Effects of environmental variables on plant communities in a ravine system in southwest Michigan.

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Abstract

Ravine systems in the temperate region of the Midwestern United States have not received the same level of scientific attention as those of tropical regions. Previous studies indicate that plants order themselves into distinct communities along the edges of a ravine, particularly the vertical axis. Research was conducted, using a ravine in southwest Michigan, to determine the make-up of herbaceous plant communities along the vertical axis. The goal was to determine if distinct plant communities existed along this axis and how these distinct communities were related to changes in the environmental gradient. Using a direct gradient analysis, it was shown that significant differences in environmental variables exist between vertical levels of the ravine. These differences correlate closely with noticeable changes in the plant communities, although it remains unclear which variable is the limiting factor in the determination of these distinct plant communities. However, it can be concluded that even relatively small changes in these environmental variables drive significant changes within these communities.

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Introduction

Research reveals that detailed studies of ravine ecosystems in the eastern United States are relatively rare (Lewin, 1974), although classification of plant communities along altitudinal gradients has been considered in numerous mountainous areas (Thomas & Anderson, 1993). While there may be similarities between ravine and mountain systems, landscape conditions which differ can have a great effect on the ecology of a system, particularly its vegetation. Differences in the landscape can change hydrological and especially microclimatic conditions, which in turn influence soil moisture (Butler, Goetz & Richardson, 1986). Differences in slope and aspect also influence soil temperature, evaporation and air movement, all of which influence soil moisture retention. The angle of the slope also greatly affects how much water infiltrates the soil and subsequent runoff and erosion, which influence both soil type and growth of vegetation (Butler et al., 1986). While these have an impact on plant growth, light, soil, moisture, and temperature have been shown to have the greatest effect on plant growth (Butler et al., 1986; Huebner, Randolph & Parker, 1995; Thomas & Anderson, 1993; Nichols, 1923). Because plants are affected by these environmental requirements they order themselves into specific communities along an environmental gradient (Thomas, & Anderson, 1993; Nichols, 1923). Lewin (1974) suggests that the most important area of vegetation variation in a ravine is the vertical axis, the axis that runs on the side of the ravine from the bottom to the top.

A number of studies support for the idea that the type and moisture of soil have great influence on plant growth. McCarthy & Small (2005) found that nutrient retentions of soil affect the type of soil. Plant communities then reflect those differences in soil type and moisture (Voicu & Comeau, 2006). For instance, climax vegetation very often is an indicator of soil moisture regimes (Daubenmire, 1968). Soil type has also been found to be affected by sedimentation and erosion (Butler et al., 1986) which could be of influence in a ravine with a steep elevation gradient.

The temperature of soil and air also has been found to have an indirect effect on plant communities in ravines in particular. As the temperature increases, especially night-time temperature, there are decreases in soil moisture, depth, and nutrient loads (Lewin, 1974), all of which have a great impact on plant growth (Nichols, 1923).

Light intensity must also be taken into consideration because its role in photosynthesis makes it one of the most important factors in a plant's growth. Voicu & Comeau (2006) have shown that a decrease of light near aspen stands due to shade decreased the ability of young spruce trees to grow. Also, Butler et al. (1986) found that in the ravines of North Dakota, the northern aspect slopes which were more shaded tended to be forested while the southern aspect, which received more sun, tended to have more grasses and low herbaceous plants.

The environmental factors studied here have been acknowledged as important factors in plant growth and have been key points of interest in a number of studies (Lewin, 1974; Huebner et al., 1995; Thomas & Anderson, 1993; McCarthy & Small, 2005; Daubenmire, 1968; Butler et al., 1986; Nichols, 1923; Battles, Armesto, Vann, Zarin, Aravena, Pérez & Johnson, 2002). The research of Battles et al. (2002) shows that these factors contributed to significant shifts in vegetation along a gradient from the bottom to the top of the ravines studied. There were three distinct communities found – the bottom of the watershed, the mid-slope transition zone and the ridgetop. In a similar study done by Lewin (1974), in the New York Finger Lake region, the bottom of the ravine was characterized by a beech-maple and basswood community, the mid-slope by hemlock, and the top of the ridge by an oak-hemlock forest. This study also identifies three communities of plants along the ravine gradient. Both studies also found undergrowth to be more dense and diverse on the low-middle slopes, and Lewin (1974) states the shrub layers tend not to be very well developed in ravines, perhaps because of these environmental variables studied.

