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Intra- and Interannual Vegetation Change: Implications for Long-Term Research

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Abstract

To draw reliable conclusions from forest restoration experiments, it is important that long-term measurements be repeatable or year-to-year variability may interfere with the correct interpretation of treatment effects. We used permanent plots in a long-term restoration study in southwestern Colorado to measure herbaceous and shrub vegetation at three dates within a single year (June, July, and August), and between years (2003 and 2005), on untreated control plots in a warm, dry mixed conifer forest. Growing season precipitation patterns were similar between 2003 and 2005, so differences in vegetation should be related primarily to differences in the sampling month. Significant indicator species for each sampling month were present within a single year (2005), primarily reflecting early-season annuals. We found no significant differences for total species abundance (2005). Species richness, abundance, and indicator species were significantly different between years for different sampling months indicating that sampling should be conducted within a similar time frame to avoid detecting differences that are not due to treatment effects or variations in year-to-year climate. These findings have implications for long-term research studies where the objectives are to detect changes over time in response to treatments, climate variation, and natural processes. Long-term sampling should occur within a similar phenological time frame each year over a short amount of time and should be based on the following criteria: (1) the sampling period is congruent with research objectives such as detecting rare species or peak understory abundance and (2) the sampling period is feasible in regard to personnel and financial constraints.

Key words: forest ecology, herbaceous, methodology, monitoring, plant community dynamics, succession.

Introduction

Long-term ecological research is necessary to understand how vegetation structure and ecological processes respond over temporal and spatial scales under both natural and experimental conditions. Results from long-term studies investigating changes in vegetation structure are sometimes viewed as “truth” without questioning whether the methodology accounted for unintended effects of sampling design, technique, observer, time of year, and other variables such as year-to-year climate variation (Burt 1994; Scott & Hallam 2002; Carlsson et al. 2005). Numerous studies have quantified how different vegetation sampling techniques can influence vegetation composition and abundance data and the detection of vegetation change over time in various ecosystems (Floyd & Anderson 1987; Bräkenhielm & Qinghong 1994; Stohlgren et al. 1995; Korb et al. 2003; Abella & Covington 2004). These studies illustrate that there is no single optimal sampling technique for all vegetation communities. Rather, specific sampling techniques have higher accuracy (how well the methods describe “reality”) and precision (the repeatability of the method) over other sampling techniques based on the plant structure of the vegetation community type (i.e., forest vs. grassland) (Carlsson et al. 2005). In addition, studies have quantified observer effects finding that more experienced observers and vegetation sampling techniques that required low personal judgment (e.g., frequency plots) had higher accuracy and precision (Gotfryd & Hansell 1985; Kennedy & Addison 1987; Tonteri 1990).

Few researchers have investigated intraannual (within one growing season) vegetation change to determine if there is an optimal time for vegetation sampling to quantify community species richness and abundance and if these variables remain constant across the growing season (Kennedy & Addison 1987; Carlsson et al. 2005). Carlsson et al. (2005) sampled intraannual vegetation change in a seminatural grassland and found no significant differences in species frequency and only slight differences in species cover due to vegetation growth. Generally, vegetation sampling occurs within the growing season with little regard to repeating measurements within a similar calendar or phenological time frame between years (interannual vegetation change). Sampling permanent vegetation plots across a short period of time provides insight into the repeatability (precision) of the sampling technique, similar to quantifying the effect of observer on vegetation community data (Gotfryd & Hansell 1985).

Assessing vegetation change is important in the context of ecological restoration where treatments are applied to encourage redevelopment of historical ecosystem

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composition, structure, and function. We examined permanent plot data from a restoration experiment in a warm, dry mixed conifer forest of southwestern Colorado. The experiment was designed to quantify the effects of two treatments: (1) restoration thinning and prescribed burning and (2) prescribed burning only, on tree and subcanopy vegetation. In this forest type, there has been a shift in species composition and abundance to shade-tolerant species such as White fir (*Abies concolor* (Gord. & Glend.) Lindl. ex Hildebr.) and Douglas-fir (*Pseudotsuga menziesii* (Mirbel) Franco) at the expense of the shade-intolerant but more fire-resistant Ponderosa pine (*Pinus ponderosa* Dougl. Ex Laws.) (Romme et al. 2003, unpublished data). Increased vertical and horizontal fuel continuity has also developed (Heinlein et al. 2005). Within our study region, this shift in forest structure has been attributed to the current fire-free period (1881–present) being longer than the pre-European pattern (mean fire interval was 14.7–17.1 years over the period 1616–1880 [Wu 1999]).

