



Photo Monitoring of High-Elevation Plants in Shenandoah National Park

Natural Resource Report NPS/SHEN/NRR—2017/1542





ON THIS PAGE

High-elevation *Sibbaldiopsis tridentata* site at Betty's Rock
Photograph by: Lea Korsmeyer, NPS

ON THE COVER

High-elevation *Sibbaldiopsis tridentata* site at Little Stony Man
Photograph by: Lea Korsmeyer, NPS

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Natural Resource Report NPS/SHEN/NRR—2017/1542

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Abstract

Shenandoah National Park staff conducted photo monitoring in 2014 at 11 sites to document the status of two state rare plant species, *Huperzia appalachiana* (Appalachian fir clubmoss) and *Sibbaldiopsis tridentata* (three-toothed cinquefoil). A subset of monitoring sites had been previously sampled by park staff in 2010, and calculations of percent cover change over time were made for these sites. The study species were selected because they occur exclusively in high-elevation habitats of the Park and are intolerant of the conditions present in lower elevation habitats. Plots were photographed with a gridded plot frame. Over the four years of the study, the average cover of *H. appalachiana* decreased (mean $\pm$ SE) $27.8 \pm 8.5\%$, and the average cover of *S. tridentata* increased by $10.9 \pm 7.9\%$. We used a two-tailed paired t-test to identify significant changes in cover at the photo monitoring sites. Cover decreased at two of the three sites monitored for *H. appalachiana*: Crescent Rocks 3 ($t(5) = 5.64$, $p = 0.002$) and Hawksbill 2 ($t(7) = 3.26$, $p = 0.01$). Cover increased at two of the four sites monitored for *S. tridentata*: Hawksbill 1 ($t(8) = 3.08$, $p = 0.02$) and Little Stony Man ($t(8) = 3.88$, $p = 0.005$). Several factors, including regional weather patterns, visitor impacts, and plant growth habit, may be contributing to these changes. The continuation of this project will inform park managers about the status of these species and the communities in which they occur throughout Shenandoah National Park.

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List of Terms

Canopy: Woody growth that is greater than 5 meters in height (Cass et al. 2015).

Climatological Normal: Average value of a climate element over 30 years calculated and established by NOAA's National Climatic Data Center (NCDC-NOAA 2015).

Clump: A cluster of individuals in the same species or other type of grouping.

Colluvium: "A general term applied to any loose, heterogeneous, and incoherent mass of soil material and/or rock fragments deposited by rainwash, sheetwash, or slow, continuous downslope creep, usually collecting at the base of gentle slopes or hill sides." (USGS 2014a).

Datum: A permanent marker indicating the placement of one leg of the sampling quadrat. The datum is a painted rebar hammered into the ground for *Huperzia appalachiana* sites and a painted nail hammered into the outcrop for *Sibbaldiopsis tridentata* sites (Leonard 2011).

Endemic: A species limited to select habitat (Weakley et al. 2012).

Gemma (plural gemmae): Vegetative propagules, common in species of *Huperzia*, that are fully formed and grow quickly following detachment from adult plant (Gola 2008).

Glacial relict species: Organisms that survived from The Pleistocene Epoch in isolated microhabitats where favorable environmental conditions persist (Braun 1955).

Herbaceous: A plant lacking woody tissue; may be any height, but is usually <1 meter tall (Cass et al. 2015).

Indicator species: Species that are highly sensitive to particular environmental stresses (Leonard 2011).

La Niña: "La Niña is characterized by unusually cold ocean temperatures in the eastern equatorial Pacific [resulting in] dryer and warmer than normal conditions across much of the southern tier...In the continental U.S., during a La Niña year, winter temperatures are warmer than normal in the Southeast and cooler than normal in the Northwest." (NOAA 2014a)

Local Extinction: A species no longer exists in a specific geographic area of its former range, though it still exists elsewhere in the world.

Mat growth: Prostrate and crowded growth of one or many individuals of the same species that can be generally spreading from a central root area (Schaffner 1905).

Metabasalt: "A low-grade, mafic metavolcanic rock with preserved evidence of its original basaltic character" (USGS 2014b).

Outcrop: Exposed bedrock.

Population: A group of individuals of a given species that are within a specified distance to another individual(s) in the same group (e.g., <200 meters between woody species, <20 meters between herbaceous species (not on rock outcrops), and <2 meters between herbaceous species on rock outcrops) (Cass et al. 2015).

Pleistocene: “The earliest Epoch of the Quaternary Period, beginning about 1.6 million years ago and ending 10,000 years ago, commonly known as the 'Ice Age', a time with episodes of widespread continental glaciation.” (USGS- NPS 2014)

Subcanopy: Woody growth between 3-5 meters in height (Cass et al. 2015).

Shrub: Woody growth between 0 and 3 meters in height (Cass et al. 2015)

Woody: Plant species with true wood or woody tissue (Cass et al. 2015).

Introduction

Shenandoah National Park is located on the crest of the Blue Ridge Mountains in northwest Virginia. The Park is 112.7 km (70 miles) long and 21.2 km (13.3 miles) across at its widest point (Conners 1988). Of the Park's 79,000 ha (197,438 ac), just two percent are rock outcrops. Despite their limited extent, much of the Park's visitation is to rock outcrops, which support some of the rarest plant communities in the Park (Fleming et al. 2007). Examples of these delicate rare plant communities include the "High-Elevation Greenstone Outcrop Barren" and the "Central Appalachian Mafic Boulderfield" (Natureserve 2017), both of which are endemic to Shenandoah National Park (Fleming et al. 2007).

A 2010 pilot study (Leonard 2011) established a protocol for monitoring the cover of low growing plant species on rock outcrops. Two species were selected *Sibbaldiopsis tridentata* (Aiton) Rydb. (three-toothed cinquefoil) and *Huperzia appalachiana* Beitel & Mickel (Appalachian fir clubmoss) to determine possible climate effects on high-elevation rare plant communities (Leonard 2011; all taxonomic information retrieved April 4, 2016 from the Integrated Taxonomic Information System on-line database, <http://www.itis.gov>).

Huperzia appalachiana is an evergreen clubmoss in the family Lycopodiaceae (Figure 1). *H. appalachiana* is ranked as "imperiled" (S2) in Virginia, and "apparently secure/secure" (G4/G5) globally (Townsend 2014). *Huperzia appalachiana* has 2-7.5 mm narrowly triangular leaves that are widest at the base with smooth margins (Weakley et al. 2012). Sometimes called *H. appressa*, it can be distinguished from the more common *H. lucidula* by its appressed morphology (the leaves point upwards and are angled toward the stem) (Weakley et al. 2012). *H. lucidula* has leaves that not only point out horizontally, but can also droop down toward the stem in addition to having a more "lustrous" appearance than *H. appalachiana*. The two species hybridize, so careful identification is important (Weakley et al. 2012). In Shenandoah National Park, *H. appalachiana* can be found growing on igneous rock outcrops on NNW facing slopes and in the colluvium at the base of rock outcrops above 850 meters (Fleming et al. 2007).

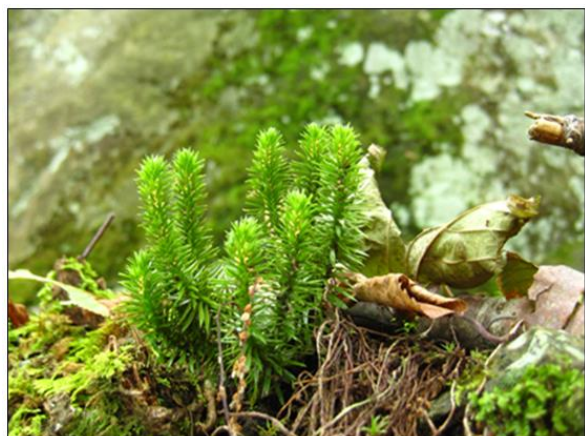


Figure 1. Photographs of *Huperzia appalachiana* (left) and flowering *Sibbaldiopsis tridentata* (right).

Sibbaldiopsis tridentata is an evergreen subshrub that grows in mats in the family Rosaceae (Figure 1). This species has a globally “secure” (G5) and state “imperiled” (S2) ranking (Townsend 2014). *S. tridentata* leaves are palmate, three-foliate, and oblong to oblong-lanceolate (Weakley et al. 2012). Leaf margins are smooth except at the tip where they have three to five teeth (Weakley et al. 2012). Plants have five-petaled white flowers in the summer, and the foliage turns red in the fall. In Shenandoah National Park, *S. tridentata* occurs on NNW facing outcrops above 1,130 meters on low angle ledges of igneous rock outcrops (Fleming et al. 2007).

Many studies have examined the effects of climate change, particularly warmer temperatures, on high-elevation and high-latitude plant communities. (Aerts 2006; Chapin et al. 1996; Epstein et al. 2000; Walker et al. 2006). The species in our study were selected as indicators of climate change effects because their habitat specificity and rarity point toward susceptibility to environmental stressors, including climatic variation (Halpin 1997; Hannah 2002; Peters and Darling 1985). Both species are near the southern extent of their geographical ranges (NatureServe 2015) and exist in isolated pockets of suitable habitat in the highest peaks of Shenandoah National Park. These species are sometimes referred to as “glacial relicts” because warming since the end of The Pleistocene Epoch (11,700 BP) has led to isolated southern occurrences of species with more widespread northern distributions (Braun 1955). As temperatures have risen, these relictual communities have persisted only where climate conditions remain suitable, such as the tops of mountains (Braun 1955). With no further upward (i.e. higher-elevation) habitat available, these communities are particularly vulnerable to local extinction if temperatures rise (Dirnböck et al. 2011; Halpin 1997; McDonald and Brown 1992; Peters and Darling 1985).

