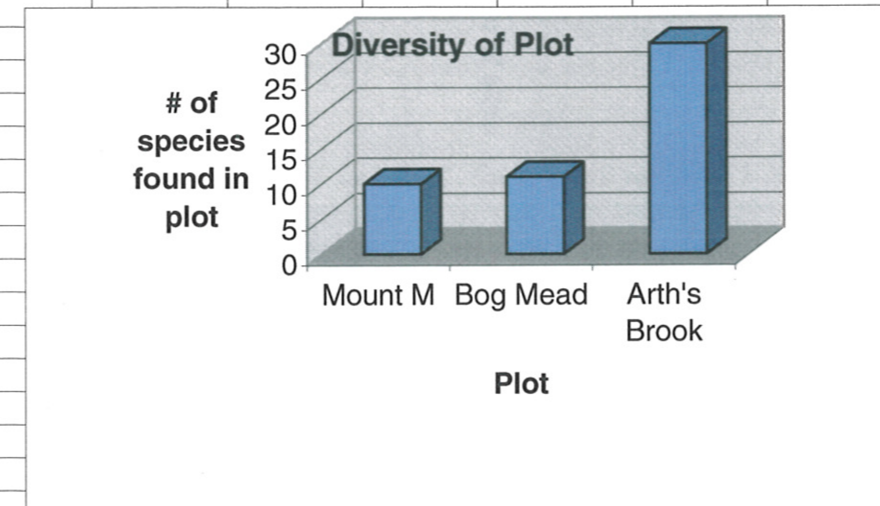


Figure 3: number of sites where species was identified The number of sites, out of three, where each species was present

Figure 4: number of individuals of each species identified The total number of individuals of each species present in the 48 plots.

Figure 5: number of plots where species was identified The number of sites, out of 48, where each species was present

Figure 6: average number of individuals of each species identified per plot The total number of each species identified divided by the number of plots where the species was present.

Figure 7: Difference in species richness in edge and interior The number of species that were present in the edge plots, interior plots and both.