Within the forest restoration experimental design, the goal of the present study was to assess the effects of measurement date on perceived vegetation changes in untreated controls. We hypothesized that there would be significant species richness and abundance differences in intraannual vegetation due to the combination of individual species' phenologies and summer monsoonal (July–August) thunderstorms. As a result, we also hypothesized that the cumulative effect of individual species' phenologies would result in significant interannual vegetation differences among different sampling time frames (June, July, and August). The specific objectives of this study were to compare (1) intraannual vegetation change across one growing season (2005) by measuring vegetation three times at 1-month intervals (June, July, August) and (2) interannual vegetation change between two time periods (2003 and 2005) to determine if the sampling time frame influences vegetation results. The latter objective is particularly important in experimental design studies where the controls are established as a reference to quantify changes in experimental units. If significant changes are found in the controls, then there is lower statistical power to infer that changes in the experimental units are due to treatments.

Methods

Study Area

The study area is located on lower Middle Mountain, approximately 18 km northwest of Pagosa Springs, in southwest Colorado. Lower Middle Mountain encompasses roughly 370 ha in Archuleta County, Colorado (T35N, R3W, Sections 16, 17, 18, and 20, N.M.P.M). Our study area is approximately 159 ha or 49% of lower Middle Mountain. Lower Middle Mountain is part of the Piedra Roadless Area. Currently, there are no open roads, but there are approximately 8 km of closed, interior roads constructed in the late 1980s to access a timber sale.

Lower Middle Mountain consists of moderately steep mountain slopes and benches. Elevations range from 2,438 to 2,743 m, with slopes in the 15–30% range on a generally south-facing aspect. The dominant soil type is Dutton loam, from silty clay loam parent material (USDA Forest Service 2004). Average daily temperatures range from a maximum of 27°C in July to a minimum of −14.3°C in January. Average annual precipitation is 67.3 cm and is distributed throughout the year with the greatest amounts occurring in July and August due to summer monsoonal thunderstorm activity. Precipitation totals during the growing season (May–August) for 2003 and 2005 were both slightly below the 57-year average and were within 1 standard deviation of 1948–2005 averages (Western Regional Climate Center 2006 [www.wrcc.dri.edu]).

Vegetation consists primarily of the warm, dry mixed conifer forest type. This forest type is dominated by Ponderosa pine, White fir, and Douglas-fir. Small pockets of both mature and young Aspen (*Populus tremuloides* Michx.) are also found throughout the study area. The midstory and understory are dominated primarily by White fir and Douglas-fir, with a variety of shrubs including Gambel oak (*Quercus gambelii* Nutt.), Snowberry (*Symphoricarpus rotundifolius* Gray), and Serviceberry (*Amelanchier alnifolia* (Nutt.) Nutt. ex M. Roemer). Occasional Ponderosa pine regeneration is present. Common herbaceous species at the site include Blue wild rye (*Elymus glaucus* Buckley), Thurber's fescue (*Festuca thurberi* Vasey), Parry's oatgrass (*Danthonia parryi* Scribn.), Muttongrass (*Poa fendleriana* (Steud.) Vasey), Little sunflower (*Helianthella quinquenervis* (Hooker) Gray), Tuber starwort (*Pseudostellaria jamesiana* (Torrey) Weber and Hartman), and Showy fleabane (*Erigeron speciosus* (Lindley) de Candolle).

Field Methods

Lower Middle Mountain was divided into four blocks. Within each block, there are 3 experimental units (approximately 16 ha/each) for a total of 12 units. Forest restoration treatments were randomly assigned to each of three units per block (control, thinning and prescribed burning, and prescribed burning only). Within each approximately 16-ha unit, 20 permanent monitoring plots were established on a 60-m grid in all four cardinal directions based on a systematic starting grid point (total $N = 4$ blocks × 3 treatment units/block × 20 plots/unit = 240 plots). All plot centers were permanently marked with iron stakes and were georeferenced with Global Positioning Systems. For this study, eight randomly selected plots from each control unit were sampled for a total of 32 plots (4 control units × 8 plots). Sampling occurred in the exact same plots over a 4.5-week period (July 10 to August 14) in 2003 and within a 2-week period in June (3–15), July (5–17), and August (2–14) 2005. Comparisons between different sampling years (interannual change) were compared with July and August 2005 data to see if the sampling time frame during the growing season influenced results.

