

Studying Southern
Appalachian, high-elevation
rock outcrop island dynamics
and species distributional
patterns using digitized
herbarium data



Katherine G. Mathews, Amanda Lafferty & Diane Styers

Department of Biology

Western Carolina University



Introduction



- The Southern Appalachian Mountains are one of the most floristically diverse regions in North America and a global plant diversity hotspot.
- The herbaria of Western Carolina University (WCUH) and Highlands Biological Station (HBSH), located in the Blue Ridge mountains and escarpment region, represent a regionally significant collection of plants, with over 30,000 dried specimens.
- The southern Blue Ridge contains many high-elevation communities that may act as islands. Montane islands are distinctive because of their unique habitats relative to the surrounding areas and their isolation on mountain peaks from like communities.

Significance

- Species on montane islands have undergone distributional shifts in association with historical climate change.
- Today, these communities are significant contributors to the biodiversity of the Southern Appalachians, containing endemic, refugial, disjunct, and rare species.
- Five high-elevation island community types are described in Schafale (2012):



Grandfather Mountain

Granitic Dome

Rocky Summit

Spruce-Fir Forest

Grassy Bald

Shrub Bald

- Montane island communities are especially vulnerable to disturbance from future climate change, human recreation, fire suppression, and pollution.
- Understanding their dynamics can help us understand how these communities formed and how they might undergo future changes.

Montane Islands in this study:

High Elevation Granitic Dome

- Communities of large rock outcrops with smooth, exfoliation surfaces with few cracks, at high elevations, generally over 3000 feet.

High Elevation Rocky Summit

- Communities of flat to vertical outcrops of fractured rock on ridge tops, upper to mid slopes, or other topographically exposed settings, at high elevations, generally above 4000 feet.



Questions

1. Do Southern Appalachian montane plant communities act like islands?
 - Do larger areas have more species?
 - Do nearby islands have more similar plant communities than more distant islands?
2. Are rocky summit communities different from granitic dome communities?
3. Can herbarium specimens be used to answer these questions?

Methods

- Digitized data from WCUH and HBSH were used to study the island dynamics of high-elevation rock outcrops in the Southern Appalachians.
- Preliminary species lists for rocky summits and granitic domes were obtained from Schafale (2012) and used to create checklists in the SERNEC web portal.
- Species were assigned potential voucher specimens from WCUH and HBSH digitized collections. Voucher specimens were verified to belong to the community.
- Databased was searched for specific locality names to add species and vouchers.

The screenshot displays the SERNEC (Southeast Regional Network of Expertise and Collections) web portal. The page title is "High Elevation Granitic Domes" and it lists authors as Kathy Mathews. The checklist includes the following data:

- Families:** 88
- Genera:** 169
- Species:** 261 (species rank)
- Total Taxa:** 264 (including subsp. and var.)

The checklist is organized by family:

- ADOXACEAE**
 - Viburnum acerifolium*
WCUH0004645 1688 [WCUH]
 - Viburnum prunifolium*
WCUH0004655 2385 [WCUH]
- AMARYLLIDACEAE**
 - Allium cernuum*
Horton, J. H. 2632 [WCUH], Kevin Caldwell 3 [WCUH], Horton, James H. 1661 [WCUH]
- ANACARDIACEAE**
 - Rhus copallina*
WCUH0004930 3045 [WCUH], Horton, J. H. 2009 [WCUH], Horton, J. H. 2379 [WCUH], Horton, J. H. 2303 [WCUH], more...
 - Rhus copallinum* var. *latifolia*
Kathy G. Mathews 458 [WCUH]
 - Rhus typhina*
Horton, J. H. 2588 [WCUH], Horton, J. H. 2371 [WCUH], Horton, J. H. 2638 [WCUH], WCUH0004943 698 [WCUH], more...
 - Toxicodendron radicans*
Dan Pittillo 11793 [WCUH], Horton, J. H. 2598 [WCUH]
- ANDREAEACEAE**

The interface includes a navigation menu (Home, Specimen Search, Images, Inventories, Dynamic Tools), a user profile (Welcome Kathy!), and an options panel on the right with search and filter settings. A map in the bottom right corner shows the study area in the Southern Appalachians, with red markers indicating specific localities near Knoxville, Asheville, and Charlotte.