Frequently, warmer temperatures alone do not explain changes in species abundance and should be examined within the context of other threats (Walther 2002). The limited habitat and rarity of the species in this study makes them sensitive to many factors including climatic changes and human impacts. Visitor trampling, rock climbing, and erosion contribute noticeably to damage of rock outcrop plant communities in Shenandoah National Park (Fleming et al. 2007). However, the areas sampled in this study were selected to be well removed from areas of high visitor use.

Shenandoah National Park staff conducted photo monitoring in 2014 at 11 sites to document the status of *H. appalachiana* and *S. tridentata*. A subset of photo monitoring sites were sampled in 2010 and we used a two-sided paired t-test to determine significance of percent cover change between sampling events. The newly established photo monitoring sites will serve as baseline information for the photo monitoring points. The study species were selected because they occur exclusively in high-elevation habitats of the Park and are intolerant of the conditions present in lower elevation habitats so they are expected to respond to climate change. We will be looking at long term changes in cover, with the addition of future sampling events, for further evidence of the species’ stability in Shenandoah National Park.

Methods

Study Areas

All study areas are located in the Central District of Shenandoah National Park on metabasalt and granite outcrops. Park staff selected sites in locations where the study species occurs, but which had limited visitor access (Leonard 2011). Eleven monitoring sites were sampled in the 2014 field season. These sites are distributed among six mountain top study areas (Figure 2). Seven of these monitoring sites were originally established by Leonard (2011), and are located at the following four mountain top study areas: Crescent Rocks, Hawksbill Mountain, Little Stony Man Mountain and Pinnacles. Four additional monitoring sites were established in 2014 at the Betty's Rock, Old Rag Mountain, Hawksbill Mountain, and Pinnacles study areas (Table 1).

***Huperzia appalachiana* Sampling Areas**

Crescent Rocks

One *H. appalachiana* photo monitoring site, Crescent Rocks Site 3, was originally established in 2010 (Leonard 2011) with six photo monitoring plots (Table 1, Figure 2).

The vegetation community at Crescent Rocks Site 3 is the “Central Appalachian Northern Hardwood Forest” (G3G4) (Fleming et al. 2007, Natureserve 2017). *Huperzia appalachiana* grows in organic colluvium at the base of the metabasalt cliffs that form Crescent Rocks. Records from 2005 indicate that 101 clumps of *H. appalachiana* were at this site (Fleming et al. 2007).

Pinnacles

Two *H. appalachiana* photo monitoring sites, Pinnacles Site 1 and Pinnacles Site 2, are located at the Pinnacles sampling area (Figure 2). Pinnacles Site 1 was originally established in 2010 with eight photo monitoring plots (Leonard 2011). Pinnacles Site 2 was established in 2014 with seven photo monitoring plots (Table 1).

The vegetation community types at Pinnacles Site 1 and Pinnacles Site 2 are a combination of the “Central Appalachian High-Elevation Boulderfield Forest” and the “Central Appalachian Heath Barren” (Fleming et al. 2007; Natureserve 2017). Both of these community types have a global rarity ranking of G2 (Young et al. 2009). In May 2006 there were 470 distinct clumps of *H. appalachiana* at Pinnacles; however, a 1990 estimate noted 850 clumps (Fleming et al. 2007). A fire in 2000 may have contributed to this dramatic decrease in population size at this site.

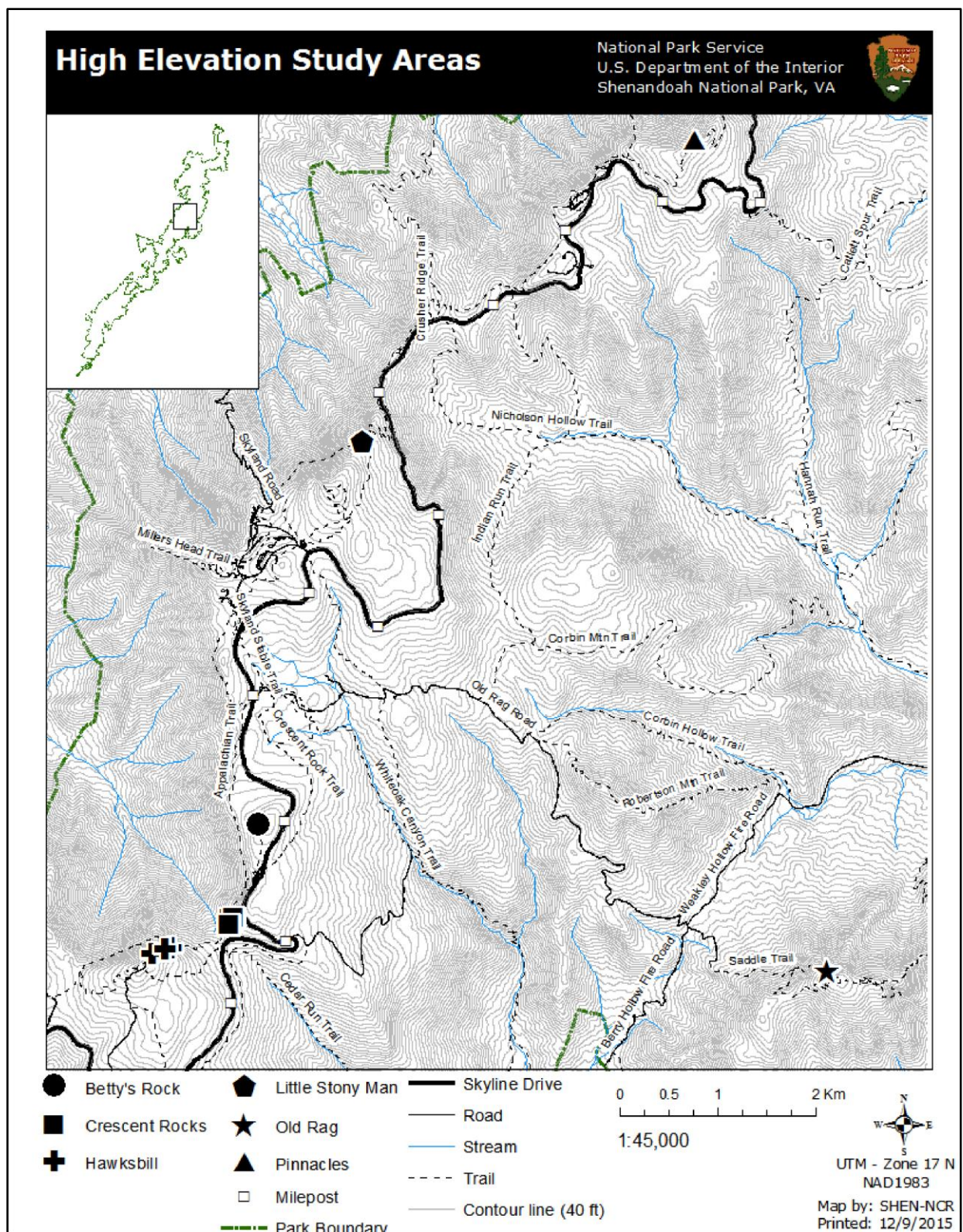


Figure 2. Map of the project sampling areas with in Shenandoah National Park.

Hawksbill Mountain

One *H. appalachiana* photo monitoring site, Hawksbill Site 3, is located in the Hawksbill Mountain sampling area (Figure 2). Hawksbill Site 3 was originally established in 2010 (Leonard 2011) with eight photo monitoring plots (Table 1).

The vegetation community at Hawksbill Site 3 is the “Central Appalachian High-Elevation Boulderfield Forest” (Fleming et al. 2007; Natureserve 2017). This area was officially closed to visitor use in late 2014 as part of the Park’s Rock Outcrop Management Plan (NPS 2014). There were 44 clumps of *H. appalachiana* recorded here in 2007 (Fleming et al. 2007). It was also noted in 2007 that previously documented *H. appalachiana* clumps found at the site in 1990 could not be relocated.

Table 1. Number of photo monitoring plots by study area, site, year established, and study species.

Study Area	Site	Year Established	<i>Huperzia appalachiana</i>	<i>Sibbaldiopsis tridentata</i>
Betty’s Rock	Betty’s Rock Site 1	2014	NA	10 photo monitoring plots
Crescent Rocks	Crescent Rocks Site 1	2010	NA	10 photo monitoring plots
Crescent Rocks	Crescent Rocks Site 2	2010	NA	8 photo monitoring plots
Crescent Rocks	Crescent Rocks Site 3	2010	6 photo monitoring plots	NA
Hawksbill Mountain	Hawksbill Site 1	2010	NA	8 photo monitoring plots
Hawksbill Mountain	Hawksbill Site 2	2010	8 photo monitoring plots	NA
Hawksbill Mountain	Hawksbill Site 3	2014	NA	8 photo monitoring plots
Little Stony Man Mountain	Little Stony Man 1	2010	NA	9 photo monitoring plots
Old Rag Mountain	Old Rag Site 1	2014	6 photo monitoring plots	NA
Pinnacles	Pinnacles Site 1	2010	8 photo monitoring plots	NA
Pinnacles	Pinnacles Site 2	2014	7 photo monitoring plots	NA

Old Rag Mountain

One *H. appalachiana* photo monitoring site, Old Rag Site 1, is located in the Old Rag Mountain sampling area (Figure 2). Old Rag Site 1 was originally established in 2014 with six photo monitoring plots (Table 1).