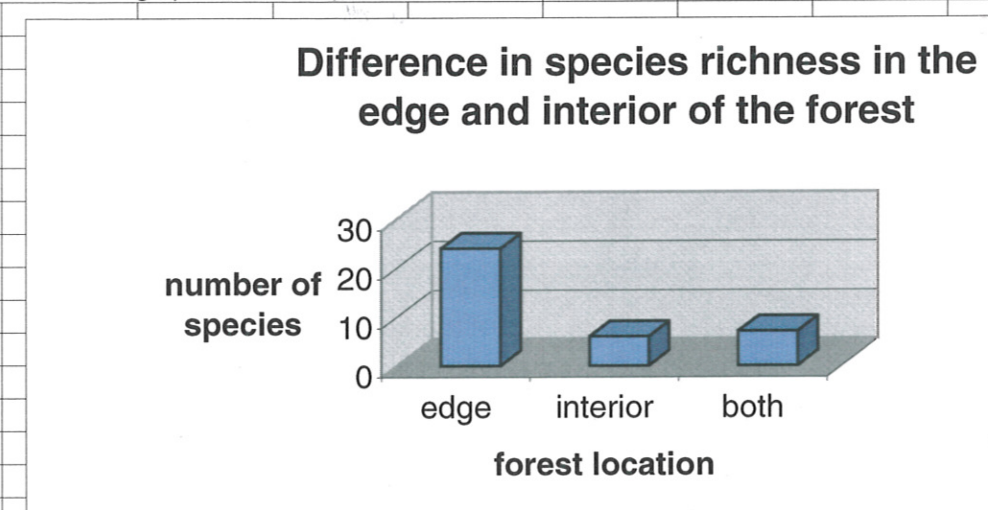


Figure 3: Number of sites (out of three) where species was identified

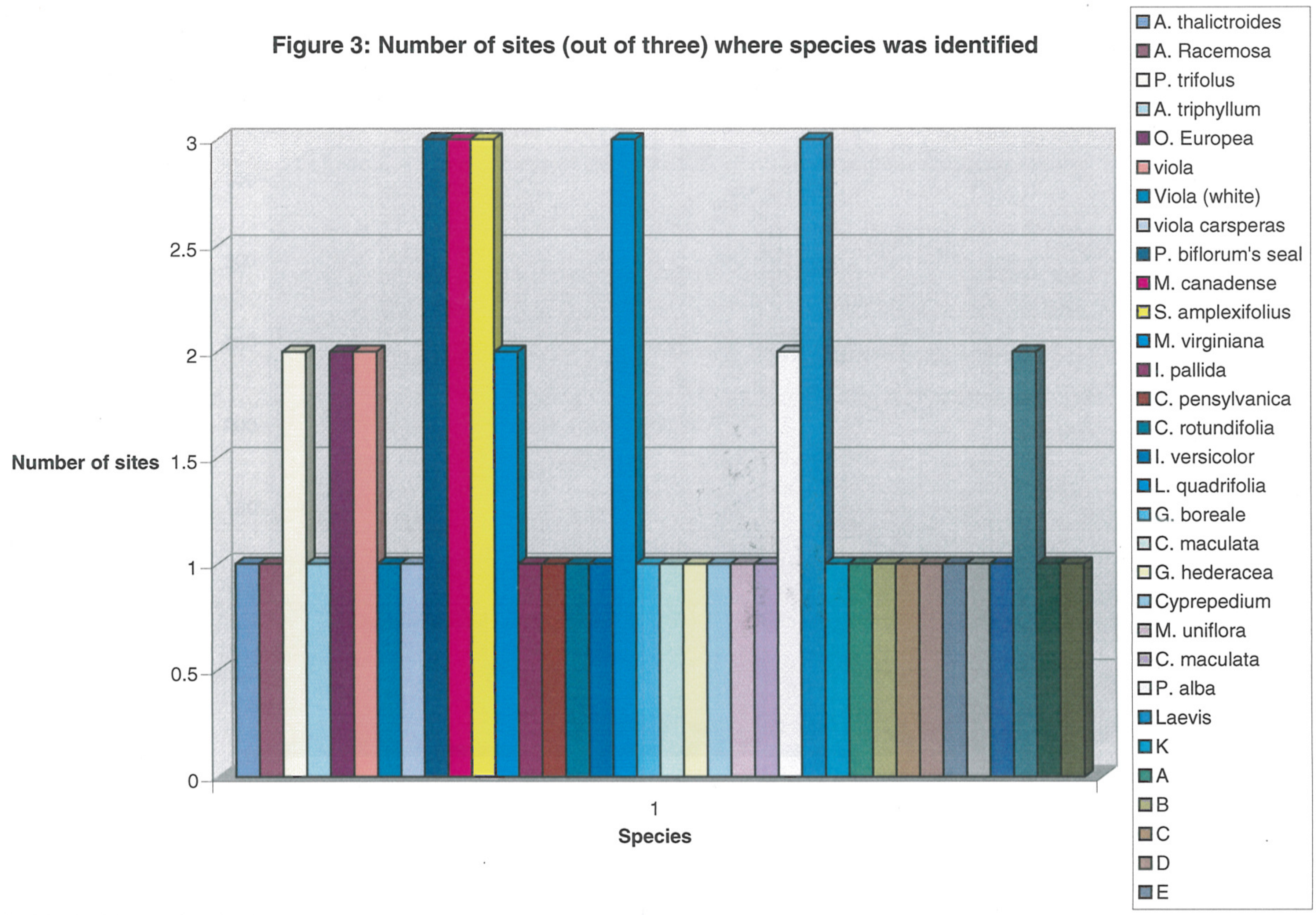


Figure 4: Number of individuals of each flower species identified

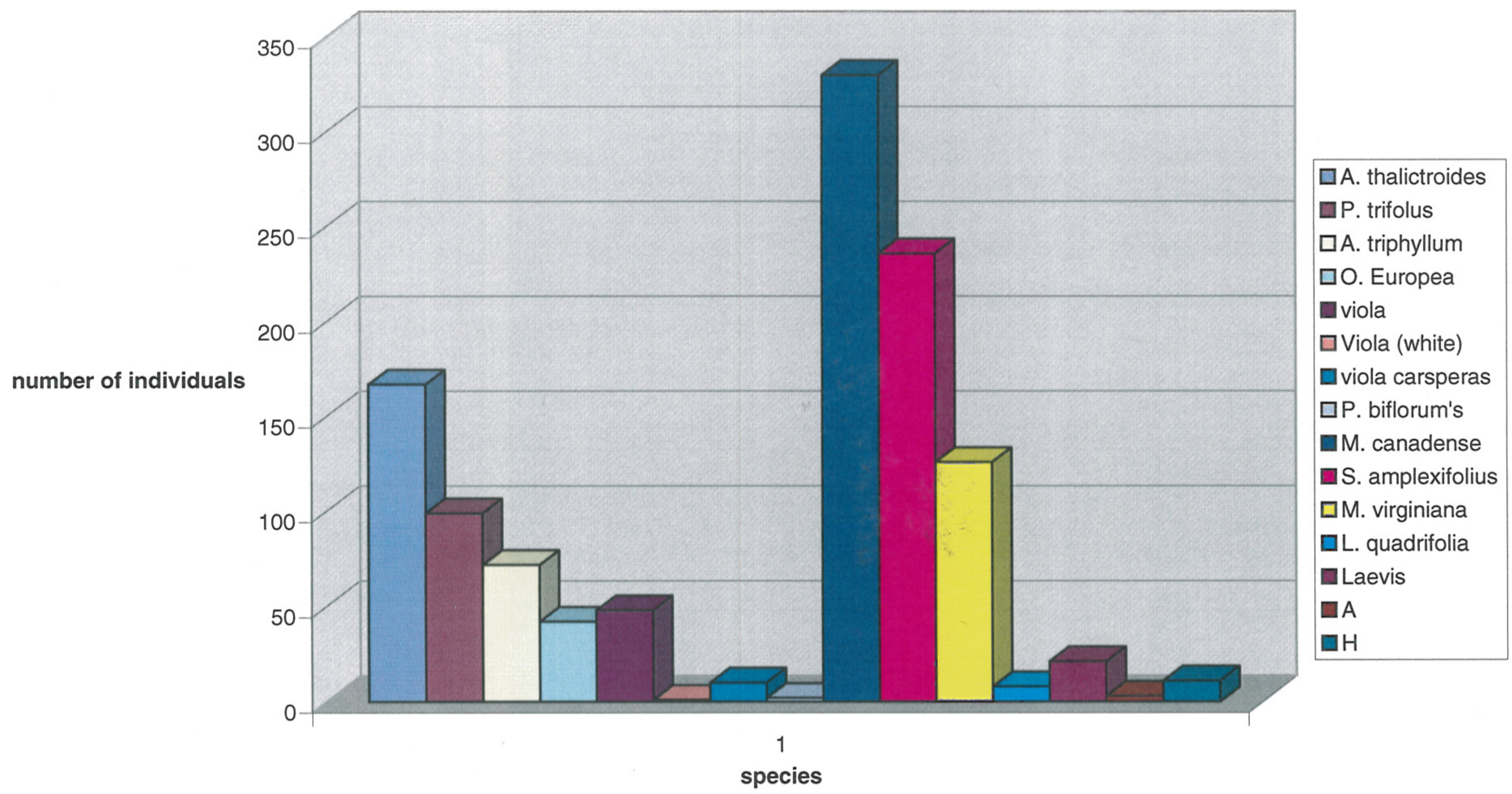


Figure 5: Number of plots (out of 48) where species was identified

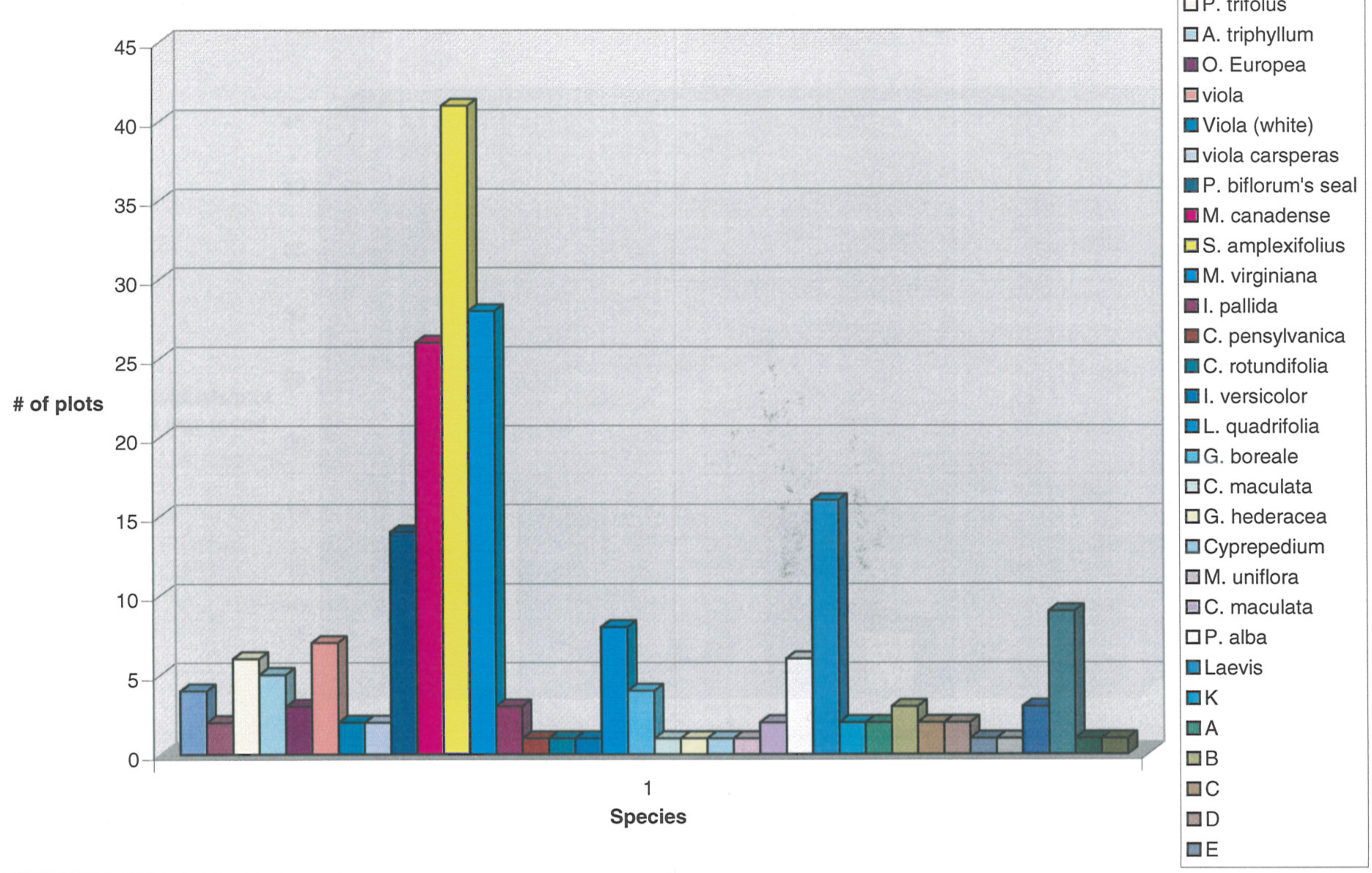


Figure 6: Approximate number of individuals found per plot

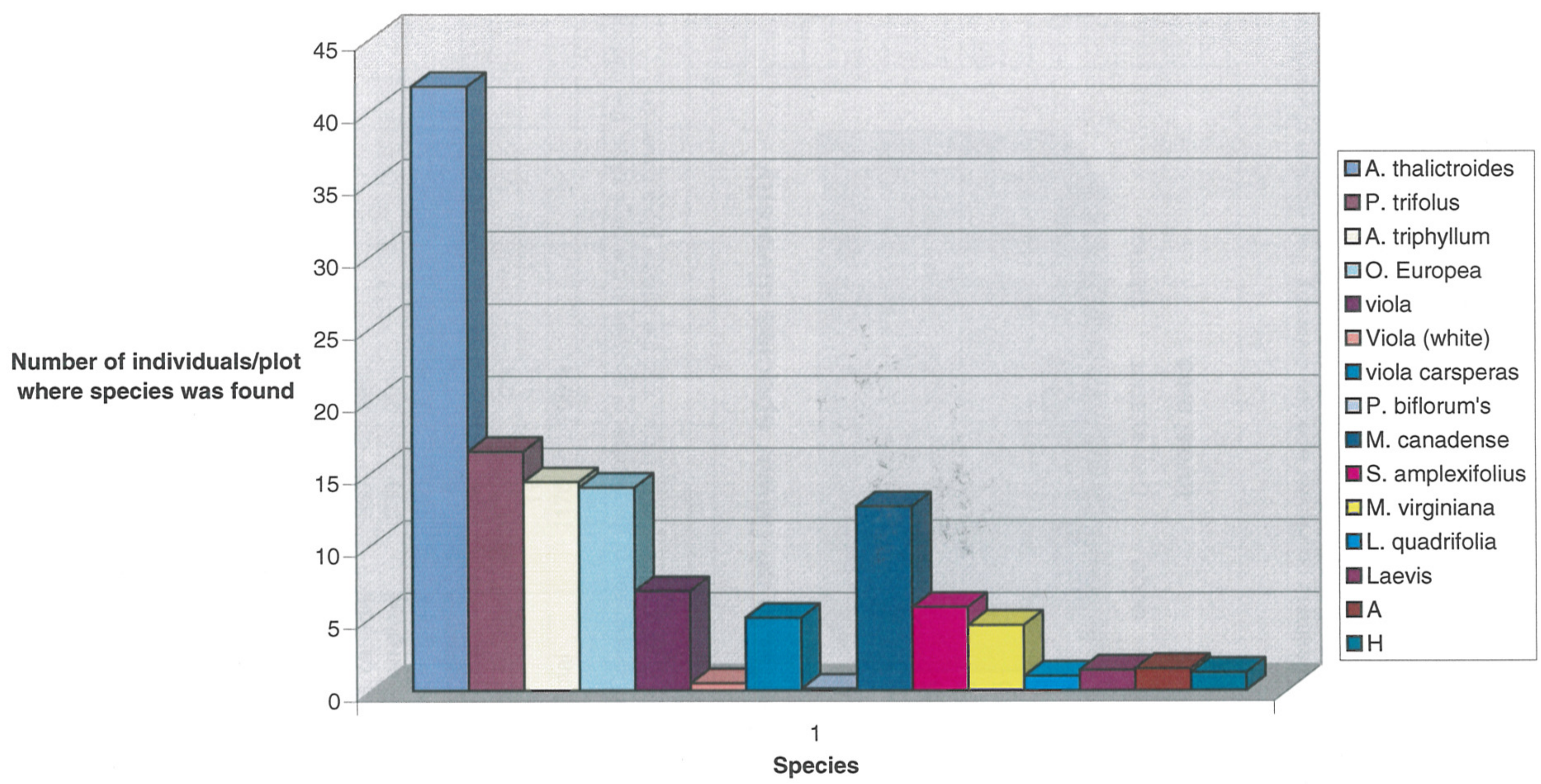


Table 4: The predominate flower species in three sites at Black Rock Forest The number of individuals of each predominate species was divided by the number of individuals of all predominate species to get the approximate % stand.

Species	individual	% stand
A. thalictroi	167	14%
P. trifolus	99	8%
A. triphyllu	72	6%
O. Europea	42	4%
viola	48	4%
Viola (white	1	0%
viola carsp	10	1%
P. biflorum	2	0%
M. canader	330	28%
S. amplexi	236	20%
M. virginiar	126	11%
L. quadrifol	8	1%
Laevis	21	2%
A	3	0%
H	11	1%
Total	1176	100%

Figure 8: Edge effects Comparison of the number of species in the edge plots, the mid-interior (those between the edge plots and the interior plots), and the interior plots based on data from Arthur's Brook.