- Voucher specimens were batch georeferenced using the Geolocate tool in the portal to create distribution maps of each island type.
- Polygons were used to map extent of rock outcrops visualized from aerial photographs in Google Maps

Western Carolina University Herbarium (WCUH) ⁺

Home >> Collection Management Menu >> **Batch Georeferencing Tools**

Query Form

All Countries All States All Counties
 All Municipalities All Processing Status ⁺
Verification status: **Family/Genus:**
 Including previously georeferenced records
Locality Term:

Return Count: 91

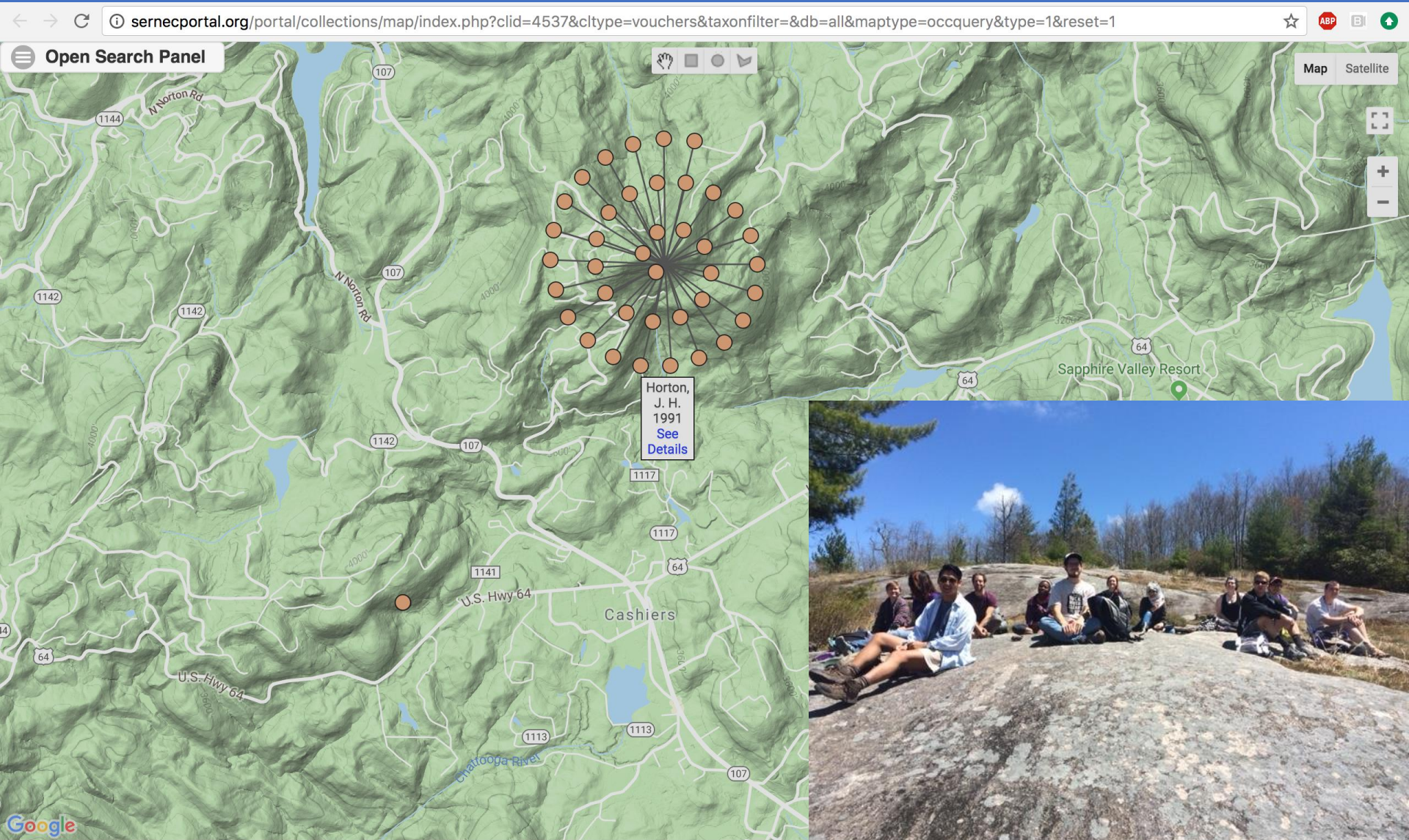
United States; North Carolina; Jackson; South slopes of Shelton Pisgah Mt. along Little Green Creek, north of Cold Mt. Gap. Elevation about 1159 m (3800 ft.). No fruits observed, leaves to United States; North Carolina; Jackson; Cashiers; Outcrop: Little Green Mountain Slope: South & West Elevation: 4000-4160 Habitat: windswept gneiss outcrop edge. Locality: About 3 mi. United States; North Carolina; Jackson; Little Green Mountain; NORTH CAROLINA Jackson County. Outcrop: Little Green Mountain. Slope: South & West. Elevation: 4000-4160. Habitat: W United States; North Carolina; Jackson; Little Green Mountain; Jackson Co., N.C. Outcrop: Little Green Mountain Slope: South & West Elevation: 4000-4160 Am't. of cover: Not specified A United States; North Carolina; Jackson; Little Green Mountain; NORTH CAROLINA Jackson County. Outcrop: Little Green Mountain Slope: South & West Elevation: 4000-4160 ft Habitat: Winds United States; North Carolina; Jackson; Little Green Mountain; North Carolina Jackson County Outcrop: Little Green Mt. Slope: n. w. & south facing gneiss [outcrop] Elevation: 4000-4160 United States; North Carolina; Jackson; Little Green Mountain; NORTH CAROLINA Jackson County. Outcrop: Little Green Mountain. Elevation: 4000-4160 feet. Habitat: edge shrubs, west. United States; North Carolina; Jackson; Little Green Mountain; NORTH CAROLINA Jackson County. Outcrop: Little Green Mountain. Elevation: 4000-4160 feet. Habitat: edge, west. Locality United States; North Carolina; Jackson; Little Green Mountain; NORTH CAROLINA Jackson County. Outcrop: Little Green Mountain. Elevation: 4000-4160 feet. Habitat: Edge. Locality: Win United States; North Carolina; Jackson; Little Green Mountain; NORTH CAROLINA Jackson County. Outcrop: Little Green Mountain. Elevation: 4000-4160 feet. Habitat: Windswept gneiss c United States; North Carolina; Jackson; Little Green Mountain; NORTH CAROLINA. Jackson County. Outcrop: Little Green Mountain. Slope: South & West. Elevation: 4000-4160 feet. Habita United States; North Carolina; Jackson; Little Green Mountain; NORTH CAROLINA. Jackson County. Outcrop: Little Green Mountain. Slope: n. to w. & south facing gneiss. Elevation: 4000-4 United States; North Carolina; Jackson; Little Green Mountain; NORTH CAROLINA. Jackson County. Outcrop: Little Green Mountain. Slope: n. to w. & south facing gneiss. Elevation: 4000-4 United States; North Carolina; Jackson; Little Green Mountain; NORTH CAROLINA. Jackson County. Outcrop: Little Green Mountain. Slope: n. to w. & south. Elevation: 4000-4160 feet. Am United States; North Carolina; Jackson; Little Green Mountain; Outcrop: Little Green Mountain ,Slope: n. to w. & south facing gneiss,Elevation: 4000-4160',Association: ,Habitat: island, sou