The vegetation community at Old Rag #1 is the “Central Appalachian Heath Barren” (Fleming et al. 2007; Natureserve 2017). In 2005-2006 *H. appalachiana* was documented here (Fleming et al. 2007).

***Sibbaldiopsis tridentata* Sampling Areas**

Betty’s Rock

One *S. tridentata* photo monitoring site, Betty’s Rock Site 1, is located in the Betty’s Rock sampling area (Figure 2). Betty’s Rock Site 1 was originally established in 2014 with ten photo monitoring plots (Table 1).

The vegetation community at Betty’s Rock Site 1 is the “High-Elevation Greenstone Outcrop Barren” (G1, endemic) occurring on a small ledge of metabasalt (Fleming et al. 2007; Natureserve 2017). A former park trail leads directly to and through the outcrop. *Sibbaldiopsis tridentata* growing in mats atop the outcrop in 2005-6 was noted to have declined from 20% to 5% from historic notes (Fleming et al. 2007).

Crescent Rocks

Two *S. tridentata* photo monitoring sites, Crescent Rocks Site 1 and Crescent Rocks Site 2, are located at the Crescent Rocks sampling area (Figure 2). Both sites were originally established in 2010 (Leonard 2011). Crescent Rocks Site 1 has ten photo monitoring plots and Crescent Rocks Site 2 has eight photo monitoring plots (Table 1).

The vegetation community in Crescent Rocks Site 1 and Crescent Rocks Site 2 is the “High-Elevation Greenstone Barren” on metabasalt cliffs and outcrops (Fleming et al. 2007; Natureserve 2017). Hundreds of mats, made up of thousands of stems of *S. tridentata* were estimated to occupy cliff and cliff face habitat at Crescent Rocks sampling area in 2005-6 (Fleming et al. 2007).

Hawksbill Mountain

Two *S. tridentata* photo monitoring sites, Hawksbill Site 1 and Hawksbill Site 3, are located at the Hawksbill Mountain sampling area (Figure 2). Hawksbill Site 1 was originally established in 2010 with eight photo monitoring plots (Leonard 2011). Hawksbill Site 2 was established in 2014 with eight photo monitoring plots.

The vegetation community of Hawksbill Site 1 and Hawksbill Site 3 is the “High-Elevation Greenstone Barren” (Fleming et al. 2007; Natureserve 2017). The *S. tridentata* photo monitoring plots are situated on massive metabasalt cliffs on the north slope of Hawksbill Mountain. This area was officially closed to visitor use in late 2014 as part of the Park’s Rock Outcrop Management Plan (NPS 2014). In 2006 the patchy mats of *S. tridentata* were estimated to cover a total area of 15-20 m² (Fleming et al. 2007).

Little Stony Man Mountain

One *S. tridentata* photo monitoring site, Little Stony Man Site 1, is located at the Little Stony Man Mountain sampling area (Figure 2). Little Stony Man Site 1 was originally established in 2010 (Leonard 2011) with nine photo monitoring plots (Table1).

The vegetation community of Little Stony Man Site 1 is the “High-Elevation Greenstone Barren” on a small outcrop of metabasalt (Fleming et al. 2007; Natureserve 2017). Visitor use is heavy in the Little Stony Man area, and restoration fences have restricted foot traffic into the *S. tridentata* habitat. This area was officially closed to visitor use in late 2014 as part of the Park’s Rock Outcrop Management Plan (NPS 2014). In 2005-6 about 100 mats of *S. tridentata* were documented in one area of 10 x 4 m (33 x 13 ft.) (Fleming et al. 2007).

Site Weather and Climate

Temperature and precipitation data are collected at nine observation stations in and around Shenandoah National Park. These data are used to report annual average temperatures and precipitation in relation to the 30-year normal. The Big Meadows weather station is the closest to the monitoring areas and is within 25 kilometers (15.5 miles) of each of the study areas and their monitoring sites.

In 2010, temperatures at the Big Meadows weather station were slightly above average, and the growing season started earlier than the 30-year normal. In the summer of 2010, there were more than twice the normal number of days when the maximum temperature exceeded 32°C (90°F). Annual precipitation levels were below normal (Knight et al. 2011). The 2010 summer was characterized by a La Niña event, resulting in warmer and drier than average conditions (NOAA 2014a).

Weather data from 2013 shows that the annual average temperature was below the climatological norm, with a late start to the growing season (Knight et al. 2014). Precipitation, including snowfall was above normal in 2013, with many months averaging more than 100% of normal values (Knight et al. 2014). NOAA (2014b) reports higher precipitation than normal for weather stations in northern Virginia for January-August 2014.

Plot Selection and Setup

The photo-monitoring protocol, designed by Leonard (2011), was adjusted in several ways in 2014 to improve sampling efficiency, safety, and repeatability. We recorded more information about the plot frame placement, such as the height of individual legs, to improve future plot setup accuracy and efficiency. In addition, helmets were used at all sites and safety ropes were used at all cliff sites. The use of safety ropes allowed us to capture more reproducible photo-points, because crew members could safely position themselves over the cliff-edge photo plot locations to gain the most informative image.

Because of the delicate nature of these sites, we took care to minimize damage to the study plants and the surrounding landscape. Upon arriving, we exchanged hiking boots for neoprene shoes to minimize trampling and damage. Impacts were further reduced by ensuring that gear was staged on

durable surfaces or non-sensitive plant communities, and that the minimum number of researchers was used to sample each site.

Six to ten plot locations were selected at each photo-monitoring site. A 0.5 x 0.25 m (1.64 x 0.82 ft.) gridded plot frame separated into 192 cells was used to delineate each plot prior to taking the documentation photo. We selected plot locations by positioning the plot frame over clumps of the study species. For the initial sample, each plot needed to be occupied by between 25% and 75% of the target species to be acceptable for sampling. Leonard (2011) recommended plots capture at least one edge of the target plant cluster within the plot frame to document potential changes in clump size and shape. Photo monitoring plots were selected if they met the above conditions and the location did not pose a safety concern to technicians.

One leg of the plot frame was determined to be the “datum” leg for the plot. For *S. tridentata* plots we drove a nail into the ground, or a rock crevice, to mark the datum location. A piece of rebar was used to mark datum locations for *H. appalachiana*. When setting up a plot, the “datum leg” should be positioned over the datum location. We leveled the plot by adjusting each leg length, and recorded the orientation of the plot’s long axis and datum leg. When setting a plot at a site that was established in 2010, we placed the datum leg over the nail or rebar, and adjusted the orientation was to match the 2010 setup. Photos taken in 2010 were used to ensure the plot was placed in exactly the same location.

Data Collection

Site Data

For each site, we collected vegetation data (See Appendix A for Data Collection Sheets) including assigning a cover class to each of four vegetation strata: canopy, subcanopy, shrub, and herb. We also recorded cover for ten exotic species in three zones around each plot: within the plot, within a five meter radius of the plot, and within a 20 meter radius of the plot. The cover classes used were: 1 (0%), 2 (>0-1%), 3 (>1-2%), 4 (>2-5%), 5 (>5-10%), 6 (>10-25%), 7 (>25-50%), 8 (>50-75%), 9 (>75-95%), and 10 (>95-100%). Target exotic species are the standard species recorded for all Rare, Threatened and Endangered (RTE) sites in the Park and include: *Ailanthus altissima* (tree of heaven), *Alliaria petiolata* (garlic mustard), *Celastrus orbiculatus* (bittersweet), *Lonicera japonica* (Japanese honeysuckle), *Microstegium vimineum* (Japanese stilt grass), *Paulownia tomentosa* (princess tree), *Perilla frutescens* (beefsteak plant), *Persicaria longisetata* (Asiatic water pepper), *Fallopia japonica* (Japanese bindweed), *Persicaria perfoliata* (mile-a-minute weed), *Pueraria montana* var. *lobata*, (kudzu), and *Rosa multiflora* (multiflora rose) (Cass et al. 2015).

Plot Data

For each plot we recorded information about the plot setup, safety rope use, and types of damage observed at the study population. Plot information included: plot number, which plot frame leg was used as the datum leg, the orientation of the long axis, and the height of each of the four plot frame legs. We also recorded safety rope use and placement of the safety rope.

We documented the type and degree of damage to each study population within a two meter radius of the plot using the same cover classes as those for exotic species. Types of damage observed included:

broken/trampled, dug/scraped, desiccated, erosion, invasive plants, browsed, trash/food (present), fire (any sign of fire in the area), people (visitation to the site), and leaf damage (Appendix A). Additionally, we drew a detailed map for all plots established in 2014. Maps for plots installed in 2010 were already complete.

Photography

We took three types of photos at each plot: a “locator” photo, a “datum” photo, and a “top-down” photo. All photos were taken with a digital Nikon D90 camera with a 28mm lens.

“Locator” Photo

The locator photo shows where the plot should be located on the rock outcrop for future reference (Figure 3). Locator photos were taken from an oblique angle and captured the plot frame in place. It is important to include landmarks such as prominent rocks, the cliff edge, tree trunks etc. in this photo.