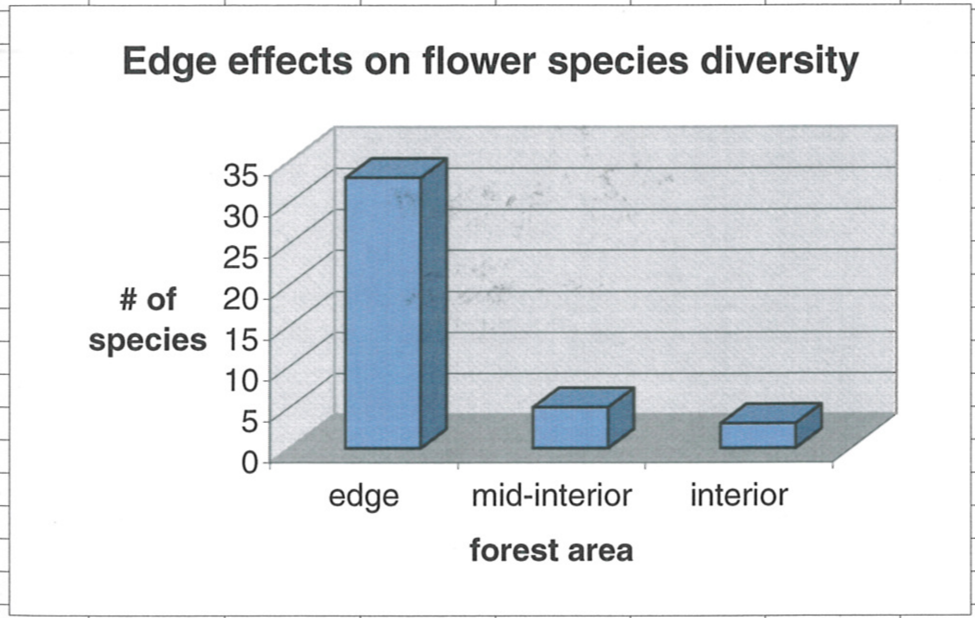
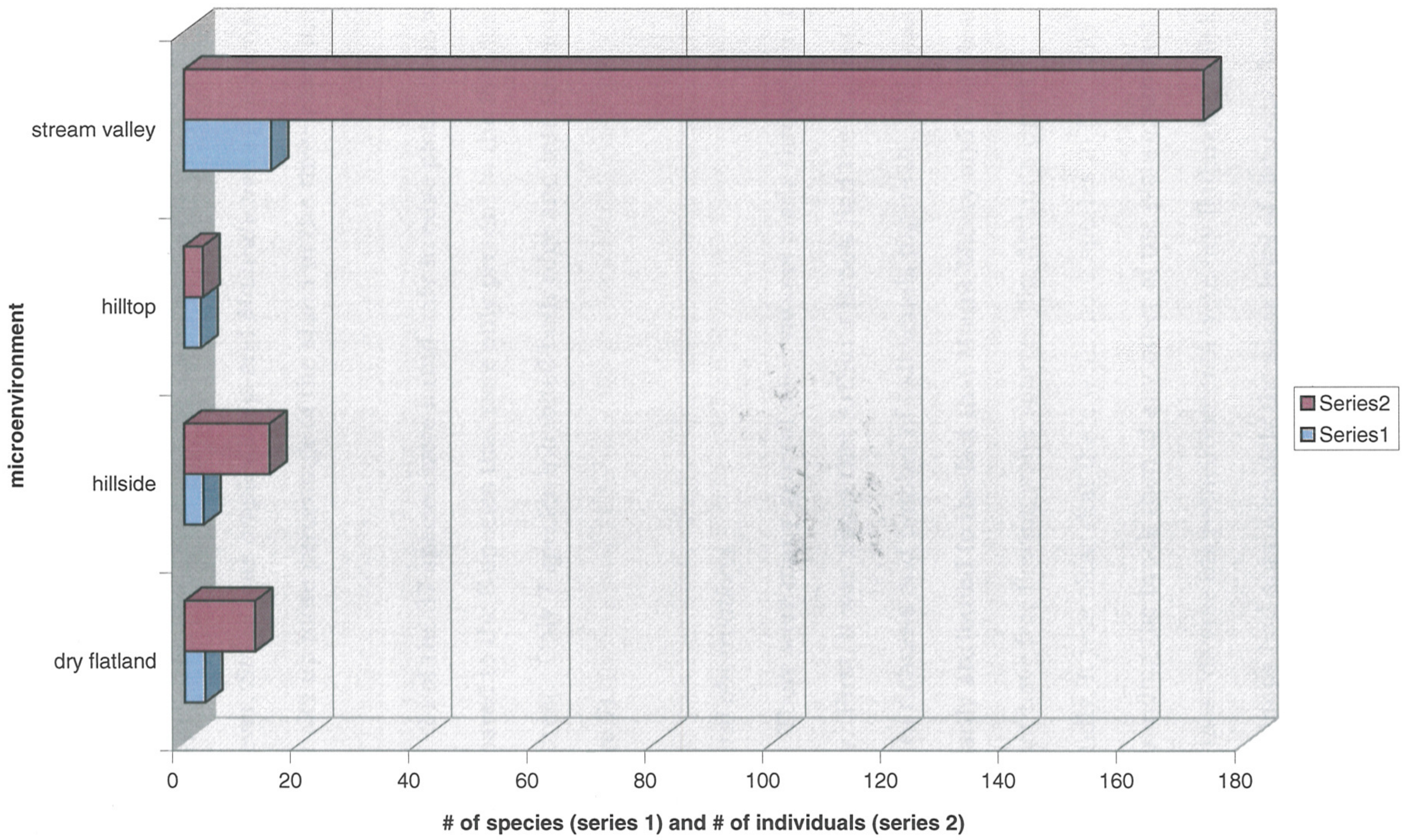


Figure 9: Effects of Microclimate on Flower species diversity The number of individuals (series 1) and the number of species, (series 2) found within each microclimate.

Figure 9: Microclimatic effects on flower species



of individuals per plot with 16.5. On the other hand, *Streptopus amplexifolius*, which was found on all but 7 of the 48 plots had only 5.8 individuals per plot. *Maianthemum canadense*, which was present on 26 plots, had approximately 12.7 individuals per plot. However, *Streptopus amplexifolius* and *Maianthemum canadense* had the make up more percentage of the stand in the three plots (table 4).

24 of the 37 species were found only in edge plots. This was compared to the 6 species that were only present in the interior of the forest. Only 7 species inhabited both edge and interior plots (figure 7).

General observations

There were many general observations made throughout the study. First, it was noted that Arthur's Brook had the highest species richness and number of individuals (figure 2). This was primarily attributed to the fact that Mount Misery and Bog Meadow did not have free flowing water sources like Arthur's Brook. Secondly, it was clear that there were more species in the plots surrounding the brook than at any other of the plots examined. The next most diverse microenvironments were dry flatlands. Hillsides and hilltops had approximately the same level of diversity (figure 9).

Another observation of great importance was the edge effects.

It appeared that the plots closest to the road had higher species richness and more individuals than those did in the interior of the forest. In fact, species richness decreased with each subsequent plot from the edge into the interior of the forest (figure 8).

Plots where *Kalmia latifolia*, a type of *Rhododendron*, was present harbored very few species. Since *Kalmia latifolia* is a woody shrub species, it shades lower lying herbaceous species. The only species that appeared to be capable of tolerating such a low influx of light was *Streptopus amplexifolius*. Some of the plots in the Mount Misery site were sans flowers. This may be attributed to the *Kalmia latifolia* or to the soils at Mount Misery, which are poorer in essential nutrients than the other sites.

Results of the different Hypotheses

The first MANOVA performed compared the number of species and individuals based on the type of microenvironments with the assumption that each species can disperse to any of the four microclimatic sites. Comparability tests performed showed that although there was no variation in the sites, there were differences among the (figure 10).

After these tests were completed, univariate F tests were performed comparing the number of individuals and number of species to site and treatment (figure 10). The second tests were

Figure 10: Effects of Microclimate on flower species: Results of the null hypothesis that species richness and individual abundance is not dependent on microclimate. The dependent variables tested were number of species and individuals. The independent varibale tested was microclimate. Two comparability tests initiated the MANOVA one for sites and the other for microclimates

Comparability test for sites

Test narr	Value	Approx F	Hypoth F	Error DF	Sig of F
Pillais	0.004	0.347	6	942	0.912

Univariate F-tests with (3,4 D.F. for site

Variable	Hypoth S	Error SS	Hypoth M	Error MS	F	Sig of F
NIND	36.9	3.7x104	12.31	79	0.156	0.926
NSPP	0.869	2.0x102	0.29	0.423	0.423	0.562

Comparability test for treatments

Test narr	Value	Approx F	Hypoth F	Error DF	Sig of F
Pillais	0.434	3.483	6	942	0.002

Univariate F-tests with (3,471) D.F. for treatment

Variable	Hypoth S	Error SS	Hypoth M	Eror MS	F	Sig of F
NIND	690	3.7x104	230	78.98	2.91	0.034
NSPP	8.09	199	2.7	0.423	6.38	0

Figure 11: Description of Subpopulation summaries of number of individuals and number of species by level of site and treatment.