We used a modification of the Modified-Whittaker sampling design (Stohlgren et al. 1995) to measure understory vegetation. One of the main objectives of this sampling design is to quantify plant foliar cover for most species in the area and to provide cover data that have low spatial autocorrelation (Stohlgren et al. 1995). We established at each plot center a 50-m line transect along the topographic (slope) gradient with 25 m below center and 25 m above center. A 10 × 50–m belt transect was centered over each 50-m line transect. All herbaceous and shrub species within the belt were recorded. We did not record any plant cover or substrate data for the belt transects. Four 1-m^2 (0.5 × 2 m) subplots were established within the belt transect at 14-m intervals with the 2-m side parallel to the transect. The 1-m^2 subplots were located in the top left and bottom right corners of the belt transect and on the right side of the line transect at 16 m and the left side of the line transect at 32 m. For each subplot, we estimated the percent cover of each species to the nearest quarter percent using cardboard cutouts of known sizes as visual guides (Tilman 1997). Ocular estimation of plant cover is a commonly used method for determining plant dominance, succession, and treatment response in vegetation analysis (Hatton et al. 1986). The estimates can total greater than 100% because percent cover was estimated independently for each species and independent of canopy position, meaning that plants could overlap each other. Individual species abundance was calculated by averaging the species abundance in the four subplots/transect. The percent cover of litter, rock, wood, and bare mineral soil was also estimated for each subplot. Ten botanists working in pairs of two sampled all 240 understory plots in 2003. Two individuals working together conducted all the 2005 sampling to eliminate observer differences between the three sampling periods; these two individuals were one of the botanist pairs that surveyed in 2003.

Statistical Analyses

Total plant richness and abundance, abundances for individual species and groups (growth form, duration, and origin), and species diversity (Simpson's D and Shannon's H) were calculated by averaging the four 1-m^2 subplots for each plot. The Shannon–Weiner's diversity index determines the average uncertainty of predicting the species of an individual randomly chosen from the community. As species richness and evenness increase within the community, the diversity index increases as well. The Simpson index is based on similar principles.

Multivariate analysis of variance repeated measures was used to determine the effect of different sampling periods on univariate herbaceous species richness and abundance data collected in 2003 and 2005. We used the Shapiro–Wilks test to determine whether data met the normality assumption and Levene's test to determine if data met the homogeneity of variance assumption (Milliken & Johnson 1984). The Greenhouse and Geisser correction for sphericity was used to determine significant differences at $p \leq 0.05$. We made multiple comparisons of means between different sampling time frames using paired t tests followed by a Bonferroni adjustment (Howell 2002). We took the original alpha value (0.05) and divided by the number of paired comparisons (3) to determine our new alpha value (0.167). These analyses were conducted using the JMP-IN statistical package (SAS Institute, Inc. 2004).

We used indicator species analysis (Dufrêne & Legendre 1997) to identify species that were particularly faithful to a specific sampling period. Indicator species analysis was calculated using PC-ORD software (McCune & Mefford 1999). A comparison between the maximum indicator value (0–100) and random trials for the occurrence of a given species (1,000 Monte Carlo randomizations) provides a p value (McCune & Grace 2002). Species with a p value ≤ 0.05 were accepted as indicator species for a particular sampling period.

Results

We detected a total of 182 species in the study area. Forbs represented the majority of plant richness with 67.8%, graminoids with 18.2%, and shrubs with 14%. Ninety-seven percent of the species were perennials and only 3% were annuals or biennials on average. Native species were significantly more abundant (95.1%), with only 4.9% being of non-native origin. The most abundant non-native species included Kentucky bluegrass (*Poa pratensis* L.), Dandelion (*Taraxacum officinale* G.H. Weber ex Wiggers), Timothy grass (*Phleum pretense* L.), and False salsify (*Tragapogon pratensis* L.). The only listed Colorado noxious weeds were Bull thistle (*Cirsium vulgare* (Savi) Tenore) and Canada thistle (*Breea arvense* (L.) Lessing).