Figure 3. Example of locator plots (*Sibbaldiopsis tridentata* plot (left) and *Huperzia appalachiana* plot (right)).

Datum” Photo

The datum photo is used for plot location and setup (Figure 4). This photo provides a zoomed in view of the datum on the outcrop. We removed the plot frame and marked the datum location with a flag to take the datum photos.



Figure 4. Example of datum photos (*S. tridentata* plot (left) and *H. appalachiana* plot (right)).

“Top-Down” Photo

Top-down photos were taken from above the plot looking straight down from the middle (Figures 5 and 6). The top-down photo is used to document the cover of the target species within the plot. When taking these photos, we found it essential to use ropes for balance in cliff sites. This allowed us to lean far enough over the plot frame to avoid taking the photos from an angle. Photos taken at cliff sites without the aid of ropes often appeared trapezoidal, and could not be used for analysis. For each plot, we took a minimum of three top-down photos at varying exposures to guarantee that the quality would be acceptable for data analysis. On sunny days, it was necessary to shade the plot in order to obtain a usable photograph for data analysis.

Photo Archiving

All of the photos and field data sheets associated with this project are archived in the NPS Integrated Resource Management Applications Data Store via reference code 2244380 (<https://irma.nps.gov/DataStore/Reference/Profile/2244380>).

Data Analysis

For each plot we selected a data analysis photo from the top-down photos. We took special care to find the best matched photo when selecting data analysis photos for comparison with sites established in 2010. We calculated plant coverages by counting occupied cells present in the digital images. We considered cells occupied if any part of a living leaf or vegetative stem was present in the cell, but we did not count flowering stems (Leonard 2011). Separate technicians counted each plot image to ensure that the counts were accurate. If discrepancies occurred, technicians examined the cell in question until presence or absence of the plant in that cell could be determined. We used a two-sided paired t-test to determine significant changes in the coverage between sampling events. Examples of plant coverage estimations are shown in Figures 5 and 6 and corresponding Tables 2 and 3, respectively. Appendices contain additional information on coverage calculations including the Plot Analysis Data Sheet (Appendix A) results from each site (Appendix B).



Figure 5. A top-down photo of *Huperzia appalachiana* and plot frame.

Table 2. The table below corresponds to Figure 5, a top-down photo of *Huperzia appalachiana* and plot frame. Squares with gray “1”s indicate presence of the plant while white “0”s indicate absence of the plant.

Grid Letter	Grid Number																								Total
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	
A	0	0	0	1	1	0	1	1	0	1	1	0	0	1	1	0	0	1	1	0	0	0	0	0	10
B	0	0	0	1	1	1	1	1	1	1	1	1	1	1	0	0	0	1	0	1	0	0	0	0	13
C	0	0	0	1	1	1	0	0	0	1	1	1	1	1	1	1	0	0	0	1	1	0	0	0	12
D	0	0	0	0	1	1	0	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	11
E	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	15
F	1	0	1	1	1	1	1	1	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	9
G	1	0	1	1	1	1	1	1	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	9
H	1	0	0	0	1	1	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	5
Total	4	0	3	6	8	7	6	6	3	6	7	6	4	5	4	3	0	2	1	2	1	0	0	0	84



Figure 6. A top-down photo of *Sibbaldiopsis tridentata* and plot frame.

Table 3. The table below corresponds to Figure 6, a top-down photo of *Sibbaldiopsis tridentata* and plot frame. Squares with gray “1”s indicate presence of the plant while white “0”s indicate absence of the plant.

Grid Letter	Grid Number																								Total
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	
A	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	14
B	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	14
C	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	15
D	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	17
E	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	19
F	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	18
G	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	17
H	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	18
Total	0	0	0	0	0	2	3	5	5	6	8	8	8	8	8	8	8	8	7	8	8	8	8	8	132

Results and Discussion

Huperzia appalachiana Sites

Crescent Rocks Site 3

We sampled six plots at Crescent Rocks Site 3 in 2010 and 2014. Mean cover of *H. appalachiana* in 2010 was $25.3 \pm 0.9\%$ which decreased to a mean of $16.8 \pm 1.9\%$ in 2014 (Figure 7). Across all plots at the site, the mean decline was $34.0 \pm 6.4\%$ between 2010 and 2014 (Appendix B). The decrease at Crescent Rocks Site 3 was significant ($t(5) = 5.64, p = 0.002$).

Canopy coverage at Crescent Rocks Site 3 was approximately 80%, with *Acer rubrum* (red maple) and *Quercus rubra* (red oak) being most common. Subcanopy cover was nearly 100% and was dominated by *Betula lenta* (sweet birch), *Castanea americana* (American chestnut), *Hamamelis virginiana* (witch hazel), and *Ilex montana* (mountain holly). Shrub cover was 80%. The most common shrub species were *Kalmia latifolia* (mountain laurel), *Sorbus americana* (American mountain ash), *Abies balsamea* (balsam fir), and *Menziesia pilosa* (minniebush). Herb cover was 40% and consisted primarily of *Carex* spp. (sedges), *Dennstaedtia punctilobula* (hay-scented fern), *Eurybia divaricata* (white wood aster), *Polygonatum biflorum* (Solomon's seal), and *Avenella flexuosa* (wavy hairgrass). No exotic species were observed at this site. Desiccation was commonly noted on the *H. appalachiana* in the plots, and there was some evidence of erosion within the site.

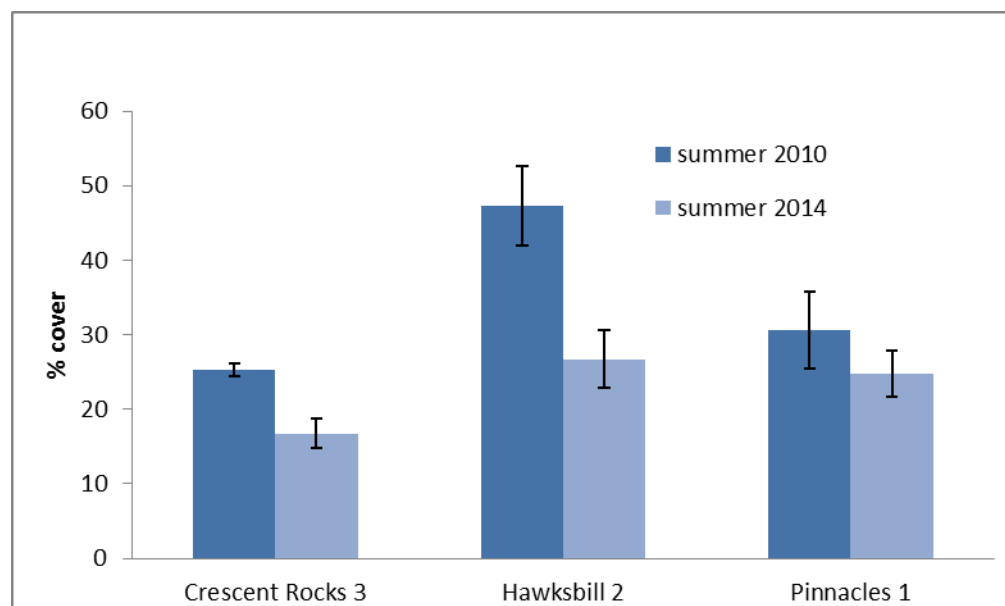


Figure 7. Percent cover of *Huperzia appalachiana* at monitoring sites that have information for both 2010 to 2014. Vertical bars show the standard error of the mean.

Hawksbill Site 2

We sampled eight plots at Hawksbill Site 2. Mean cover of *H. appalachiana* in 2010 was $47.3 \pm 5.4\%$ which decreased to a mean of $26.7 \pm 3.9\%$ in 2014 (Figure 7). Across all plots at the site, the mean decline was $38.3 \pm 10.7\%$ between 2010 and 2014 (Appendix B). The decrease at Hawksbill Site 2 was significant ($t(7) = 3.26, p = 0.01$).

There was 40% cover each for canopy, subcanopy, and shrub layers at Hawksbill Site 2. Canopy trees were dominated by *Quercus rubra*, *Sorbus americana*, and *Betula lenta*. Subcanopy species were *Abies balsamea*, *Quercus rubra*, *Sorbus americana*, and *Betula lenta*. Shrubs were *Ilex montana*, *Menziesia pilosa*, *Sorbus americana*, and *Betula lenta*. Herbaceous species were *Dennstaedtia punctilobula*, *Maianthemum canadense* (Canada mayflower), *Amianthium muscitoxicum* (fly poison), *Oclemena acuminata* (mountain aster), and *Avenella flexuosa*. There were no exotic species observed in this site. Much of the *H. appalachiana* at this site was desiccated.

Old Rag Site 1

We established six plots at Old Rag Site 1 in 2014. No 2010 plots existed at this site. *Huperzia appalachiana* mean cover was 59.8 ± 7.5 cells (Appendix B).

There was little to no canopy cover at Old Rag Site 1 and about 80% subcanopy cover, contributed by *Sorbus americana*, *Kalmia latifolia*, and *Ilex montana*. The only species in the shrub layer was *Kalmia latifolia*, which provided 20% cover. Herbaceous species were *Dennstaedtia punctilobula* and *Avenella flexuosa*. There were no exotic species or disturbances recorded at this site.