This descriptive study focuses on an in-depth study of the herbaceous plant community of a Great Lakes regional ravine, focusing particularly on how the variables of soil moisture, soil type, aspect, slope, light intensity, relative humidity and soil and air temperature affect the plant communities. While these factors have been acknowledged as impacting the type and kind of plant growth in the aforementioned studies, none focuses on this regional ravine community. We hypothesize that these factors will significantly influence, as they do in other regions, the vegetation communities a ravine system. We believe that there will be a shift in plant communities in response to the varying environmental conditions of soil moisture, soil type, light intensity, relative humidity and soil and air temperature along a gradient from the base of the ravine system to its ridgetop.

Methods

The location for the study was a ravine system known as the “Little Grand Canyon” located on at the Pierce Cedar Creek Institute. The location of the study site was N 42º 32’ 42.68813”, W 85º 16’ 26.2668” in Baltimore Township, Barry County, Michigan. The ravine is composed almost entirely of a beech-maple hardwood forest type with a major herbaceous layer covering the forest floor.

In order to identify the different plant communities, a series of 14 line transects were performed as outlined in Mitchell (2005) and Elzinga, Salzer, Willoughby, & Gibbs (2001). Starting in early May of 2006, line transects were set up to collect data on the herbaceous cover of the ravine. Each of the transects was ~35m in length. The transects ran perpendicular to the axis of the ravine and were placed from the bottom of the ravine to the top on the southern slope. These transects were placed according to their position in the ravine based on slope aspect and soil type as determined by aerial photographs and GIS soil type layers (PCCI GIS, unpublished). The location of each transect was then entered into a Thales MobileMapper GPS device. Beginning at the top of the ravine, using a rope and belay system, the researcher took measurements of each herbaceous plant that intersected the transect line at the point of intersection (Elzinga et al., 2001; Lewin, 1974). The transect, species and measurement of intersection were recorded for each plant from the top to the bottom. Aspect was also recorded for each transect, the method for which is discussed below. Each transect was measured three times throughout the summer in order to account for the full range of summer understory plants (McCarthy & Small, 2005). Two weeks were allowed to pass between repetitions of a transect measurement in order to allow change to occur. Five representative transects of the fourteen transect were completed a fourth time in late August.

To assess soil moisture, the researcher took samples of the soil using a soil corer at elevations five meters apart along the five representative transects. The soil was taken to a lab, and a portion of it was weighed, dried at 90ºC for 36 hours, and reweighed (Butler et al., 1986). Soil type was determined by classifying the soil cores to using a

Munsell soil color book and the U.S. Soil Classification System (Lewin, 1974; Butler et al., 1986).

Aspect of each transect was measured using a compass (Thomas & Anderson, 1993; Lewin, 1974) and slope was measured using a Suunto PM-5 clinometer. Light intensity, ground and air temperature, and relative humidity were measured once every hour by Onset HOBO data loggers set up at 5m intervals along the five representative transects. They were chosen based on measurements of aspect, soil type as determined by a GIS overlay map, and spacing along the ravine.

Studies indicate that plant communities can be classified as they respond to environmental conditions (Nichols, 1923; Lewin, 1974; Butler et al., 1986). Because of this, we used what Lewin (1974) calls the direct gradient analysis. This approach takes data collected along a perceived environmental gradient and analyzes it according to that gradient. "This method requires a large amount of data, but if the field work is done carefully and good environmental data recorded as well, direct gradient analysis produces clear, detailed, effectively interpretable results" (Lewin, 1974). The data gathered about the environmental variables was compared with any noticed changes in plant communities along the ravine side gradient. Single-factor ANOVA tests were run on the environmental data gathered from the data loggers to determine if there was a significant difference between each environmental factor at different slope intersects.

Results

A measure called the *importance value (IV)* was used (Brower, Zar, and von Ende, 1998) to assess the data obtained from the line transects. Importance value is a ratio of density, coverage, and frequency of a particular plant. Importance values for each plant were calculated for each time the transect was measured and can be seen graphically in Figures 1-4.