Intraannual Change

There were no significant differences among total herbaceous and shrub abundance across the three 1-month interval sampling periods during the 2005 growing season ($F = 3.47$; $p = 0.157$), although the July sampling period was approximately 15% higher than June or August abundance values (Tables 1 & 2). There were marginally significant differences for total species richness over these three sampling periods during the 2005 growing season ($F = 9.39$; $p = 0.0963$) and no significant differences for diversity indexes (Table 1). Indicator species analysis showed six indicator species for the June 2005 sampling period with no indicator species for either July or August 2005 (Table 5). All six of the June indicator species were spring/early summer forbs. Two of these species were no longer detectable in either the July or the August sampling periods (Bitterroot (*Lewisia nevadensis* (A. Gray) B. L. Robinson) and an unknown lanceolate single-leaf spring

Table 1. Herbaceous and shrub understory total species richness, species abundance (plant foliar cover in percent), and Simpson's and Shannon's diversity indices across four different sampling time periods.

	2003	*June 2005*	*July 2005*	*August 2005*
Total species richness	44.87 (2.09)a	39.47 (1.41)a	42.03 (1.70)a	41.28 (1.53)a
Total abundance	25.08 (2.98)a	28.88 (2.16)a	34.30 (3.20)b	29.92 (4.28)a
Simpson *D* index	0.83 (0.02)a	0.86 (0.01)a	0.86 (0.09)a	0.86 (0.09)a
Shannon *H* index	2.38 (0.08)a	2.39 (0.07)a	2.44 (0.05)a	2.38 (0.08)a

Significant differences were determined using repeated measures multivariate analysis of variance. Data are expressed as $\overline{X}(N = 4)$ plusmn SE. Different letters in the same row indicate significance at $p \leq 0.05$ among different sampling time periods. Sampling occurred over a 4.5-week period (July 10 to August 14) in 2003 and within a 2-week period in June (3–15), July (5–17), and August (2–14) 2005.

forb that did not flower in 2003 or 2005). There were no significant differences among the three 1-month interval sampling periods during 2005 for any forest floor substrates (litter, rock, wood, or bare mineral soil).

Interannual Change

Total herbaceous and shrub abundance was significantly higher ($F = 98.58$; $p = 0.0022$) during the July 2005 sampling period (34.3%) than in 2003 (25.08%) (Table 1). Specifically, forb ($F = 10.54$; $p = 0.048$) and shrub ($F = 25.06$; $p = 0.015$) abundances were higher in the July 2005 sampling period than in 2003 (Table 2). There were no significant differences in graminoid cover between these two sampling periods. Perennial abundance was significantly higher in July 2005 than in 2003 ($F = 47.43$; $p = 0.009$), with no significant differences between annual and biennial abundance for the two sampling periods (Table 2). Native species abundance was also significantly higher in July 2005 than in 2003 ($F = 89.54$; $p = 0.0034$), with no significant differences for non-native abundance (Table 2). There were no significant differences in total species richness or Simpson's or Shannon's diversity indices between 2003 and July 2005 (Table 1). Similarly, there were no significant differences in species richness by growth form, duration, or origin (Table 2) between the two sampling periods.

Indicator species analysis showed that the difference between these two sampling periods was primarily driven by six forb species having higher cover values in July 2005 than in 2003 and one graminoid, Thurber's fescue, having higher cover in 2003 than in July 2005 (Table 3). There were significant differences between the 2003 and the July 2005 sampling periods for the litter substrate ($F = 24.03$; $p = 0.031$); all other forest floor substrates were similar between the two sampling periods.

Total herbaceous and shrub abundance was not significantly different ($F = 6.77$; $p = .08$) between 2003 and

Table 2. Herbaceous and shrub understory growth form, duration, and origin richness and abundance (plant foliar cover in percent) across four different sampling time periods.