Pinnacles Site 1

We sampled eight plots at Pinnacles Site 1 in 2010 and 2014. Mean cover in 2010 was $30.6 \pm 5.1\%$ which decreased to a mean of $25.6 \pm 3.1\%$ in 2014 (Figure 7). Across all plots at the site, the mean decline was $11.0 \pm 10.7\%$ between 2010 and 2014 (Appendix B). The decrease at Pinnacles Site 1 was not significant.

Canopy cover at Pinnacles Site 1 was 80% with a species composition of *Quercus rubra* and *Betula lenta*. There was 60% subcanopy cover with *Sorbus americana* and *Tsuga canadensis* (eastern hemlock). There was 80% shrub cover with *Kalmia latifolia*, *Menziesia pilosa*, and *Ilex montana*. There was 60% herb cover, primarily attributed to *Dennstaedtia punctilobula*. There were no exotic species or disturbances recorded at this site.

Pinnacles Site 2

We established seven plots at Pinnacles Site 2 in 2014. No 2010 plots existed at this site. *Huperzia appalachiana* cover was 58.9 ± 12.3 cells (Appendix B).

There was 80% canopy cover at Pinnacles Site 2 of *Betula lenta* and *Quercus rubra*. Both the subcanopy and shrubs each made up 60% cover with *Ilex montana* and *Betula alleghaniensis* (yellow birch) representing subcanopy, and *Kalmia latifolia* and *Sorbus americana* representing shrub species. *Dennstaedtia punctilobula* was the only herbaceous species recorded at this site. There were no exotic species or other disturbances recorded at this site.

***Sibbaldiopsis tridentata* Sites**

Betty's Rock Site 1

We established ten plots at Betty's Rock Site 1 in 2014. No 2010 plots existed at this site. There was an average of 89.1 ± 10.2 cells occupied by *S. tridentata* in the plots at this site (Appendix B).

There was little to no canopy and subcanopy cover at Betty's Rock. There was approximately 20% shrub cover, characterized by *Sorbus americana* and *Gaylussacia baccata* (dwarf huckleberry), and 20% herb cover consisting mainly of *Solidago simplex* var. *randii* (Rand's goldenrod). There were no exotic plant species observed within the plots, but in the five meters surrounding the plot, *Centaurea stoebe* ssp. *micranthos* (spotted knapweed) and *Poa compressa* (Canada bluegrass) were each estimated to occupy less than 1% of the entire area. These species also occurred within the 20 meter radius surrounding plots, along with *Alliaria petiolata*, all of which were estimated to account for less than 1% of the total area. The study plants appeared to be in good health, despite the existence of an abandoned park trail at this location.

Crescent Rocks Site 1

We sampled ten plots at Crescent Rocks Site 1 in 2010 and 2014. Mean cover of *S. tridentata* in 2010 was $69.1 \pm 4.5\%$ which increased to a mean of $70.3 \pm 4.8\%$ in 2014 (Figure 8). Across all plots at the site, the mean increase was $2.5 \pm 4.7\%$ between 2010 and 2014 (Appendix B). The increase at Crescent Rocks Site 1 was not significant.

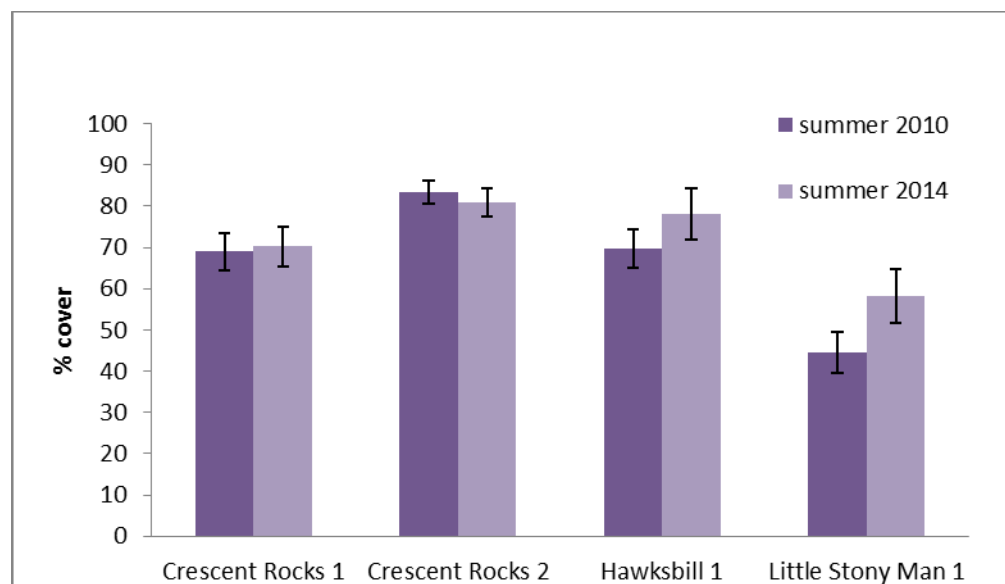


Figure 8. Percent cover of *Sibbaldiopsis tridentata* at monitoring sites that have information for both 2010 to 2014. Vertical bars show the standard error of the mean.

There was little to no canopy cover at Crescent Rocks Site 1. There was 20% cover of both subcanopy and shrub-sized plants. Subcanopy species consisted of *Kalmia latifolia*, *Hamamelis virginiana*, and *Quercus rubra*, and shrub species were *Menziesia pilosa* and *Betula lenta*. There was 40% herb cover, consisting mainly of *Potentilla simplex* (common cinquefoil), *Houstonia caerulea* (bluets), *Avenella flexuosa*, and *Maianthemum canadense*. Less than 1% cover of *Rumex acetosella* (field sorrel) occurred within the plots, and while no other exotic species were observed within 20m of the plot, *Alliaria petiolata* and *Persicaria longisetata* were seen while walking to the site. While there was some evidence of trash and food at this site, as well as some trampling, digging, and scraping by wildlife, the study plant looked to be in good overall condition.

Crescent Rocks Site 2

We sampled eight plots at Crescent Rocks Site 2 in 2010 and 2014. We were only able to duplicate seven of the “Top-down” photos for data analysis. Mean cover of *S. tridentata* in 2010 was $83.4 \pm 2.9\%$ which decreased to a mean of $80.9 \pm 3.5\%$ in 2014 (Figure 8). Across all plots at the site, the mean decrease was $3.1 \pm 5.5\%$ between 2010 and 2014 (Appendix B). The decrease at Crescent Rocks Site 2 was not significant.

There was little to no canopy cover at Crescent Rocks Site 2. There was 20% cover of subcanopy, shrubs and herbs. The subcanopy was *Betula lenta*, shrub species were *Menziesia pilosa* and *Kalmia latifolia*, and herbs were *Avenella flexuosa*, *Dianthus armeria* (Deptford pink), and an unidentified aster (Asteraceae). Less than 1% cover of *Rumex acetosella* occurred within the plots and reached 2-5% cover within five meters of the plots, but there were no other exotic species observed within 20 meters. In 2014 there was evidence of a fire ring and burned area on ground. The *S. tridentata* appeared healthy and undamaged by the fire disturbance.

Hawksbill Site 1

We sampled nine plots at Hawksbill Site 1 in 2010 and 2014. Mean cover of *S. tridentata* in 2010 was $69.7 \pm 4.6\%$ which increased to a mean of $78.1 \pm 6.2\%$ in 2014 (Figure 8). Across all plots at the site, the mean increase was $11.2 \pm 3.9\%$ between 2010 and 2014 (Appendix B). The increase at Hawksbill Site 1 was significant ($t(8) = 3.08, p = 0.02$).

There was little to no canopy or subcanopy cover at Hawksbill Site 1. There was approximately 20% shrub and herb cover, with the most common shrub species being *Sorbus americana*, *Menziesia pilosa*, and *Betula lenta*. The herbaceous plant layer was dominated by *Avenella flexuosa*. There were no exotic species observed in this site. There was little to no disturbance, and the study plants appeared to be in good health.

Hawksbill Site 3

We established eight plots at Hawksbill Site 3 in 2014. No 2010 plots existed at this site. There was an average cover of 135.3 ± 10.6 cells of *S. tridentata* in the plots at Hawksbill Site 3 (Appendix B).

There was little to no canopy or subcanopy and 20% shrub cover at Hawksbill Site 3. Shrub cover consisted of *Sorbus americana*, *Diervilla lonicera* (northern bush-honeysuckle), and *Betula lenta*. Herbaceous plant cover was 60%, and consisted of *Avenella flexuosa*, *Polypodium virginianum* (rock polypody), *Micranthes petiolaris* (Michaux's saxifrage), and *Hylotelephium telephioides* (Allegheny stonecrop). There were no exotic species observed in this site. The *S. tridentata* at this site appeared to be in good health and no disturbances were recorded.

Little Stony Man Site 1

We sampled nine plots at Little Stony Man Site 1 in 2010 and 2014. Mean cover of *S. tridentata* in 2010 was $44.4 \pm 5.0\%$ which increased to a mean of $58.2 \pm 6.5\%$ in 2014 (Figure 8). Across all plots at the site, the mean increase was $32.8 \pm 8.2\%$ between 2010 and 2014 (Appendix B). The increase at Little Stony Man Site 1 was significant ($t(8) = 3.88, p = 0.005$).