Over the course of the summer certain plants had importance values that were significantly higher than the rest of the plants. For example, Figure 1 shows that Rue Anemone (35m*IV = 0.525;* 25m*IV=0.59*) and Stinging Nettle (5m*IV =0.587;* 15m*IV=0.505*) are by far the most important species from that time period, followed closely by Blue-stemmed Goldenrod (35m*IV =0.395*) and Pennsylvania Sedge (35m*IV =0.332*). Figures 1-4 also illustrate at what level of the ravine gradient (distance from bottom) each of these species are important. Thus, though Rue Anemone and Stinging Nettle have similar importance values, Rue Anemone's *IV* is significant only in the ravine gradient from 25-35m, whereas Stinging Nettle has a significant *IV* only within the first 15m. Likewise, Pennsylvania Sedge and Blue-stemmed Goldenrod only have *IV* values present near the top of the ravine gradient, whereas Skunk Cabbage only has *IV* values within the first 5m.

The Figures also show a differentiation between plants which are exclusive to a particular level of the ravine gradient and those which are generalists and found across the gradient. Although numerous plants are specific to certain areas of the ravine, there are several that are found *only* at one gradient level. For example, as Figure 1 shows, although Jewelweed and Mitrewort had relatively low *IV* values, they are only found at the 15m level. Again in Figure 3, Greenbrier and Horsetail have relatively low *IV* values, but they are only found at the 25m level. On the other hand, *Viola* species and Christmas fern are distributed relatively equally across all levels of the ravine (Figure 1), as is Eastern Woodland Sedge (Figure 3).