	2003	*June 2005*	*July 2005*	*August 2005*
Growth form				
Forb richness	27.69 (1.89)a	26.94 (1.69)a	28.22 (1.71)a	27.38 (1.49)a
Graminoid richness	8.69 (0.29)a	6.60 (0.20)a	7.82 (0.40)a	7.94 (0.51)a
Shrub richness	5.19 (0.28)a	4.47 (0.13)a	4.50 (0.15)a	4.47 (0.13)a
Forb abundance	9.79 (2.02)a	12.37 (1.58)a	14.32 (2.18)b	11.91 (2.44)a
Graminoid abundance	5.05 (0.19)a	4.56 (0.96)a	5.63 (0.48)a	5.56 (0.29)a
Shrub abundance	10.24 (1.69)a	11.96 (1.62)a	14.35 (0.60)b	12.45 (1.69)a
Duration				
Annual richness	1.22 (0.62)a	0.82 (0.21)a	0.81 (0.32)a	0.63 (0.30)a
Biennial richness	0.38 (0.10)a	0.60 (0.24)a	0.60 (0.19)a	0.60 (0.19)a
Perennial richness	43.28 (1.93)a	38.06 (1.35)a	40.63 (5.28)a	40.00 (1.39)a
Annual abundance	0.11 (0.11)a	0.25 (0.18)a	0.10 (0.09)a	0.04 (0.04)a
Biennial abundance	0.06 (0.06)a	0.05 (0.04)a	0.05 (0.05)a	0.06 (0.06)a
Perennial abundance	24.91 (2.69)a	28.59 (3.81)a	34.15 (3.60)b	29.80 (4.05)a
Origin				
Non-native richness	1.84 (0.24)a	1.75 (0.18)a	2.0 (0.24)a	2.06 (0.24)a
Native richness	42.98 (1.87)a	37.66 (1.48)a	39.16 (1.64)a	39.16 (1.52)a
Non-native abundance	0.51 (0.29)a	0.96 (0.45)a	0.94 (0.47)a	0.70 (0.41)a
Native abundance	24.56 (0.69)a	27.92 (0.71)a	33.83 (0.67)b	29.21 (0.18)a

Significant differences were determined using repeated measures multivariate analysis of variance. Data are expressed as $\bar{X}(N = 4)$ plusmn SE. Different letters in the same row indicate significance at $p \leq 0.05$ among different sampling periods. Sampling occurred over a 4.5-week period (July 10 to August 14) in 2003 and within a 2-week period in June (3–15), July (5–17), and August (2–14) 2005.

Table 3. Indicator species analysis for interannual sampling periods: 2003 and July 2005.

Species	*Importance Value*	*p*
2003		
Festuca thurberi	33.2	0.023
July 2005		
Achillea millefolium	56.2	0.042
Antennaria parvifolia	30.4	0.046
Arenaria lanuginosa	31.2	0.001
Erigeron speciosus	34.9	0.050
Mertensia fransiscana	40.4	0.005
Pseudostellaria jamesiana	56.2	0.048

Sampling occurred over a 4.5-week period (July 10 to August 14) in 2003 and within a 2-week period in July (5–17) 2005.

August 2005 (Table 1). In addition, there were no significant differences between these two sampling periods for species richness, species diversity, or abundance for growth form, duration, or origin (Table 2). The Mantel test for plant community data in 2003 and August 2005 indicated no significant difference ($r = -0.0055$; $p = 0.325$) between the two sampling periods. Indicator species analysis showed two species being faithful to the 2003 sampling period, Thurber's fescue and Peavine (*Lathyrus* ssp.) and only one species with the August 2005 sampling, Spreading sandwort (*Arenaria lanuginosa* (Michx.) Rohrb.) (Table 4). There were no significant differences between the 2003 and the August 2005 sampling periods for any forest floor substrates (litter, rock, wood, or bare mineral soil).

Discussion

We detected patterns over the three sampling periods within one growing season (June–August 2005). Spring/early summer species were associated more with the June sampling period as indicated through indicator species analysis. These species were in higher abundance during the June sampling period, yet often withered completely by the August sampling period and therefore were not detected. Forb cover was approximately 2% higher during the July sampling period than in June or August, indicating that forbs in the warm, dry mixed conifer tend to peak in abundance in early July. This pattern was evident visually by the observers (J. E. Korb, Fort Lewis College, personal observation, 2005) with numerous species significantly decreasing between the July and the August sampling periods, e.g., Northern bedstraw (*Galium borale* L.), Peavine, and Tuber starwort). Forbs in the Asteraceae family peaked in abundance during the August sampling period, which is common for this family in the Southwest (Weber & Whittmann 2001). Graminoid cover was approximately 1% higher in July and August in comparison to June sampling. This pattern is congruent with graminoid abundance patterns in other vegetation communities (Nigel & Poulton 1998).

Table 4. Indicator species analysis for interannual sampling periods: 2003 and August 2005.

Species	*Importance Value*	*p*
2003		
Festuca thurberi	31.5	0.047
Lathyrus spp.	58.3	0.048
August 2005		
Arenaria lanuginosa	25.0	0.004

Sampling occurred over a 4.5-week period (July 10 to August 14) in 2003 and within a 2-week period in August (2–14) 2005.

Table 5. Indicator species analysis for intraannual sampling periods during the 2005 growing season.