There was 20% cover of all vegetation strata in four of the plots at Little Stony Man Site 1. Canopy species were *Quercus rubra* and *Abies balsamea*. The subcanopy was *Kalmia latifolia*, and shrubs consisted of *Vaccinium pallidum* (upland low blueberry), *Spiraea betulifolia* (birchleaf spiraea), and *Betula lenta*. Dominant herbaceous species were *Avenella flexuosa* and *Solidago simplex* var. *randii*. In the remaining five plots there was very little to no canopy or shrub cover. Subcanopy cover was 20% and was composed mainly of *Betula lenta*. Herbaceous cover was also 20% and consisted of *Solidago simplex* var. *randii*, *Avenella flexuosa*, *Danthonia spicata* (poverty oatgrass), and *Houstonia longifolia* (longleaf bluets). There were no exotic species recorded at this site. In three of the nine plots, there was a small amount of broken or trampled *S. tridentata*.

Summary of Plant Cover Changes, 2010-2014

Three *H. appalachiana* monitoring sites were sampled in both 2010 and 2014. For these three sites, the mean *H. appalachiana* cover decreased by an average of $27.6 \pm 8.5\%$ (Figure 7, $n = 3$). The decrease was significant between sampling periods for *H. appalachiana* at two of the three sites: Crescent Rocks Site 3 ($t(5) = 5.64, p = 0.002$) and Hawksbill Site 2 ($t(7) = 3.26, p = 0.01$).

Four *S. tridentata* monitoring sites were sampled in both 2010 and 2014. At these four sites, the cover of *S. tridentata* increased at three sites and decreased at one site, for an average percent change of $10.9 \pm 7.9\%$ (Figure 8, $n = 3$). The increase between sampling periods for *S. tridentata* was significant at Hawksbill Site 1 ($t(8) = 3.08, p = 0.02$) and Little Stony Man Site ($t(8) = 3.88, p = 0.005$).

We were unable to compare all of the 2010 data with that from 2014 because some photo points did not have sufficient information for replication. These quality control issues were addressed in 2014 modifications to the protocol, and should not be a factor in future years.

Assessing and predicting a particular species' response to climate change is difficult because many species are understudied and adequate information is not available. The Climate Change Vulnerability Index, developed by NatureServe, is a tool to aid land managers with predicting a species reaction to climate change, by classifying vulnerability according to sensitivity and exposure (Young et al. 2010). This tool provides a useful way to look at data from the current photo monitoring study in the context of other available data.

In the Climate Change Vulnerability Index, **Exposure** is determined by predicted temperature and precipitation changes. **Sensitivity** incorporates three factor groups: “1. indirect exposure to climate change, 2. specific factors, including dispersal ability, temperature and precipitation sensitivity, physical habitat specificity, interspecific interaction and genetic factors, and 3. documented response to climate change (through data or models)” (Young et al. 2010).

Exposure

Weather impacts to the study species may have influenced our results. The warmer than average temperature and lower than average precipitation in 2010 may partially explain the poor condition of *S. tridentata* during the initial sampling. Using the same logic, the wetter and cooler weather in 2013 may explain the more robust condition of *S. tridentata* in 2014. Both study species are found in thin

well-drained soils, where evaporation from warmer temperatures can quickly diminish moisture gained from precipitation events (Major 1963). *Huperzia appalachiana* populations occur in more sheltered habitat at the base of cliffs and under canopy cover and could explain why they were able to withstand the conditions in 2010 compared to *S. tridentata*. Additionally, the severe winter of 2013 may have negatively impacted cover of *H. appalachiana*, because higher snowfall amounts and deeper, longer snow cover in 2013 may have increased erosion on the unstable slopes where populations occur. While these explanations are not evidence of response to climate trends, they suggest that the indicator plants are sensitive to deviations from climatological normal. Consistent deviations from climatological normal could amplify impacts to sensitive species over time.

Sensitivity

Indirect Exposure

The populations of *H. appalachiana* and *S. tridentata* within this study may be indirectly vulnerable to climate change. Increased colonization by woody species in high-elevation areas is a predicted, and documented, response to warming temperatures (Cannone et al. 2007; Capers and Stone 2011; Robinson et al. 2010; Chapin et al. 1996; Epstein et al. 2000). Such colonization would cause increased competition with herbaceous species, such as *S. tridentata* and *H. appalachiana*. *S. tridentata* requires open habitat, so its existence will be threatened by encroachment of woody or other species (NatureServe 2015). *H. appalachiana* has both sun and shade forms (Beitel and Mickel 1992), but the communities in which this species occurs will be transformed by woody encroachment. As habitat becomes milder in these cooler pockets of the park, it will be more suitable to a variety of species and infestations of non-native are anticipated to occur (Walther et al. 2009). Invasive species already present near populations of *S. tridentata* and within the study sites, such as *Centaurea stoebe* ssp. *micranthos* (spotted knapweed), *Poa compressa* (Canada bluegrass), and *Rumex acetosella* (sheep sorrel), may also compete with the rare species for resources.

Specific Factors

In Shenandoah National Park, the selected indicator species are found at the edge of their geographic range in limited habitats which possess suitable environmental conditions. The edge of a species distribution is more vulnerable to extirpation than its continuous range (Lesica and McCune 2004). Low genetic variability is of particular concern for species that are at the periphery of their geographic range (Eckert 2002; Hampe 2005) or that are isolated from other populations with which they can exchange genes. In such cases, low genetic variability is problematic because it leads to lack of resilience and ability to withstand disturbances (Lesica and McCune 2004).

Reproductive factors may play a role in the trends seen in *H. appalachiana* cover between the two sample periods. In *Huperzia* species, sexual reproduction through spores is very slow and many spores are inactive (Whittier 1998). However, it is common for *Huperzia* species to propagate vegetatively through gemmae (Gola 2008). This process takes place most frequently in the immediate vicinity of parent stems (Beitel and Mickel 1992). Mountain populations of *Huperzia* species produce more gemmae than their counterparts in lowland areas (Gola 2008). The populations we visited in this study have potential for colonization into adjacent suitable habitat. However,

certain populations in the Park may be at greater risk than others to disturbances, because of their close proximity to trails (Fleming et al. 2007).

Huperzia appalachiana coexists beneath varied canopy cover in the Park (subcanopy and canopy estimates ranged from 40-80% in the study sites), but may be limited by competition with lower woody or herbaceous growth. Individual stems of *H. appalachiana* live for 12-15 years, during which they produce spores and gemmae (Bietel and Mickel 1992). Dead and dying stems, noted as desiccated in our field notes, are a common characteristic of this species (Bietel and Mickel 1992). Therefore, we can expect to see change in the top-down photos between sampling cycles, but we should also see new growth around the desiccated stems. Individual plots may be less informative about a population than the site average, and replicating photo points may not capture new growth.

Reproductive factors may also influence the population trends in *S. tridentata*. *S. tridentata* is limited to fewer outcrops in Shenandoah National Park than *H. appalachiana*; however, *S. tridentata* is locally abundant in the few rock outcrops where it occurs (Weakley et al. 2012). Its ability to colonize new areas, through sexual reproduction and subsequent dispersal, is limited by a dry, dehiscent seed (achene) of 1.2-1.5mm (Weakley et al. 2012) and the small amount of suitable habitat with appropriate substrate. Roach and Marchand (1984) found low germination, slow growth and high mortality for *S. tridentata* in restoration studies. Mats of *S. tridentata* may colonize adjacent areas more frequently through clonal growth than sexual reproduction and dispersal (Marchand and Roach 1980). There is some room for expansion of *S. tridentata* within the monitoring sites where the species currently occurs; however, competition with woody and herbaceous species is a limiting factor.

Documented Response

The third factor of the Climate Change Vulnerability Index is documented or modeled response to climate change. The current photo-monitoring study will provide information that can inform this factor. As a method of tracking changes between 2010 and 2014, the photo-monitoring is more accurate than our previous site visit methodology, which was subject to individual monitoring personnel interpretation. Several studies that examine changes in high-elevation plant communities base their analyses on species composition from historical data (Capers and Stone 2011; Roach and Marchand 1984; Robinson 2010), including historic photo points (Gorben 2011). The photos allow us to take a closer look at the indicator species to track change more rapidly, rather than infer from the larger scale, which will take longer to reflect change.

Conclusions

The results of this study show the dynamic nature of *H. appalachiana* and *S. tridentata* cover on high-elevation rock outcrops in Shenandoah National Park. The declines in *H. appalachiana* at Crescent Rocks and on Hawksbill are statistically significant. These declines appear ominous; however, with only two data points there is no proof that this is a trend, and future sampling may yield different results. Despite this, field protection of these populations will need to be enhanced to decrease the chance of human caused stressors such as trampling. Additional monitoring of *H. appalachiana* populations, with special attention to not only the photo plots, but also the surrounding areas, is warranted in future years to determine if plant cover is being lost or is shifting to an adjacent location. The increase in cover of *S. tridentata* at Little Stony Man and Hawksbill was statistically significant. Weather conditions may explain some of this change. However, another likely influence was the installation of protective barriers at Little Stony Man in 2011. Future monitoring of both species will inform us as to whether the species abundances are permanently changing, or if they are demonstrating natural cycles of growth and decline.