Deg. Min. Sec. Decimal
Latitude: N =
Longitude: W =
Error (in meters): **Datum:**
Footprint WKT:
Sources:
Remarks:
Verification Status:
Elevation: to meters to feet
Processing status: Georefer by:

Statistics

Records to be Georeferenced
 Total: 24684
 Percentage: 88.4%

Plant community data for each island is available to the public on SERNEC and the montane islands website



Methods

- ArcMap GIS was used to map specimens and calculate area of rock outcrops
- 17 outcrops containing 10 or more specimen records selected for spatial analyses
- Spatial analyses were performed on plant community data using Mantel tests:
 - Species presence-absence data recorded for rock outcrops; converted to Jaccard distance matrix
 - Created additional distance matrices of Euclidean distance measures obtained from lat/long coordinates to compare plant community similarity based on:
 - geographic proximity
 - elevation
 - outcrop area
- PC-Ord used to perform multivariate ordination (nonmetric multidimensional scaling, NMS) and indicator species analysis based on species composition of rock outcrops

Results: Data characteristics

Locality data

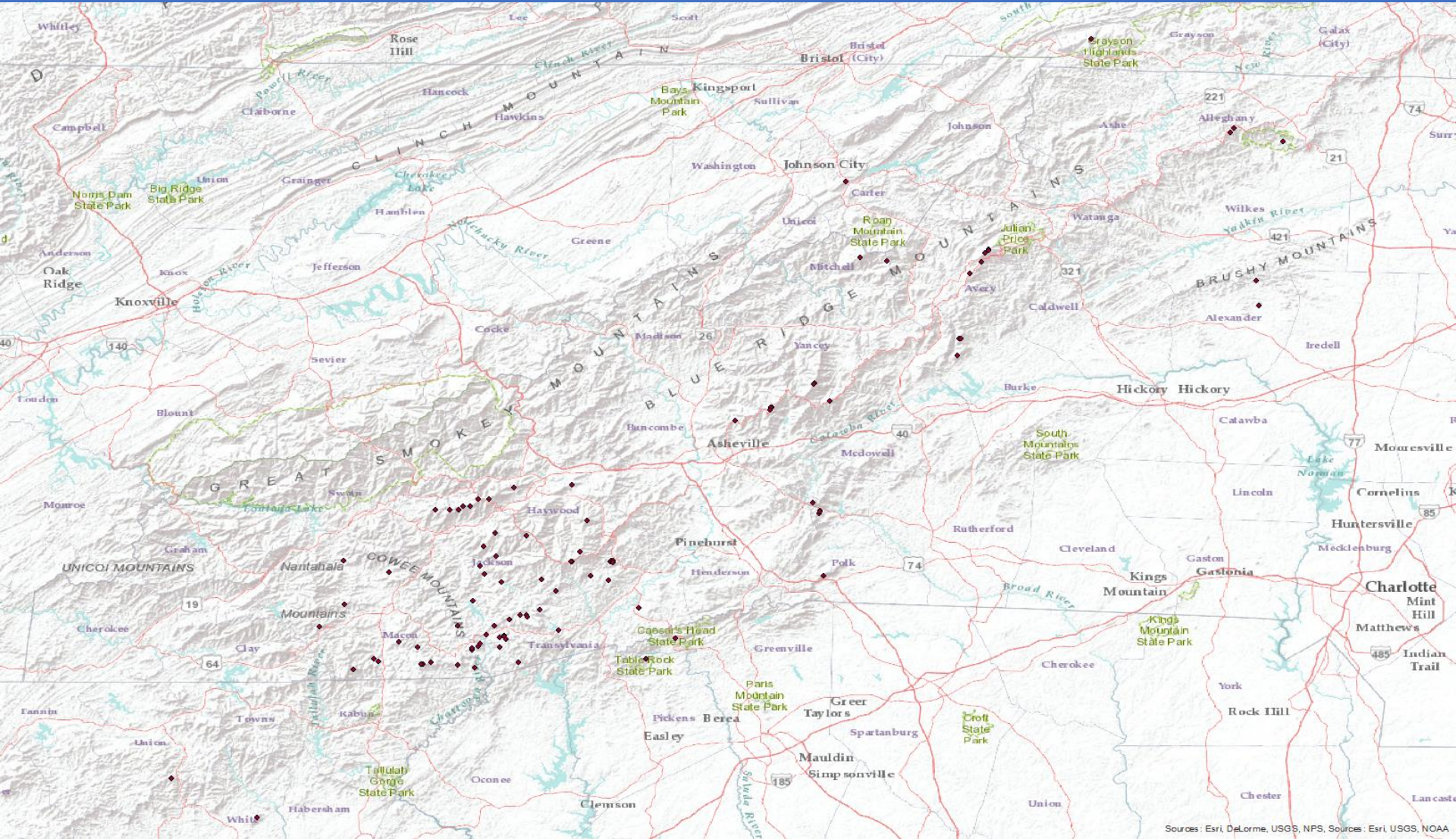
- Extent of the study area: 17,387 km²
320 linear km, NE Georgia to SW Virginia
- Elevational range: 564-1,908 m (1,850-6,260 ft)
- Outcrop area range for spatial analyses = 12--491 m²