Species	*Importance Value*	*p*
Claytonia lanceolata	15.6	0.018
Delphinium nuttallianum	20.9	0.021
Mertensia franciscana	28.0	0.050
Lewisia nevadensis	19.1	0.047
Thlapsi montanum	17.1	0.044
Unknown spring forb	16.4	0.027

Indicator species were only detected for the June (3–15) sampling period.

Sampling in 2003 occurred over a 4.5-week period (July 10 to August 14). As a result, we were interested in testing to see if there was a difference between sampling years (2003 and 2005) with either the July or the August 2005 data. Our results showed significant differences between the 2003 and the July 2005 data and no significant differences between the 2003 and the August 2005 data. These findings are important because they illustrate that the sampling period, even within a few weeks, influenced understory vegetation community data and therefore their interpretation. When we compared the July 2005 data with the 2003 data, we found that there was significantly higher overall understory abundance in 2005. There were no significant differences in growing season precipitation between these 2 years and therefore trying to interpret these results would be difficult if we would not have collected data across the growing season in 2005. Year-to-year variation in understory vegetation due to climate has been found in similar southwestern forest types such as Ponderosa pine where precipitation is the limiting factor to plant growth (Korb et al. 2003; Abella & Covington 2004). One possible interpretation would be that year-to-year observer differences were influencing results. Numerous studies have investigated the role of interobserver variation in vegetation assessments and have found some level of variation among observers for species identification and species cover abundances due to variation in plot placement and observer expertise (Tonteri 1990; Scott & Hallam 2002; Ringvall et al. 2005). Some level of variation is to be expected with repeat sampling where the same observers are not able to be used year to year;

however, with numerous plot replicates and calibration among observers for sampling methodology as was done in this study, observer noise can be minimized. When we compared the August 2005 data with the 2003 data, we found no significant difference in overall understory abundance, which is desirable because the sampling occurred in areas with no treatments, during a similar phenological time frame, and there were no significant differences in growing season precipitation between these 2 years. This finding also supports that interobserver differences between the 2003 and the 2005 sampling periods were minimal. The lack of significant differences between herbaceous and shrub richness and abundance between 2003 and August 2005 indicates that the understory vegetation sampling design we chose for this long-term monitoring project is repeatable across time (precision), which is important in long-term time series data. Precision is more important in time series data than accuracy because the sampling methodology needs to be repeatable (Gotfryd & Hansell 1985). Our findings are congruent with other studies that have shown visual estimation to have higher precision over other sampling methodologies (Bräkenhielm & Qinghong 1994; Korb et al. 2003; Abella & Covington 2004) supporting the use of visual estimates for long-term vegetation studies. We recommend that posttreatment herbaceous and shrub understory sampling for this long-term study should occur within a similar phenological time frame (approximately the end of July to early August) to eliminate the possibility that sampling timing will influence results. Sampling timing should be identified based on a similar phenological time frame rather than a specific calendar date due to year-to-year variation in precipitation and temperature that is commonly found in semiarid environments.

Conclusion and Recommendations

The results from this study indicate that there is no optimal sampling time frame for the herbaceous and shrub understory in the warm, dry mixed conifer. Specifically, different species will have higher abundances at various times during the growing season due to individual species' phenologies. However, regardless of what sampling time frame is chosen for a particular study, we recommend sampling be conducted within a similar phenological time frame each year or significant differences may be detected that are not due to treatment effects or large variations in year-to-year climate but simply changes in the sampling time frame among years. This finding has implications for long-term research studies where the objectives are to detect changes over time in response to treatments, climate variation, and natural processes such as vegetation successional changes. We recommend that monitors should not arbitrarily determine when to sample understory herbaceous and shrub vegetation. A specific sampling time frame should be chosen based on the following criteria: (1) the sampling period is congruent with research objectives such as detecting richness and abundance and (2) the sampling period is feasible in regard to personnel and financial constraints. By sampling within a similar phenological time frame each year, the possibility that changes over time in long-term understory vegetation studies are due to variations in the sampling time frame rather than the questions being investigated can be minimized.

Implications for Practice

- There is no optimal sampling time frame for the herbaceous and shrub understory for any vegetation type.
- Long-term, repeat sampling should occur within a similar phenological time frame each year over a short amount of time.
- The determination of the sampling time frame needs to be congruent with individual research objectives, such as detecting rare species or peak understory abundance, and sampling feasibility in regard to personnel and financial constraints.

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