Additional protective measures, including permanent camping closures, off-trail visitor use closures and climbing guidelines were implemented in the fall of 2014 as part of the Park's recently approved Rock Outcrop Management Plan (NPS 2014). Sampling areas at Hawksbill and Little Stony Man are now closed to climbing and all other off-trail uses (NPS 2014). The trail leading to Betty's Rock has been abandoned and rehabilitated (NPS 2014). The three remaining sample areas at Crescent Rocks, Old Rag, and Pinnacles are still open to off-trail use (NPS 2014). Future monitoring results may be influenced by these protective measures.

This project provides direction to Park management, and also presents a protocol that can serve as an example to other land-managers and scientists interested in tracking changes in cover of low-growing indicator species through photo-monitoring. An additional benefit of the project will be the acquisition of data that will better inform Climate Change Vulnerability assessments for *H. appalachiana* and *S. tridentata*, two species which may serve as indicators for extremely rare plant communities in Shenandoah National Park.

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New Site Data Sheet 2010 and 2014

27

FIELD DATA SHEET FOR PLOTS		Data Collector: _____
SITE NAME: _____	DATE: _____/_____/_____	
SITE ID: _____	PLOT #: _____ of _____	
WORK CREW: _____		
TARGET SPECIES: _____		
BEARING OF LONG AXIS OF PLOT: _____ degrees	(From datum to opposite end of plot)	
Declination set? ☐ Yes ☐ No		
INDICATE MARKER LEG (N, S, E, W, NE, SW, ETC): _____		
PHOTOS: (Indicate storage number on roll or in camera)		
Top Down _____		
Marker point _____		
Locator _____		
photos _____		
Other photos _____		
(These are temporary numbers which will be changed during the filing process)		
PLOT NOTES (continue on rear if needed)		
PLOT LOCATOR SKETCH (If plots are close together, multiple plots may be drawn on one map)		
Indicate north and bearing + distance to landmarks		

Directions and Site Description Data Sheet 2014

RTE PHOTO MONITORING DIRECTIONS & DESCRIPTION																							
Species: _____			Date: _____ (MM/DD/YY)																				
Site Name: _____			Population ID: _____																				
Plot Number: (of) _____			Field Team: _____																				
UTM Coordinates of _____ point: _____ e, _____ n +/- _____ m																							
Datum: NAD 27 NAD 83 GPS Unit: Garmin ____ Trimble ____ Pt Ln Poly Temp. GPS File _____																							
Camera: _____ Photo Numbers: _____																							
Directions to Site (include a scale, north arrow, location of permanent markers/ monument trees, photopoints)																							
Monument trees / Other markers: <table style="width: 100%; border-collapse: collapse;"> <thead> <tr> <th style="text-align: left; width: 25%;">Species</th> <th style="text-align: center; width: 10%;">dbh (cm)</th> <th style="text-align: center; width: 10%;">Tag #</th> <th style="text-align: center; width: 10%;">Bearing</th> <th style="text-align: center; width: 10%;">Distance (m)</th> <th style="text-align: left; width: 35%;">Destination (What does this lead to?)</th> </tr> </thead> <tbody> <tr> <td>_____</td> <td>_____</td> <td>_____</td> <td>_____</td> <td>_____</td> <td>_____</td> </tr> <tr> <td>_____</td> <td>_____</td> <td>_____</td> <td>_____</td> <td>_____</td> <td>_____</td> </tr> </tbody> </table>						Species	dbh (cm)	Tag #	Bearing	Distance (m)	Destination (What does this lead to?)	_____	_____	_____	_____	_____	_____	_____	_____	_____	_____	_____	_____
Species	dbh (cm)	Tag #	Bearing	Distance (m)	Destination (What does this lead to?)																		
_____	_____	_____	_____	_____	_____																		
_____	_____	_____	_____	_____	_____																		
Comments on frequency, magnitude, and distribution of disturbance; size of area considered, and target species distribution at site; monitoring/management actions needed to ensure the protection of this species; and any other observations:																							

SHEN RTE PHOTO MONITORING DATA SHEET - Page 1

Species: _____ Date: _____ (MM/DD/YY)

Site Name: _____ Population ID: _____

Plot Number: (_____ of _____) Field Team: _____

Marker Leg (N, S, E, W, NE, SW, etc.) _____

Orientation of Long Axis of Plot (bearing from marker leg along long edge of plot): _____

Species Composition:

	Approx. Cover						Dominant Species
Canopy	0	20	40	60	80	100	_____, _____, _____, _____, _____
Subcanopy	0	20	40	60	80	100	_____, _____, _____, _____, _____
Shrub	0	20	40	60	80	100	_____, _____, _____, _____, _____
Herb	0	20	40	60	80	100	_____, _____, _____, _____, _____

Notes:

Exotic Species Cover Classes 1 (0%), 2 (0.1 - 1%), 3 (1-2%), 4 (2-5%), 5 (5-10%), 6 (10-25%), 7 (25-50%), 8 (50-75%), 9 (75-95%), 10 (95-100%)

Species	w/in plot	5 meters beyond	20 meters beyond	Notes
AILALT				
ALLPET				
CELORB				
LONJAP				
MICVIM				
PAUTOM				
PERFRU				
PERPOS				
FALJAP				
PERPER				
PUEMON				
ROSMUL				
others?				(write in species)
others?				(write in species)

Photo Monitoring Data Sheet –Page 2 2014

SHEN RTE PHOTO MONITORING DATA SHEET - Page 2			
Species: _____		Date: _____ (MM/DD/YY)	
Site Name: _____		Site ID: _____	
Plot Number: (____ of ____)		Field Team: _____	
Weather: C PC S		Marker Leg (N, S, E, W, NE, SW, etc.) _____	
Orientation of Long Axis of Plot (bearing from marker leg along long edge of plot): _____			
Safety Rope? : Y N		Placement #: _____	
Evidence of impacts with 2m of plot.			
Cover Classes: 1 (0%), 2 (0.1 - 1%), 3 (1-2%), 4 (2-5%), 5 (5-10%), 6 (10-25%), 7 (25-50%), 8 (50-75%), 9 (75-95%), 10 (95-100%)			
Cover Code #	Damage(s) Observed	Cover Code #	Damage(s) Observed
	Broken/Trampled		Browsed
	Dug/Scraped		Trash/Food
	Desiccated		Fire
	Erosion		People
	Invasive Plants		Leaf Damage
	Other:		

Individual leg position	
Leg	Length (cm)
1	
2	
3	
4	

Camera ID: _____ Datum marker point (minium of 1 photo): File name and number: _____ _____ _____	Top Down plot photos (minimum of 3 photos): File name and number: _____ _____ _____
Plot Locator Image(s) (minimum 1 photo): _____ _____ _____	Other photos (methods, people, etc): _____ _____ _____

Notes: (plot, location, access, set-up, etc.)

Plot Analysis Data Sheet 2010 and 2014

PLOT ANALYSIS DATA SHEET																								(to be completed upon analysis of photographic record)	
SITE NAME: _____												Population ID: _____													
TARGET SPECIES: _____																									
PLOT #: _____ (of)																									
INITIAL FIELD WORK DATE: _____																									
FIRST ANALYSIS																									
ANALYSIS DATE: _____																									
ANALYST: _____																									
PHOTO: _____																									
CELLS OCCUPIED: 0 of 192												PERCENT CELLS OCCUPIED: 0 %													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	TOTAL
A																									0
B																									0
C																									0
D																									0
E																									0
F																									0
G																									0
H																									0
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SECOND ANALYSIS																									
ANALYSIS DATE: _____																									
ANALYST: _____																									
PHOTO: _____																									
CELLS OCCUPIED: 0 of 192												PERCENT CELLS OCCUPIED: 0 %													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	TOTAL
A																									0
B																									0
C																									0
D																									0
E																									0
F																									0
G																									0
H																									0
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
When counting occupied cells only count what is visible																									
Do not count flowering stems when counting occupied cells (leaf and stems only)																									
Indicate if dead leaves/stems are counted, otherwise do not count.																									

Appendix B: Plot Data and Calculations

Site: Crescent Rocks 1

Species	Site	Plot	2010	%cover 2010	2014	% cover 2014	%change
SIBTRI	CRX 1	1	100	52.1	93	48.4	-7.0
SIBTRI	CRX 1	2	133	69.3	107	55.7	-19.5
SIBTRI	CRX 1	3	174	90.6	178	92.7	2.3
SIBTRI	CRX 1	4	154	80.2	124	64.6	-19.5
SIBTRI	CRX 1	5	137	71.4	174	90.6	27.0
SIBTRI	CRX 1	6	143	74.5	153	79.7	7.0
SIBTRI	CRX 1	7	139	72.4	140	72.9	0.7
SIBTRI	CRX 1	8	153	79.7	163	84.9	6.5
SIBTRI	CRX 1	9	88	45.8	110	57.3	25.0
SIBTRI	CRX 1	10	105	54.7	108	56.3	2.9
Average			132.6	69.1	135.0	70.31	2.5
Stdev			27.0	14.1	30.8	16.0	15.7
Sterror			8.5	4.5	9.7	4.8	4.7

Notes: SIBTRI = *Sibbaldiopsis tridentata*, year columns indicate number of occupied cells with 192 total potential cells, Stdev = standard deviation, Sterror = standard error.