Number of individuals by site and treatment

Site	Mean	Standard deviation	Cases
Mount Misery	0.475	1.38	120
Bog Meadow	1.57	6.21	180
Arthur's Brook	5.83	14.8073	180
Total	2.9	10.1	480

Treatment	Mean	Standard deviation	Cases
dry flatland	1.17	3.74	150
hillside	1.4	5.18	240
hilltop	0.375	0.952	40
stream valley	17.3	24.3	50
Total	2.9	10.1	480

Number of species by site and treatment

Site	Mean	Standard deviation	Cases
Mount Misery	0.175	0.443	120
Bog Meadow	0.372	0.626	180
Arthur's Brook	0.783	0.999	180
Total	0.477	0.794	480

Treatment	Mean	Standard deviation	Cases
dry flatland	0.373	0.608	150
hillside	0.317	0.571	240

hilltop	0.2	0.405	40
stream valley	1.78	1.17	50
Total	0.477	0.794	480

Figure 12: Effects of *Kalmia latifolia* on species richness and abundance Results of MANOVA testing the null hypothesis that species richness and abundance is independent on the presence of *Rhododendron* and the results of the comparability test. The dependent varibales tested were the nunmber of species, the number of individuals of all species and the number of individuals of *Streptopus amplexifolius.* The independent variable was the abundance of *Kalmia latifolia.*

Comparability test for *Rhododendron*

Test narr	Value	Exact F	Hypoth D	Error DF	Sig of F
Pillais	0.092	16.2	3	476	0

Univariate F-tests with (1,· D.F. for *Rhododendron*

Variable	Hypoth S	Error SS	Hypoth M	Error MS	F	Sig of F
Twisted s	0.44	1.0x103	0.44	2.16	0.203	0.652
Nindividu	2.1x103	4.7x104	2.1x103	98	21.2	0
Nspecies	24.1	278	24.1	0.581	41.5	0

Figure 13: Effects of the road Results of the analysis of the road as a cause of species diversity in plots situated approximately 100 feet or less from the road. The dependent variables examined were number of species and number of individuals of all species with the road as the independent variable. A comparability test was done before the analysis.

Comparability test for the road

Test narr	Value	Exact F	Hyoth DF	Error DF	Sig of F
Pillais	0.123	33.5	2	477	0

Univariate F-tests with (1, 478) D.F.

Variable	Hypoth S	Error SS	Hypoth M	Error MS	F	Sig of F
Nindividu	4.2x103	4.5x104	4.2x103	93.7	44.3	0
Nspecies	33.8	268	33.8	0.561	60.3	0

similar to the first ones in that the F values were only significant for each treatment, not for the sites. This simplifies the data since treatment is the sole significant factor. Therefore, there is a significant difference of species and number of individuals among microenvironments but not between sites. This is especially evident when the summaries of the number of individuals and the number of species by site and treatment are compared (figure 11).

In order to examine the possible allelopathic relationship, a MANOVA was done comparing the two different categories to the number of *Streptopus amplexifolius*, overall species diversity and number of individuals within each plot (figure 12). The results for *Streptopus amplexifolius* were not significant. However, the number of species and individuals compared to the abundance of *Kalmia latifolia* were both significant.

Since leaf area index (LAI) readings were taken by site, not by plot, it is difficult to analyze the relationship between light and flower diversity. However, the average LAI readings were highest at Bog Meadow, 0.235 micromoles, then Arthur's Brook, 0.187 micromoles, and lastly Mount Misery, 0.119 micromoles (table 2). By looking at these numbers it would seem as if light has some significance, since Mount Misery had the fewest species. Although, Bog Meadow, which had fewer species than Arthur's Brook, had a higher average light reading. It is difficult to access the accuracy of these readings since they were taken by site, not by plot.

The edge effects and the proximity of the road as a constant disturbance were also analyzed. When the road and species abundance were compared by MANOVA, the F values were significant (figure 13). This hypothesis will be looked at in greater detail in the discussion section since it is difficult to base this hypothesis solely on statistical data.

The soil samples were used to examine the effects of the soil quality on the diversity of the flower species. Each site was relatively similar in soil quality. However, there were slight differences noted, mainly within Mount Misery (figure 14-18). The main factors being compared among the different soils are the phosphorous content, availability of organic matter (figure 15), pH (figure 14), magnesium (figure 16), phosphorous (figure 17), and aluminum levels (figure 18). This study only examined the different contents of the topsoil, although both topsoil and subsoil samples were collected.

Figure 14: Average pH concentration is soil at each of the sites The average of two composite samples taken in 1995 (BRF, 1995) from the topsoil at Mount Misery, Arthur's Brook and Bog Meadow.

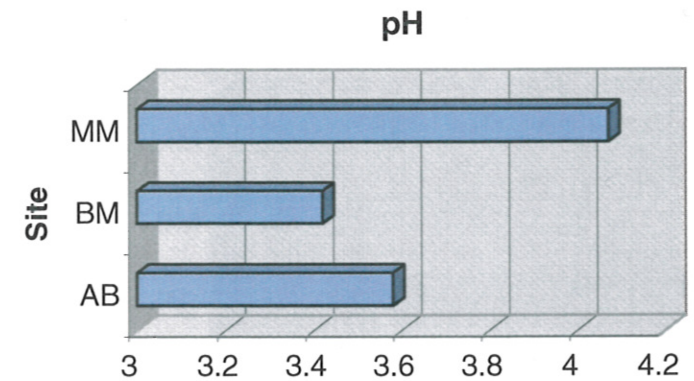


Figure 15: Average % LOI at each site The average of two samples taken in 1995 (BRF, 1995) from the topsoil of Mount Misery, Arthur's Brook, and Bog Meadow. The % LOI was achieved by loss of ignition method (Farrell, 1997).

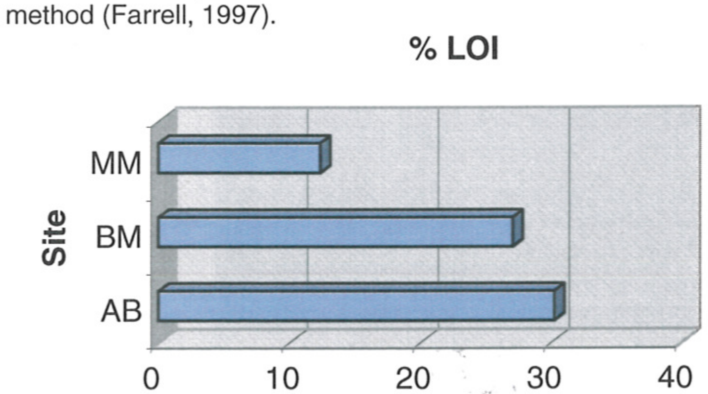


Figure 16: Average Magnesium content at each site The average of two samples of magnesium collected in 1995 from the topsoil of Mount Misery, Arthur's Brook and Bog Meadow (BRF, 1995).

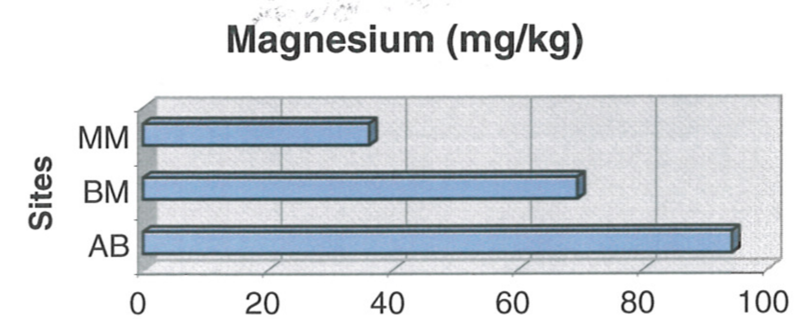


Figure 17: Average phosphorous content at each site: The average of two composite samples taken from the topsoil of Mount Misery, Arthur's Brook, and Bog Meadow in 1995 (BRF, 1995).