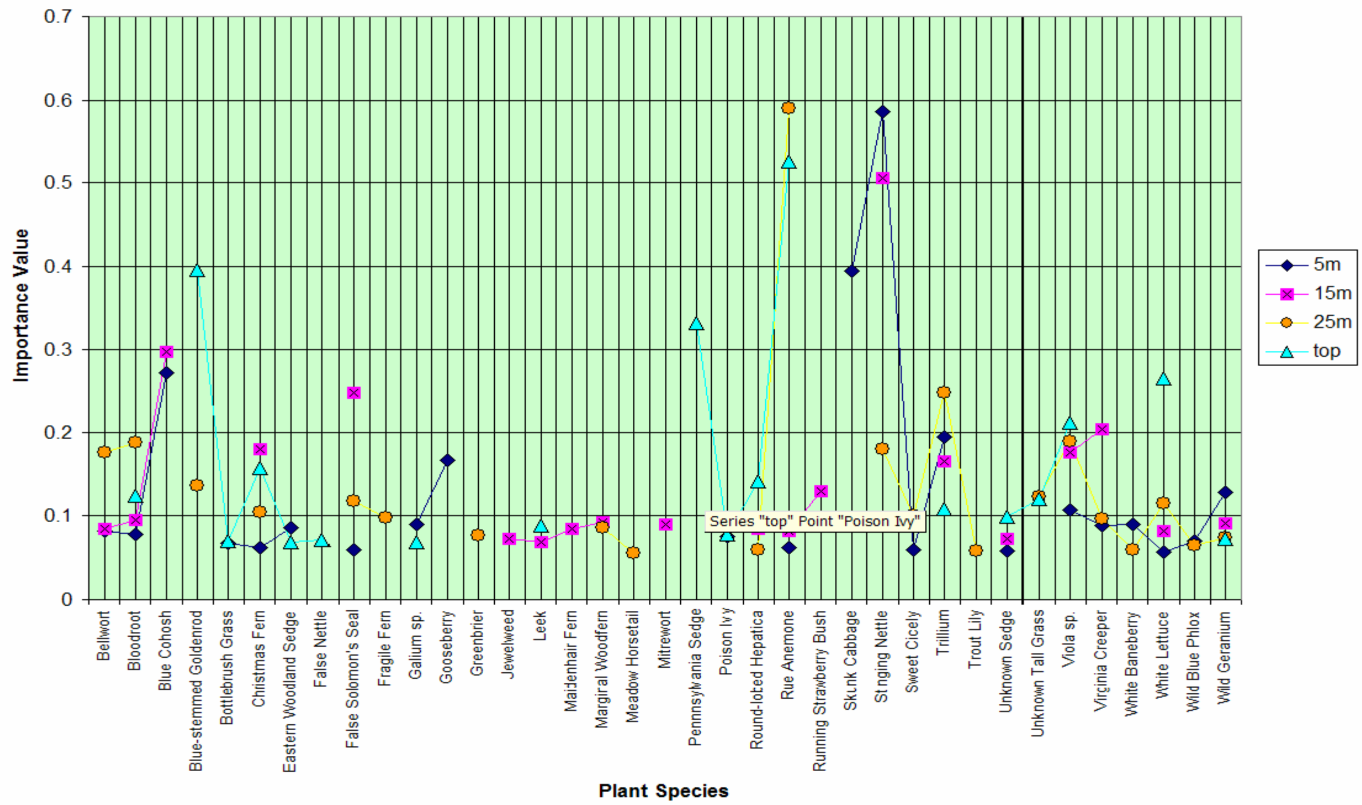

Figure 1: Average Importance Values for Transect Series A

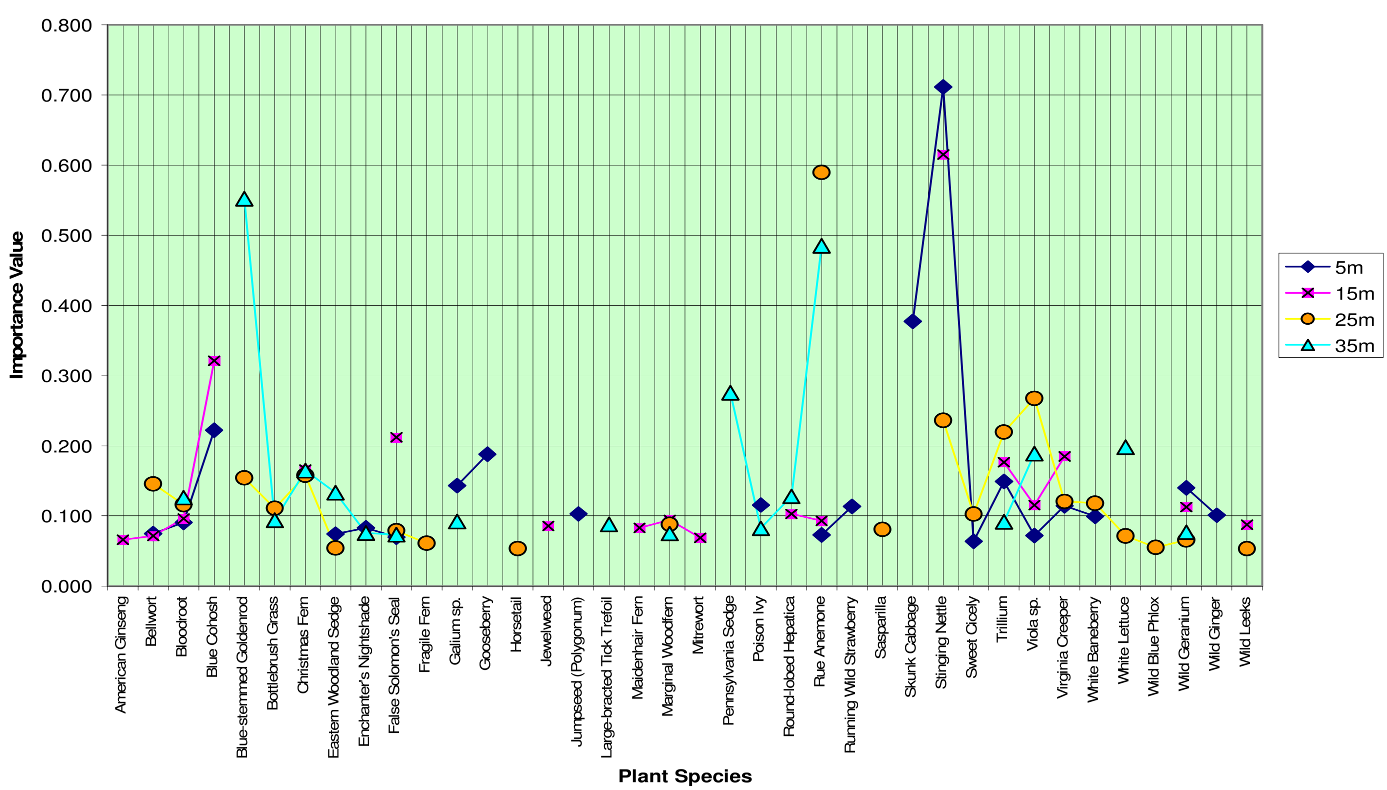

Figure 2. Average Importance Value for transect series B

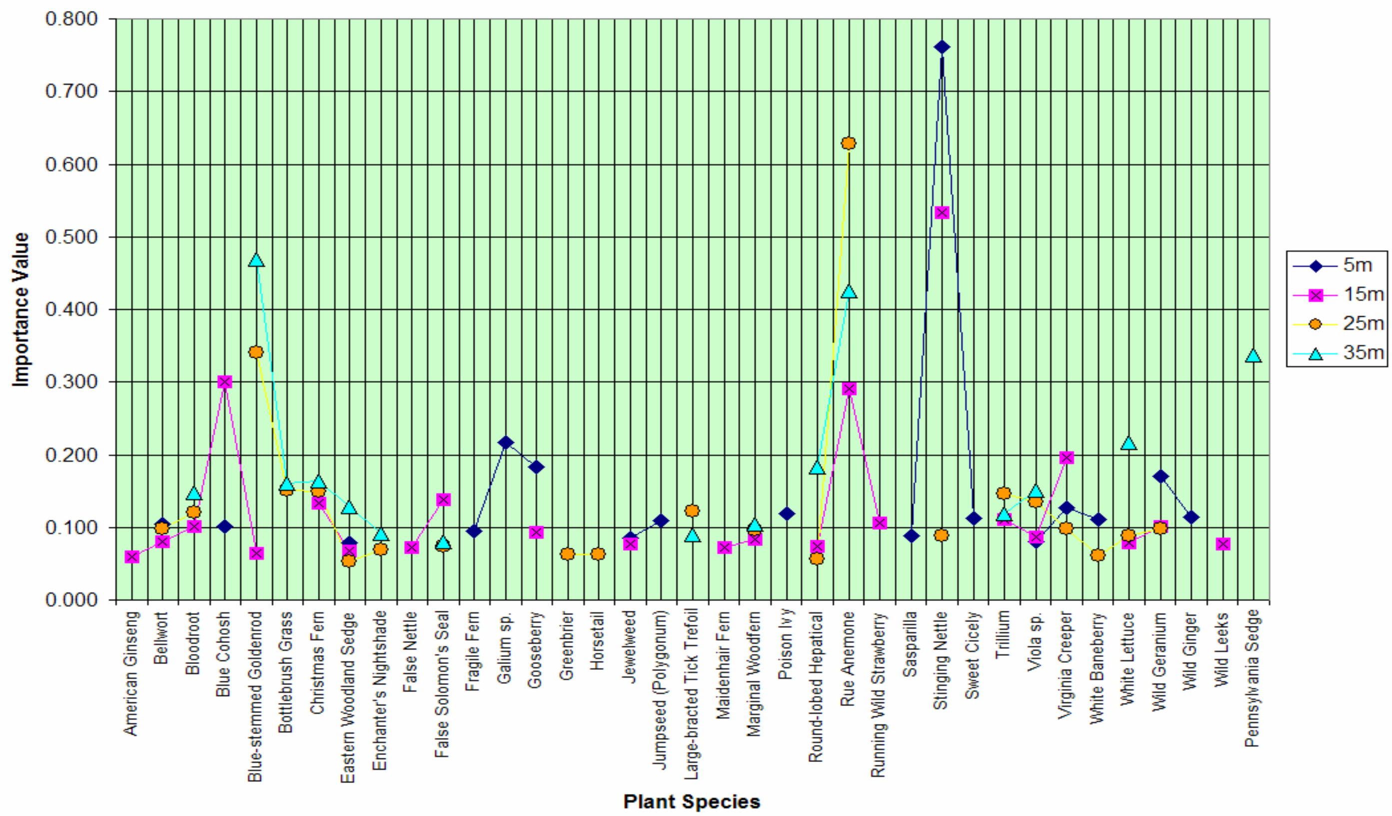