Specimen data

	Outcrops	Specimens	Species
Total	80	828	277
Reduced Spatial	17	660	255

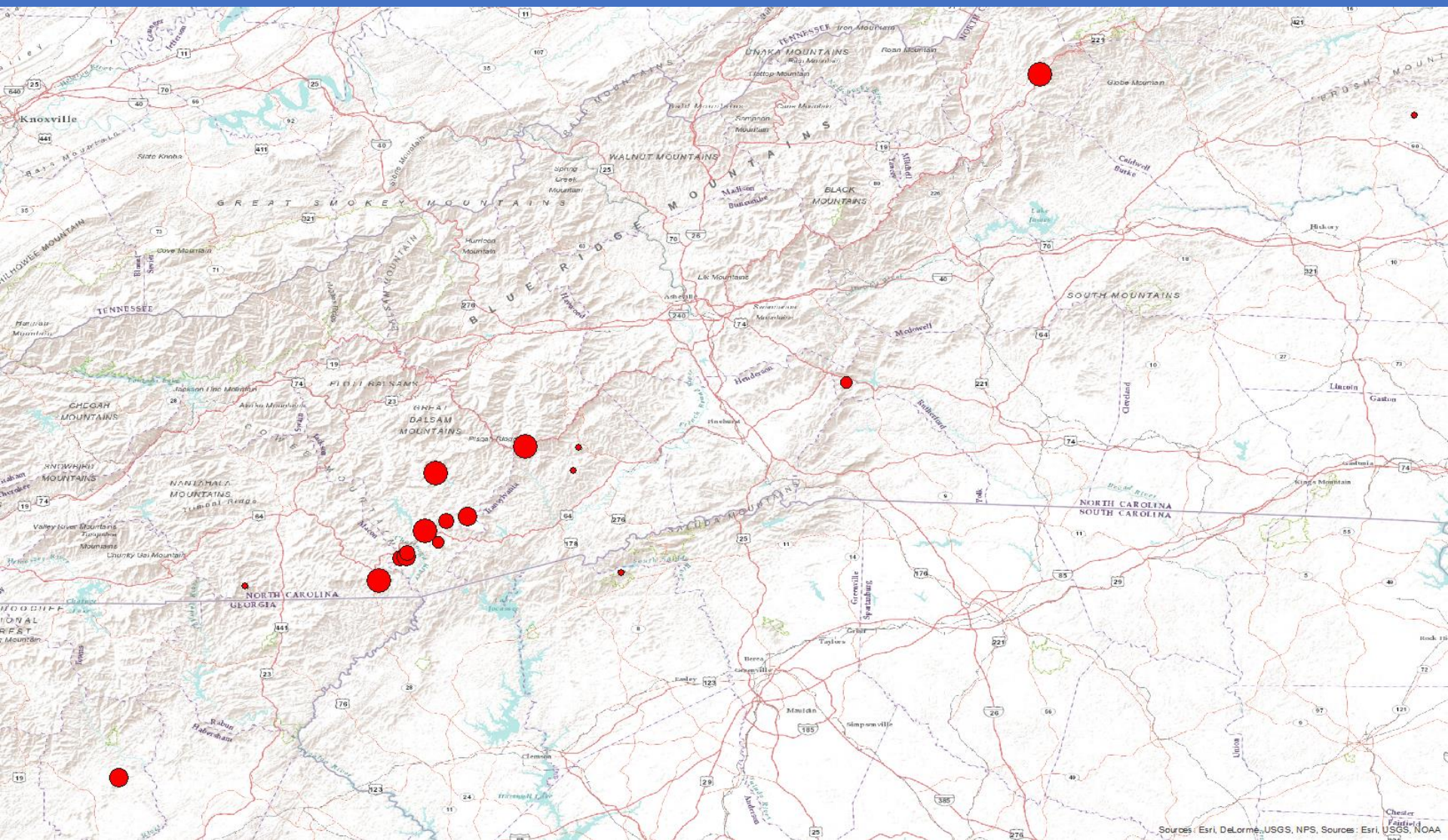
- Reduced dataset for spatial analyses: N per island =11--84 species (mean=30.9, median=21.5);
- Raunkiaer life-forms for all species: (vascular plants only – 266 species)
 - Phanerophytes (trees, shrubs, woody vines): 34%
 - **Hemicryptophytes (perennial herbs): 50%**
 - Cryptophytes (underground perennating herbs): 7%
 - Therophytes (annual herbs): 9%