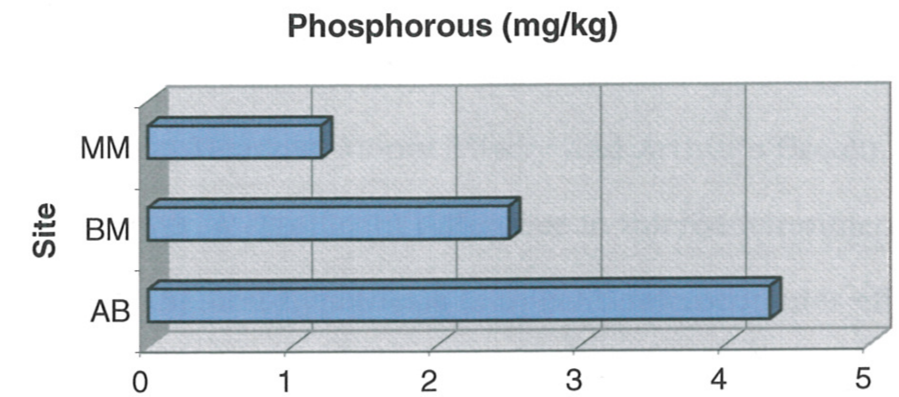
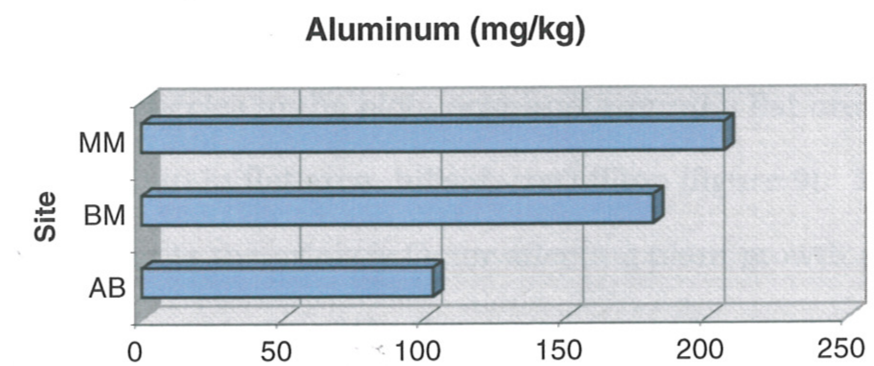


Figure 18: Average Aluminum conten at each site: The average of two composite samples taken from the topsoil of Mount Misery, Arthur's Brook, and Bog Meadow in 1995 (BRF, 1995).



Discussion

The results of the first MANOVA test showed that there was no significance in the number of species and individuals among the different sites (Bog Meadow, Mount Misery and Arthur's Brook), There was, however, a significant difference in microenvironments. This shows that the first hypothesis is upheld; microclimates effect flower species diversity (figures 10 and 11).

Flower growth and diversity significantly differs between microenvironments. There was a considerably larger amount of individuals and species in the plots near and around a flat area with a water source than in flat area, hillside, or hilltop (figure 9). This implies that water is the primary factor affecting plant growth and diversity since the majority of the flower species and individuals were found on plots near a water source. This hypothesis has also been supported in theory. It has been claimed that the sole significant parameter inhibiting the dispersion and productivity of flower species on a worldwide basis is water availability, either through minimal soil water levels or by way of high evaporative demands. The ability of plants to survive in areas of limited water is dependent on their capability to withstand periods of drought. Some species can effectively adapt to water stress by dropping leaves or closing stomata, while others are osmotic adjusters. These plants are capable of lowering the water potential at which point stomata close and photosynthesis ends (Reaka-Kudla, 1992).

One study, conducted at the University of Minnesota by Tilman and El-Haddi (1992), examined the effects of drought on biodiversity. During the drought year of 1988, species richness in four different grassland fields dropped an average of 37%. The following year, when plant biomass and precipitation recovered, species richness did not. Tilman and El-Haddi concluded that rare species and those incapable of adapting to a changing environment were the most vulnerable to environmental stress and it was these species which did not recover from periods of drought (Reaka-Kudla, 1992). However, it is clear that plants respond to a variety of environmental factors, not just water stress. Furthermore, all species of plants respond differently to environmental conditions.

The results of the flower survey showed some species like *Anemonella thalictroides* and *Panax trifolius* appeared in clumps. These were usually situated around or near the water source at Arthur's Brook. However other species like *Streptopus amplexifolius* and *Maianthemum canadense* appeared in a majority of the plots, yet only had a small average of individuals per plot (figure 6). These findings suggest that while certain species may flourish in one type of microclimate, other species may remain stable in number throughout different microenvironments.

Melick and Seppelt (1997) conducted a study on vegetation patterns in relation to climate and endogenous changes in Wilkes Land, continental Antarctica. Melick and Seppelt looked at plant communities in relation to short-term microclimatic vacillations and long-term climate change within the Wilkes Land since deglaciation. Melick and Seppelt claim that because of the extreme nature of the Antarctic environment, small differences within microenvironment lead to major changes in plant communities. They looked primarily at the growth of lichens and bryophytes and noted that both are greatly influenced by the amount of moisture they receive. Thus, they concluded that plant patterns are controlled more by microclimate than by competition (Melick and Seppelt, 1997). This finding is similar to the finding in the present study. Most species identified in the three sites at Black Rock Forest were located in the lower flat regions surrounded by a water source, thus supporting the theory that microclimate is the primary factor affecting plant diversity. However, it is difficult to parallel these studies since the species and climate differ drastically.

Even though it is clear that water is an essential 'nutrient', it is not the only abiotic factor affecting plant growth. Other microclimatic characteristics that were examined at each microenvironment were light influx, slope, and soil quality. Unfortunately, this study is limited on soil data. However, there is a good amount of soil data that was collected in 1995 and tested in

1996 at each of the three sites. Although only small differences were found among the three sites, there were differences and these are important to investigate since soil has a major impact on flower growth. The different components of the soils that were compared in this study were the percentage of organic matter or LOI, the availability of phosphorous, magnesium, phosphorous, and aluminum, and the pH in water.

Out of the three sites, Arthur's Brook had the highest percentage of organic matter. Being that organic matter gravely impacts soil quality and productivity, this is what is expected since Arthur's Brook had high species richness and abundance. Since phosphorous is a limiting agent in plant growth it is essential in areas with high diversity such as Arthur's Brook. The phosphorous content was also greatest at Arthur's Brook. However, Arthur's Brook also had the highest pH content in water. Since acid retards plant growth, this result was unexpected. Plant growth is also negatively affected by aluminum. Correlating with the levels of diversity, aluminum concentration was lowest at Arthur's Brook. The quantity of three important micronutrients, calcium, magnesium and potassium, were also highest at Arthur's Brook, second highest at Bog Meadow and lowest at Mount Misery (BRF, unpub. 1995).