Site: Crescent Rocks 2

Species	Site	Plot	2010	%cover 2010	2014	% cover 2014	%change
SIBTRI	CRX 2	1	150	78.1	129	67.2	-14.0
SIBTRI	CRX 2	2	159	82.8	142	74.0	-10.7
SIBTRI	CRX 2	3	168	87.5	170	88.5	1.2
SIBTRI	CRX 2	4	165	85.9	159	82.8	-3.6
SIBTRI	CRX 2	5	135	70.3	153	79.7	13.3
SIBTRI	CRX 2	6	182	94.8	138	71.9	-24.2
SIBTRI	CRX 2	7	162	84.4	188	97.9	16.0
SIBTRI	CRX 2	8	NA	NA	164	85.4	NA
Average			160.1	83.4	155.4	80.9	-3.1
Stdev			14.7	7.7	19.1	9.9	14.6
Sterror			5.6	2.9	6.7	3.5	5.5

Notes: SIBTRI = *Sibbaldiopsis tridentata*, year columns indicate number of occupied cells with 192 total potential cells, Stdev = standard deviation, Sterror = standard error.

Site: Crescent Rocks 3

Species	Site	Plot	2010	%cover 2010	2014	% cover 2014	%change
HUPAPP	CRX 3	1	53	27.6	34	17.7	-35.8
HUPAPP	CRX 3	2	47	24.5	26	13.5	-44.7
HUPAPP	CRX 3	3	45	23.4	19	9.9	-57.8
HUPAPP	CRX 3	4	52	27.1	37	19.3	-28.8
HUPAPP	CRX 3	5	51	26.6	44	22.9	-13.7
HUPAPP	CRX 3	6	43	22.4	33	17.2	-23.3
Average			48.5	25.3	32.2	16.8	-34.0
Stdev			4.1	2.1	8.7	4.5	15.7
Sterror			1.7	0.9	3.6	1.9	6.4

Notes: HUPAPP = *Huperzia appalachiana*, year columns indicate number of occupied cells with 192 total potential cells, Stdev = standard deviation, Sterror = standard error.

Site: Hawksbill 1

Species	Site	Plot	2010	%cover 2010	2014	% cover 2014	%change
SIBTRI	HAWK 1	1	180	93.8	192	100.0	6.7
SIBTRI	HAWK 1	2	117	60.9	122	63.5	4.3
SIBTRI	HAWK 1	3	148	77.1	174	90.6	17.6
SIBTRI	HAWK 1	4	141	73.4	174	90.6	23.4
SIBTRI	HAWK 1	5	128	66.7	166	86.5	29.7
SIBTRI	HAWK 1	6	145	75.5	174	90.6	20.0
SIBTRI	HAWK 1	7	148	77.1	152	79.2	2.7
SIBTRI	HAWK 1	8	88	45.8	85	44.3	-3.4
SIBTRI	HAWK 1	9	110	57.3	110	57.3	0.0
Average			133.9	69.7	149.9	78.1	11.2
Stdev			26.7	13.9	36.0	18.7	11.7
Sterror			8.9	4.6	12.0	6.2	3.9

Notes: SIBTRI = *Sibbaldiopsis tridentata*, year columns indicate number of occupied cells with 192 total potential cells, Stdev = standard deviation, Sterror = standard error.

Site: Hawksbill 2

Species	Site	Plot	2010	%cover 2010	2014	% cover 2014	%change
HUPAPP	HAWK 2	1	77	40.1	78	40.6	1.3
HUPAPP	HAWK 2	2	127	66.1	41	21.4	-67.7
HUPAPP	HAWK 2	3	58	30.2	45	23.4	-22.4
HUPAPP	HAWK 2	4	114	59.4	49	25.5	-57.0
HUPAPP	HAWK 2	5	51	26.6	47	24.5	-7.8
HUPAPP	HAWK 2	6	88	45.8	12	6.3	-86.4
HUPAPP	HAWK 2	7	126	65.6	74	38.5	-41.3
HUPAPP	HAWK 2	8	85	44.3	64	33.3	-24.7
Average			90.8	47.3	51.3	26.7	-38.3
Stdev			29.2	15.2	21.1	10.9	30.4
Sterror			10.3	5.4	7.4	3.9	10.7

Notes: SIBTRI = HUPAPP = *Huperzia appalachiana*, year columns indicate number of occupied cells with 192 total potential cells, Stdev = standard deviation, Sterror = standard error.

Site: Hawksbill 3

Species	Site	Plot	2014	% cover 2014
SIBTRI	HAWK 3	1	131	68.2
SIBTRI	HAWK 3	2	142	74.0
SIBTRI	HAWK 3	3	157	81.8
SIBTRI	HAWK 3	4	66	34.4
SIBTRI	HAWK 3	5	153	79.9
SIBTRI	HAWK 3	6	145	75.5
SIBTRI	HAWK 3	7	157	81.8
SIBTRI	HAWK 3	8	131	68.2
Average			135.3	70.5
Stdev			29.8	15.6
Sterror			10.6	5.5

Notes: SIBTRI = *Sibbaldiopsis tridentata*, year columns indicate number of occupied cells with 192 total potential cells, Stdev = standard deviation, Sterror = standard error.

Site: Pinnacles 1

Species	Site	Plot	2010	%cover 2010	2014	% cover 2014	%change
HUPAPP	PINN 1	1	33	17.2	44	29.9	33.3
HUPAPP	PINN 1	2	49	25.5	39	20.3	-20.4
HUPAPP	PINN 1	3	111	57.8	78	40.6	-29.7
HUPAPP	PINN 1	4	72	37.5	38	19.8	-47.2
HUPAPP	PINN 1	5	27	14.1	28	14.6	3.7
HUPAPP	PINN 1	6	53	27.6	67	34.9	26.4
HUPAPP	PINN 1	7	46	24.0	41	21.4	-10.9
HUPAPP	PINN 1	8	79	41.1	45	23.4	-43.0
Average			58.8	30.6	47.5	25.6	-11.0
Stdev			27.5	14.3	16.5	8.7	30.1
Sterror			9.7	5.1	5.8	3.1	10.7

Notes: HUPAPP = *Huperzia appalachiana*, year columns indicate number of occupied cells with 192 total potential cells, Stdev = standard deviation, Sterror = standard error.

Site: Pinnacles 2

Species	Site	Plot	2014	% cover 2014
HUPAPP	PINN 2	1	96	50.0
HUPAPP	PINN 2	2	68	35.4
HUPAPP	PINN 2	3	84	43.8
HUPAPP	PINN 2	4	84	43.8
HUPAPP	PINN 2	5	12	6.3
HUPAPP	PINN 2	6	45	23.4
HUPAPP	PINN 2	7	23	12.0
Average			58.9	30.7
Stdev			32.7	17.0
Sterror			12.3	6.4

Notes: HUPAPP = *Huperzia appalachiana*, year columns indicate number of occupied cells with 192 total potential cells, Stdev = standard deviation, Sterror = standard error.

Site: Little Stony Man 1

Species	Site	Plot	2010	%cover 2010	2014	% cover 2014	%change
SIBTRI	LSM 1	1	121	63.0	130	67.7	7.4
SIBTRI	LSM 1	2	83	43.2	132	68.8	59.0
SIBTRI	LSM 1	3	128	66.7	158	82.3	23.4
SIBTRI	LSM 1	4	101	52.6	164	85.4	62.4
SIBTRI	LSM 1	5	96	50.0	105	54.7	9.4
SIBTRI	LSM 1	6	59	30.7	65	33.9	10.2
SIBTRI	LSM 1	7	61	31.8	69	35.9	13.1
SIBTRI	LSM 1	8	44	22.9	71	37.0	61.4
SIBTRI	LSM 1	9	75	39.1	112	58.3	49.3
Average			85.3	44.4	111.8	58.2	32.8
Stdev			28.6	14.9	37.6	19.6	24.6
Sterror			9.5	5.0	12.5	6.5	8.2

Notes: SIBTRI = *Sibbaldiopsis tridentata*, year columns indicate number of occupied cells with 192 total potential cells, Stdev = standard deviation, Sterror = standard error.

Site: Betty's Rock 1

Species	Site	Plot	2014	% cover 2014
SIBTRI	Betty's 1	1	79	41.1
SIBTRI	Betty's 1	2	86	44.8
SIBTRI	Betty's 1	3	140	72.9
SIBTRI	Betty's 1	4	106	55.2
SIBTRI	Betty's 1	5	132	68.8
SIBTRI	Betty's 1	6	69	35.9
SIBTRI	Betty's 1	7	99	51.6
SIBTRI	Betty's 1	8	31	16.1
SIBTRI	Betty's 1	9	66	34.4
SIBTRI	Betty's 1	10	83	43.2
Average			89.1	46.4
Stdev			32.1	16.7
Sterror			10.2	5.3

Notes: SIBTRI = *Sibbaldiopsis tridentata*, year columns indicate number of occupied cells with 192 total potential cells, Stdev = standard deviation, Sterror = standard error.

Site: Old Rag 1

Species	Site	Plot	2014	% cover 2014
HUPAPP	Old Rag 1	1	36	18.8
HUPAPP	Old Rag 1	2	64	33.3
HUPAPP	Old Rag 1	3	78	40.6
HUPAPP	Old Rag 1	4	47	24.5
HUPAPP	Old Rag 1	5	51	26.6
HUPAPP	Old Rag 1	6	83	43.2
Average			59.8	31.2
Stdev			18.4	9.6
Sterror			7.5	3.9

Notes: HUPAPP = *Huperzia appalachiana*, year columns indicate number of occupied cells with 192 total potential cells, Stdev = standard deviation, Sterror = standard error.

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

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U.S. Department of the Interior



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