All rock outcrop locations



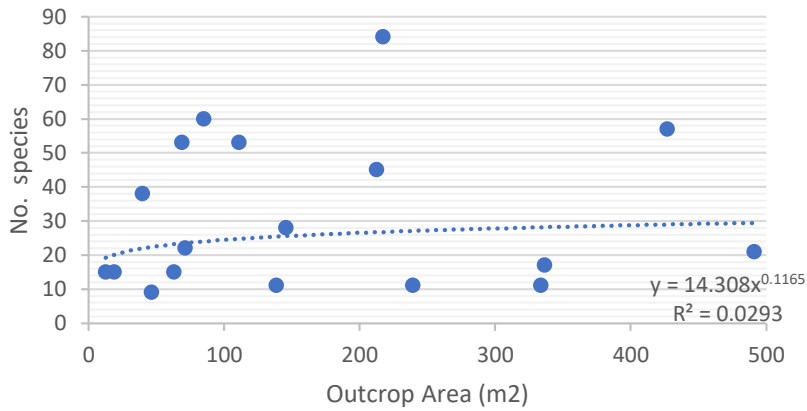
Sources: Esri, DeLorme, USGS, NPS, Sources: Esri, USGS, NOAA

17 rock outcrops for spatial analyses showing relative sampling density (#specimens/unit area)