Bog Meadow, which had the second highest species richness, also had the second highest percentage of organic matter, phosphorous content, magnesium content, potassium content, calcium content, aluminum content and acidic levels. Mount Misery was the opposite of Arthur's Brook, with the lowest percentage of organic matter, available phosphorous, calcium, potassium, magnesium, and pH and the highest aluminum content. Since Mount Misery had the fewest species, the pH level remains the only enigma. However, the lack of species richness may be attributed to the presence of *Rhododendron maximum*.

This study looked at the allelopathy between *Rhododendron* and flowering plants. Molisch coined the term allelopathy in 1937 referring to the biochemical interactions, which can include both inhibitory and stimulatory, between all plant species and forest microorganisms. Unlike competition, which includes the removal or reduction of a factor which is essential to another organism or plant which shares the same habitat, allelopathy is the result of a compound being added to the environment (Rice, 1984).

The toxic diterpene acetylandromedol has been identified in the leaves and flowers of *Rhododendron* (Harborne, 1993). *Streptopus amplexifolius* was the only flower that seemed to either be immune to the toxicity of the *Rhododendron* or dependent on the toxic for growth. At Mount Misery, on the plots on the south east side of White Oak Road, which was abundant in *Kalmia latifolia*, *Streptopus amplexifolius* was the only herbaceous plant present in 43% of the plots while another 29% contained no flowers. Occasionally, at other sites, *Medeola virginiana* and less often *Maianthemum canadense* grew within close proximity to the *Kalmia latifolia.* However, *Streptopus amplexifolius* was the only flower that grew underneath and among the *Rhododendron.*

The results of the MANOVA showed that there was no statistical relationship when comparing the abundance of *Kalmia latifolia* with that of *Streptopus amplexifolius* (figure 12). Unlike *Streptopus amplexifolius*, however, there was a significantly smaller number of all other plant species and individuals in the presence of *Kalmia latifolia* suggesting indeed that these are affected when *Kalmia latifolia* is nearby. This test is imprecise because the data on the *Kalmia latifolia* was collected by Dan Farrell in 1996 by site, not by the meter square samples. And, although it was not proven significant, this study will not rule out the possible immunity of *Streptopus amplexifolious* to the chemicals emitted by *Kalmia latifolia*, presuming that these chemicals contain elements inhibiting flower growth. However, these chemicals may also aid in the growth of *Streptopus amplexifolious* and may even encourage the productivity of the species.

In 1992, Duffy and Meier published a widely criticized study on the recovery rate of herbaceous understory. They compared regrowth in secondary forest areas to primary forests. They focused on herbaceous understory because they may be some of the forest species most sensitive to massive disturbances such as clear-cutting (Duffy and Meier, 1992). This study received a lot of criticism by Johnson, Ford, and Hale, particularly because Duffy and Meier chose not to sample from areas of the forests that contained *Kalmia latifolia* in their understories since light is inaccessible to flower species growing underneath the shrub (Elliot and Loftis, 1992). Since the present study may have found a strong correlation between *Rhododendron* and flower species, one wonders why Duffy and Meier chose not to sample sites with *Rhododendron.*

Another explanation for the few species and individuals identified in areas where *Kalmia latifolia* abounds is the limited amount of light that penetrates the ground layer under the *Kalmia latifolia.* It is possible that *Streptopus amplexifolius* is capable of tolerating low levels of light; thus this species is not affected by the presence of the *Rhododendron.*

Streptopus amplexifolius may be the most abundant species in the interior of the forest because of its adaptation to low light influx in areas covered with woody plant species. If it is true that light is the dominant component in determining which species remain and which vanish in long-undisturbed forests, the recently abundant species should possess adaptations for seasonally low light flux, whereas the species, which have disappeared, should lack such adaptions. This premonition is upheld (Brewer, 1980). The majority of the plots on the edge of the forest contained less shrubbery and more flower species then those in the interior of the forest. Brewer's hypothesis is supported by the findings of this study since *Streptopus amplexifolius*, the most abundant of the species, was found in all microenvironments. Another possible explanation is that *Streptopus amplexifolius* is dependent on low light coupled with the toxic diterpene acetylandromedol for growth and productivity. Other species however have only been found in lower lying plots which don't posses as much shrubbery. Since most of the edge or lower lying plots were stream or dry flatland, *Kalmia latifolia* and other shrubs were more prevalent on hillsides and hilltops.

Since most of the dry flatlands and stream valleys were on the edge of the forest, as opposed to the interior, an edge effects hypothesis was also tested. Edges are unique settings in composition, arrangement, function, and physical surroundings (Chen, 1991). Only 13 out of the 37 species and limited individuals were found in the interior of the forest as opposed to the 31 found on the edge plots (figure 7). An obvious microclimatic gradient exists from the edge into the forest interior (Chen, 1991). Moreover, the edge effect hypothesis also examined slope as a factor affecting flower growth and diversity.

Since the areas that were on a stream valley and flat land had slopes of 0-5%, this study has found that when there is little to no slope flowers are more likely to occur than in areas which have greater than a 5% slope. The hilltop plots, which were all within the interior of the forest sites, contained the fewest species and number of individuals. In fact there were more species richness and abundance in all lower lying plots, further suggesting slope has an influence on flower diversity. However, this theory isn't as strongly supported as the proximate hypothesis: the presence of the road enhances edge effects.

There is one road in The Black Rock Forest that runs parallel to Bog Meadow and Arthur's Brook and bisects Mount Misery. These roads are considered a reoccurring disturbance because they are constantly being cleared of overgrowth. The presence of the road is believed to bring in new species since the gap it causes in the forest allows a greater influx of light and rainwater. Since disturbance often introduces new species, the presence of the road affects the surrounding vegetation. The abundance of light and water causes increased diversity and abundance and the formation of a transition zone between the road and the lower lying plots. Although there is an edge effect between the start of the sites and the road, the boundary area between the two may cause migration of plant species into two surrounding zones. This migration increases the diversity and abundance within the plots closest to the road.

The proximity to the road as a constant disturbance is considered the strongest alternative hypothesis. Past studies have shown that immediately after disturbance, vegetative regrowth resumes rapidly and then after the local ecology develops, the rate of vegetative recovery slows down (Brewer, 1980); (Phillips and Shure, 1990); (Nicholson and Monk, 1974); and (Huston, 1994). The rapid regrowth after disturbance results from an increased influx of light, soil moisture, soil temperature and solar radiation (Moore and Vankat, 1986). The plots near the road had the greatest diversity and number of individuals as a result of these microclimatic factors. Those steeper and further from the road showed less diversity and individuals. This hypothesis is examining the possibility that there is more migration on the lower lying treatment as a result of the road. If this is true then it would make sense that the majority of the species identified were found closest to the road.

The hypothesis that considers the proximity to the road as a constant disturbance causing increased edge effects was formulated based on a study in Cameroon on the role that ecotones play in generating rainforest biodiversity. Smith, Wayne, Girman and Bruford (1997) studied the gene flow and morphological divergence between twelve different populations of a prevalent species of rainforest passerine. An ecotone is a transition zone where a rainforest and a savanna intergrade. Smith et al found that ecotone habitats might contain species with evolutionary adaptions that may help maintain diversity within the rainforest through natural selection (Smith et al, 1997).