Figure 3: Average Importance Values for Transect Series C

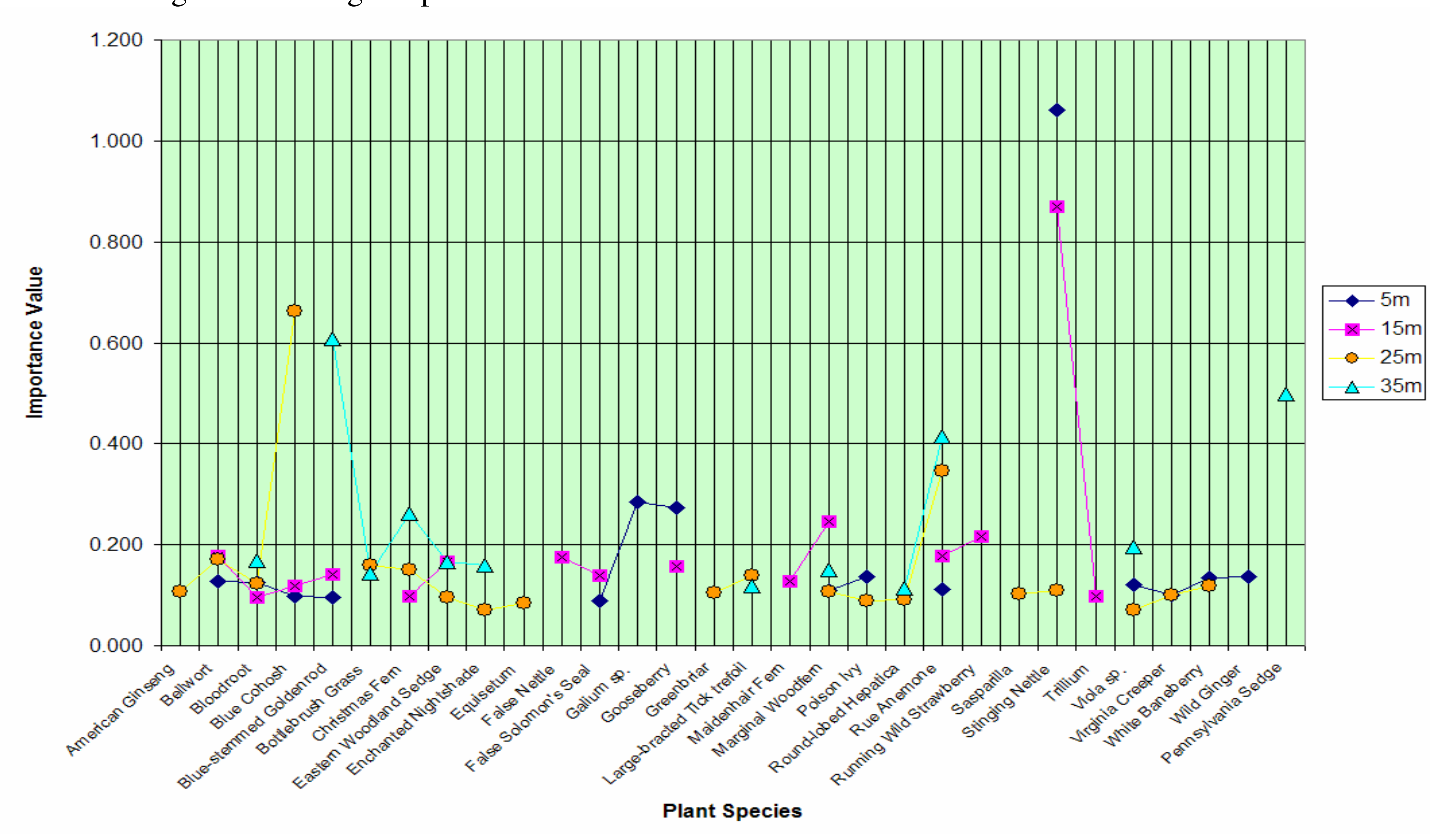

Figure 4: Average Importance Values for Transect Series D

Looking at the *IV* values which were most prominent at each gradient level (Table 1) shows that some plants carry over between levels, such as Blue Cohosh from 5-15m and Blue-stemmed Goldenrod from 25-35m. Those plants with an asterisk next to their name were specific to that one gradient level throughout the research.