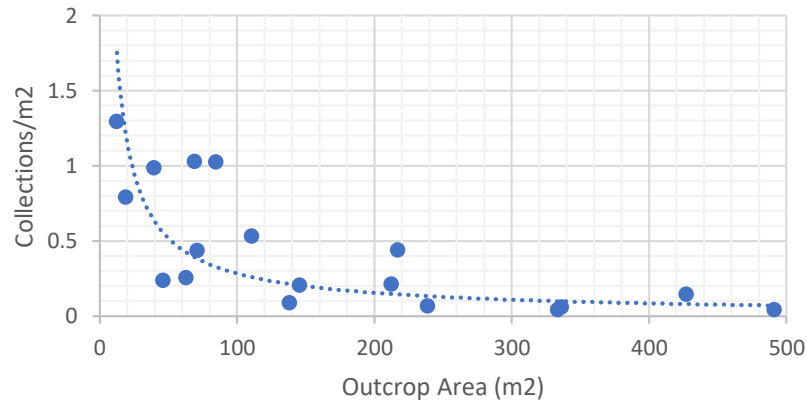


Do larger rock outcrops contain more species?

Species diversity does not increase with outcrop area...

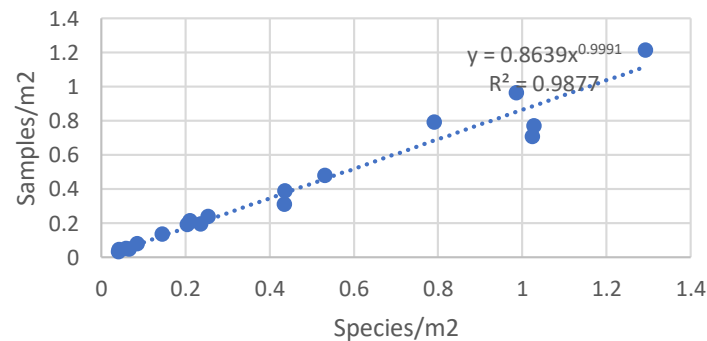


But collection intensity decreases with outcrop area...



And species diversity correlates with collecting intensity...

So larger outcrops are undercollected.