Smith, Wayne, Girman and Bruford looked at six ecotone and six central rainforest populations of the little greenbul. Although they were examining the same species, they found phenotypical differences among the species. They concluded that this species had developed different characteristics in order to adapt to diverse microclimates. This study looked at five different morphological characteristics. Four out of the five characteristics were found to differ among the central rainforest and the ecotone populations while only one trait differed between the ecotone regions and two traits differed between the forest sites. They concluded that large ecotones act as dwellings where populations branch off from their rainforest counterparts. Their findings on the morphological divergence of bird species show that ecotones are primary interaction zones between species and subspecies.

The proximity of the road to the lower lying microenvironments was also tested by MANOVA. The null hypothesis tested was that the road has no affect on the number of species and individuals present in the plots within close proximity. If there were no significance then the plots closest to the road would not be any more diverse than those further into the forest. From the MANOVA results it was possible to reject the null hypothesis (figure 13). In other words, the greater diversity near the road may be attributed to natural selection.

There is a strong correlation between these two studies. There were few differences in species within the forest on each site. However, in the plots close to the road there were many different species observed. Often, in these lower lying areas, only one individual of certain species was observed within the treatment. On the contrary, as the sites moved back further into the forest fewer and more similar species were identified.

Phillips and Shure (1990) found similar results within the early onset of forest regeneration. This experiment looked at different disturbances ranging from small gap formation, such as a fallen tree, to fires, tornadoes and intensified logging, such as clearcuts. Phillips and Shure concluded that intermediate levels of disturbance lead to maximum species diversity. They based their conclusion on the presence of both pioneer and climax species in each of the studied areas. Phillips and Shure's study correlates to the present study since the road can only be thought of as an intermediate to low source of disturbance.

Phillip and Shure suggest that immediately after a disturbance occurs, gap formation tends to increase the availability of light and water. Moreover, the absence of the predisturbance vegetation increases the available nutrient supply that was being used by the primary species. Immediately following a disturbance net primary productivity is initially reduced, but quickly recovers with the increased availability of resources (Phillips and Shure, 1990). In this study, Phillips and Shure were looking at the size of disturbances in order to assess the effects of resource release on forest recovery. The three environmental aspects they compared were solar radiation, soil temperature, and air temperature.

The road is a reoccurring disturbance in that it is constantly being cleared for enhanced visibility. Brewer (1980) suggests that recurrent disturbance seems to preserve diversity. This theory is supported by the present study's conclusions since the transition zone between the road and the sites were clearly more diverse than the other areas of the sites, some of which had been treated over 60 years ago. Also, Brewer claims that the species that remain in the forest after it has recovered from a disturbance will adapt to the low influx of light. This may explain why *Streptopus amplexifolius*, which was the most abundant and pervasive species in all the inner forest treatment areas, grew among the *Kalmia latifolia*. It may have been the only species that has thus far adapted to low levels of light.

Since this last hypothesis may seem like a reach beyond the data, it is important to examine other studies to support it in theory.

Statistically, this hypothesis is clearly supported. It is clear from the studies that examined disturbances that there is a dramatic recovery of vegetation on the herbaceous understory. And after time this rate of recovery decreases to a slower level as the higher layers of canopy develop. The forest then adapts to the new surroundings. This study contends that the plots near the road are similar to the rainforest ecotones in that they contain a mixture of flowers from further in the forest and those from the disturbance zone (area along the road). Thus, these plots are more diverse than the others, which are similar to the forest-forest environments from the Cameroon study.

Conclusion

Stream valley microclimates foster spring flower diversity by offering low slopes and soil moisture, two ideal conditions for herbaceous understory. Sunlight is another factor influencing flower diversity since it is the energy source used to drive photosynthesis. Although light and water are the most common factors governing flower diversity, other factors also play a main role in vegetative development. Most importantly however is the species ability to survive conditions of limiting resources and competition. Without this capability, the species is not likely to survive chance events such as disturbances or drought.

Competition can take a series of forms. Usually competition involves the ability of one species to absorb the majority of a particular resource either through physical or chemical characteristics. Spring ephemeral flowers are among the most sensitive group in a forest environment and are thus vulnerable to competition. Once the canopy emerges these species are left without light, eventually leading to their demise.

This study has found a clear relationship between *Rhododendron* and flower species. If there is an abundance of *Kalmia latifolia* few flower species are capable of surviving. This may be attributed to an allelopathic relationship in which the *Kalmia latifolia*'s chemicals invade the soil inhibiting the growth of flowers, or it may be caused by the inability of light to penetrate the *Rhododendron*. If an allelopathic relationship does exist, then it is possible that *Streptopus amplexifolius* may be immune to this negative relationship since it is the only species that grows among the shrub. This immunity may be through adaption to low light influx or *Streptopus amplexifolius*'s ability to tolerate the chemical. Another possibility is that *Streptopus amplexifolius* is dependent on the chemicals emitted by *Kalmia latifolia* for growth and production. If this is the case, it may also be true that *Streptopus amplexifolius* can only survive conditions of limited light. Thus the species may rely on both factors for its successful productivity.

Soil also plays a role in the diversity of spring flower species. However, the limited number of soil samples makes it difficult to extrapolate conclusions based on the data. It is clear that the increased abundance of essential macronutrients and organic matter found in Arthur's Brook may be attributed to the increased species abundance and richness found in that site. Furthermore, the limited nutrients found in Mount Misery may have led to the few species identified at this site. Although it may be that the latter hypothesis is a direct result of the increased slope and abundance of *Rhododendron* at many of the plots in the Mount Misery site.

Another clear relationship was identified between the road and the diversity of spring flowers at the lower lying plots. Although this was verified statistically, it is still hard to reach conclusions without more data. After examining past studies the author concludes that reoccurring disturbances, such as a road, has a positive effect on flower diversity since the strong abiotic forces present along the road lead to a transition zone or edge effect on the lower lying plots.

This study concludes that there are many aspects affecting flower diversity and that a relationship exists between flower species and their microenvironments; however, each species reacts differently to different environmental stimulus. Therefore, whether the main cause of flower growth is the soil moisture, amount of light, soil content, slope or competition is hard to pinpoint. Moreover, it is the amalgamation of many factors that causes or inhibits flower growth and diversity.

Recommendations

It would have been interesting to take soil samples at each of the 48 plots. Since soil can change drastically from one part of a site to the next it is unfortunate that this study had such few soil samples. If soil samples were taken at every microenvironment, it would have been possible to do a full comparison of soil to plant growth. Moreover, since there was not a lot of information on light influx due to the structure of the ceptometer, it would have been helpful to have solar radiation and soil temperature measurements to enhance the information about light influx.

An accurate measurement of the amount of *Kalmia latifolia* at each 1 meter sample plot would have helped provide more information, which may have led to different findings on the allelopathic relationship between *Kalmia latifolia* and other flowers. It may have also changed the F value for the correlation between *Streptopus amplexifolius* and *Kalmia latifolia*. Laboratory tests on the chemicals emitted by *Kalmia latifolia* may also be illuminating. By isolating the chemicals and introducing them into soils where *Streptopus amplexifolius* normally grows, one may be able to assess the actual relationship between the two species. One could also test which other flowers would be capable of growing in such vicinity. If no such relationship were identified, it would be interesting to test the ability of *Streptopus amplexifolius* to adapt to low influxes of light and compare this to other species.

Narrowing the study down to just one site may also be an option. The soils and species of flowers would most likely be more similar, and it would be interesting to see how one forest site can differ so much. Furthermore, by comparing the diversity and abundance of flower species along the roadside to those within plots every 25 feet until the heart of the forest, one may be able to better analyze the edge effects hypothesis.

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