Table 1
Prominent plants at each level of the ravine

5m	15m	25m	35m
Blue Cohosh	Blue Cohosh	Blue-stemmed Goldenrod	Blue-stemmed Goldenrod
Gooseberry	Gooseberry	White Lettuce	White Lettuce
Skunk Cabbage*	Jewelweed	Fragile Fern*	Pennsylvania Sedge*
Stinging Nettle	Stinging Nettle	Greenbrier*	*Galium* sp.
Galium sp.	Maidenhair Fern*	Rue Anemone	Rue Anemone
Jumpseed*	Mitrewort	Bottlebrush Grass	Bottlebrush Grass
Wild Ginger*	Marginal Woodfern	Marginal Woodfern	
	American Ginseng*	Sarsaparilla*	

Another aspect of the plant communities investigated were changes to the plants at various gradients levels over time. Data show that there were four species for which showed important changes over this time: Stinging Nettle, Rue Anemone, Blue Cohosh, and Skunk Cabbage (Figure 5). While the *IV* for these plants remains high throughout the study (Figures 1-4), there are significant changes occurring when these are compiled to assess their changes over time. At 5 and 15m, the *IV* for Stinging Nettle (SN) slowly increases on average over the first three transect measurement, but the on the fourth measurement its *IV* value increases dramatically. Interestingly, at 25m the *IV* of Stinging Nettle decreases over the first three measurements, with only a slight increase in the fourth measurement.

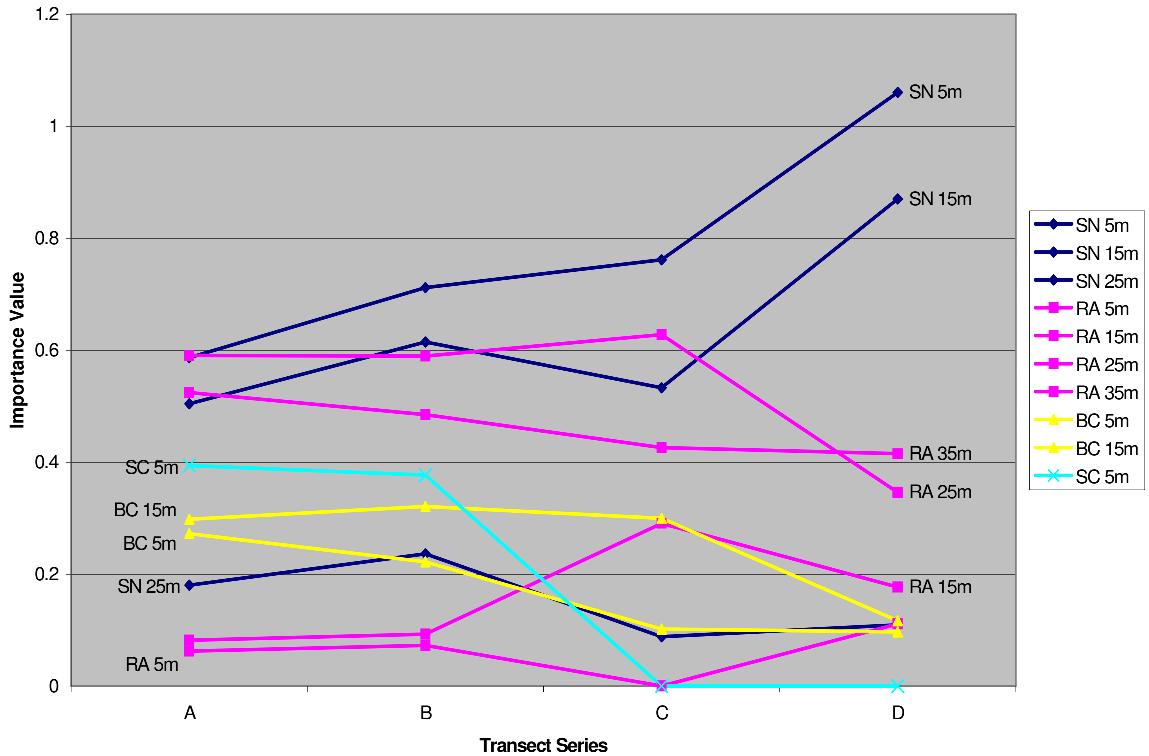

Figure 5. Changes in importance value (*IV*) over time.