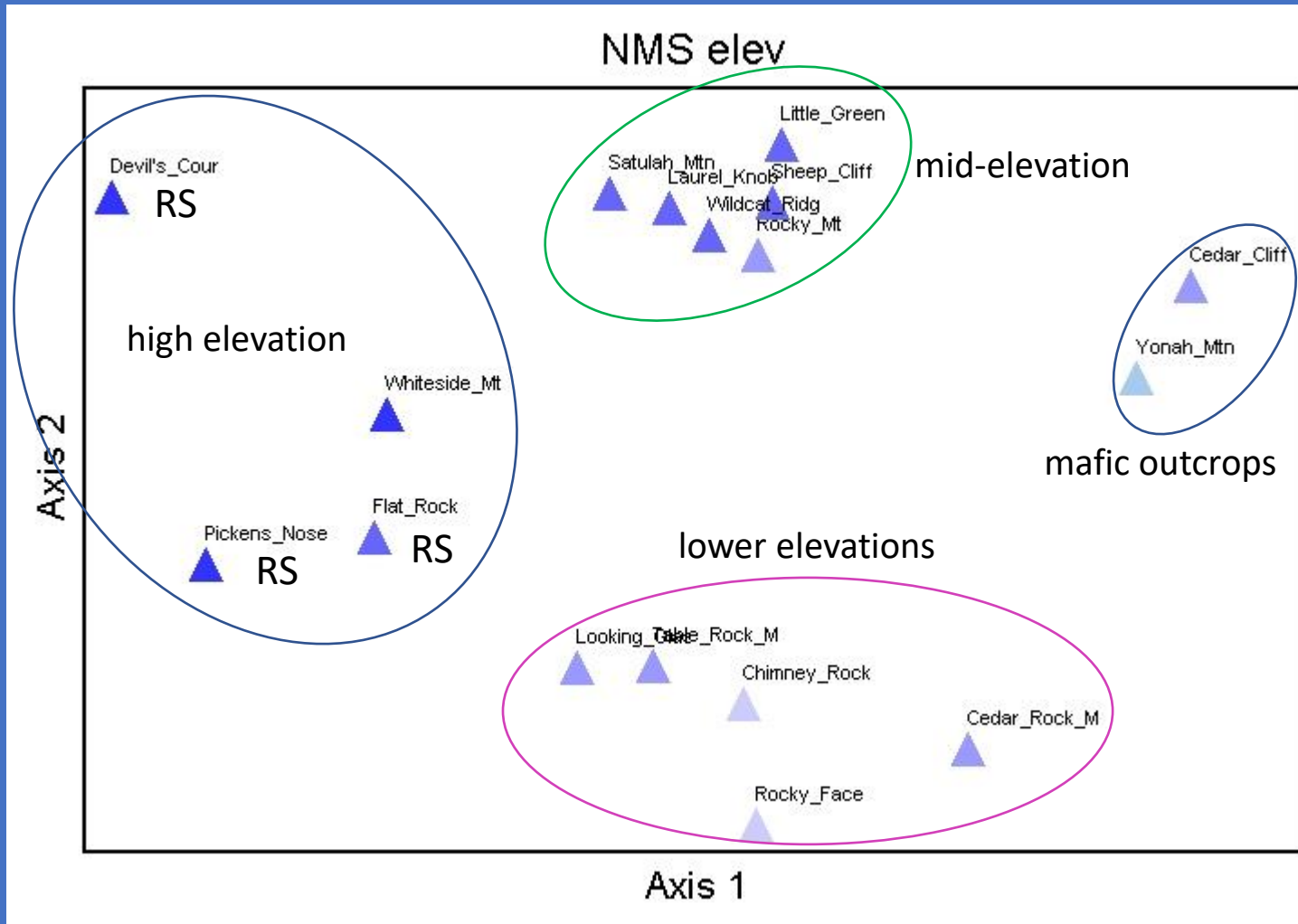


Does nearness affect similarity of species composition?

(a) Correlations between species turnover, Euclidean geographic distance, outcrop area distance and elevational distance between all pairs of sites, and (b) partial correlations between species turnover and geographic distance after controlling for the effect of environmental distance. Mantel's r is shown and the associated P-value for a two-tailed test based on 10,000 permutations (* $P < 0.05$, ** $P < 0.01$, *** $P < 0.001$).

Mantel test results	N species	Geographic distance	Outcrop Area distance	Elevation distance
(a) Correlations				
All species	254	0.250*	-0.089	0.417***
Woody species	87	0.246*	-0.069	0.296**
Herbaceous species	167	0.193	-0.074	0.365***
Northern affinity species	19	0.156	-0.127	0.119
(b) Partial correlations				
	Geographic correlations corrected for elevation			
All species			0.094	
Woody species			0.142	
Herbaceous species			0.049	
Northern affinity species			0.118	

NMS ordination on species composition of rocky summits (3) & granitic domes (14) shows roughly elevational groupings as opposed to groupings by geographic nearness or island type



RS=rocky summit

Darker blue symbols represent higher elevations

Sorbus americana only indicator species found (Rocky Summit)

Conclusions & Future Directions

Elevation is a greater indicator of plant community turnover than island size or proximity of islands;

climate change could strongly affect survival of plant communities that are dependent on pseudo-alpine conditions

- Include more environmental data (temperature, moisture, aspect), although elevation is a proxy for many of these
- Analyze plant community data from other island types (spruce-fir, grass bald, shrub bald) for comparison.

Herbarium specimens contain useful data for comparative studies of floristic communities and should inform further research and conservation efforts, but difference in sampling efforts need to be accounted for.

- Add specimens from other herbaria to increase sampling of individual islands and add temporal component – most WCUH specimens collected in 1960s & 70s.





Acknowledgements

- SERNEC community
- NSF ADBC subcontract for funding specimen digitization efforts of WCUH
- WCU Hunter Library Scholar Award for release time and graduate assistantship for Amanda Lafferty
- Jim Costa of HBSH & Hunter Library staff for collaborative support & website development
- Undergraduate work-study students at WCU for specimen imaging, label transcription & georeferencing