Similarly, Rue Anemone (RA) also undergoes a change. At 25 to 35m the *IV* decreases on average over the four transect measurement. However, at 15m its *IV* value increases during the third measurement, only to drop again by the fourth. Again at 5m its *IV* value drops to nearly zero by the third measurement and then jumps back up by the fourth transect measurement.

Skunk Cabbage (SC) and Blue Cohosh (BC) also show this change over time, though on a slightly smaller scale. Blue Cohosh begins the season with decent *IV* values at 5 and 15m, and over the time of the study its *IV* gradually decreases. Skunk Cabbage also begins with a high *IV* at 5m and decreases in *IV* by the second measurement. By the third and fourth measurements, however, Skunk Cabbage was completely gone from the ravine. It is clear that these four plants in particular are being affected by some change in the ravine over time.

The environmental gradient factors were analyzed next. As far as aspect is concerned, transects ranged from WNW 280º at Transect 10 to ENE 80º at Transect 5. Slope of the ravine was also assessed and the average was found to be 32º. Analysis of soil samples found that when comparing each gradient level of the ravine to the other levels (i.e. 5m to 15m, 5m to 25m, etc.) there was no significant difference in soil moisture between the different gradient levels of the ravine (t-test assuming equal pairs; *$p>.10$).*

The data from the HOBO data loggers measured four major environmental variables over a period of eight weeks. These variable included: light intensity (LM), air temperature (ºC), soil temperature (ºC), and relative humidity (%). Data was gathered at four gradient levels within the ravine: 5m, 15m, 25m, 35m (top) (Table 2). The data from the loggers was compiled for each transect and submitted to a single-factor ANOVA test.

Table 2
Averages of Various Environmental Variables

	Air (ºC)	Soil (ºC)	Light (LM)	Relative Humidity (RM)
5m	20.57	18.49	3.54	86.83
15m	20.78	18.91	1.27	84.06
25m	21.15	19.35	1.91	81.58
35m	21.36	19.71	2.16	79.21

Separate tests were run for each variable between each gradient level. Significant differences in each environmental variable were found between every other gradient level (5m, 15m, 25m, and 35m)($p<.001$). Although differences did not appear to be large at first glance, such as a half a degree mean difference or less between 5m and 15m, our large body of data allowed us to identify very significant differences between all levels. Thus light intensity, air temperature, soil temperature and relative humidity change significantly along the vertical axis gradient of the ravine.

Conclusions

It is clear from the results that forested herbaceous plants in a Great Lakes ravine system order themselves into specific communities related to the significant differences in environmental variables along the vertical axis gradient of the ravine. Because of our knowledge of the way plants depend on environmental variables to order themselves into communities (Nichols, 1923; Lewin, 1974; Butler et al., 1986), we conclude that the shifts in plant communities are a direct result of the environmental variables measured in this study with the exception of soil moisture.

Certain plants, such as Rue Anemone, Skunk Cabbage, Pennsylvania Sedge and others, are dependent upon very specific environmental requirements for growth and thus are limited to a particular gradient level within the ravine, as has been described by others in different ravine systems (Battles et al., 2002; Lewin, 1974). Other plants, more generalist species, do not face such strict limitations and thrive along the entire vertical gradient axis. It is important to note that these changes, although significant, are very small. Some plant species are very sensitive to these small changes in their environment, which may have great implications for situations like climate change or development, which disrupt the natural environment.

Although there is a relationship between these changes in the environmental variables along the vertical axis gradient of the ravine and the plant communities at each gradient level, we were unable to determine which variable may be the limiting factor, or if it is a combination of factors. Further research to assess this aspect of this particular type of ravine system may be warranted in the future.

Overall, we completed a baseline study which both assessed the make-up of the major plant communities of the Little Grand Canyon and established that they are dependent on specific environmental variables along this gradient. It is our hope that this research will be of use to those seeking to further study ravine systems in the Midwestern United States.

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