Measuring Restoration Success

CASRI Partnership VIRTUAL Conference 2020

November 4 – 5, 2020

CASRI's 2020 "Measuring Restoration Success" conference will focus on quantitative and qualitative measures of success for restoration of the red spruce-northern hardwood ecosystem in Central Appalachia. Decades of boots-on-the-ground restoration actions and associated research and monitoring has resulted in quantifiable success stories and lessons learned, all of which provide important knowledge to inform future actions and approaches.

This conference gathers managers, practitioners, scientists, and leaders in the field to discuss the latest research findings, problem-solve common management challenges, and network to advance new and emerging partnerships. Strong partnerships will enable the network to continue to advance landscape resilience and connectivity of red spruce forests across the region.

SCHEDULE

Wednesday November 4, 2020 --- ZOOM link Day 1

Time	Topic	Speaker
9:00 – 9:10	Welcome and housekeeping	Katy Barlow
9:10 – 9:50	Keynote Presentation: Are We Hitting the Mark for Red Spruce Restoration?	Jamie Schuler
Session 1: History of CASRI		
10:00 – 10:15	The Blister Swamp Conservation and Restoration Project Twenty Years Later	Alton Byers
10:15 – 10:30	Red spruce in West Virginia: Early Reports from A. D. Hopkins and the W.Va. Agricultural Experiment Station	James Rentch
10:30 – 10:45	Session 1 Discussion Panel	
Session 2: Soils and Vegetation		
11:00 – 11:10	Informed Red Spruce Restoration and Conservation Planning using Soil Organic Carbon as an Indicator for Management Outcomes	James Leonard
11:10 – 11:20	Methods for Increasing Native Plant Diversity on Minelands in the Red Spruce Ecosystem	Anna Branduzzi
11:20 – 11:35	Session 2 Discussion Panel	

11:35 – 12:30	Lunch	

Session 3: Red Spruce – Growth and Genetics

12:30 – 12:40	Anamorphic Site Index Curves for Central Appalachian Red Spruce in West Virginia, USA	John Brown
12:40 – 12:50	An Assessment of Select Central Appalachian Red Spruce Allometric Relationships	Joseph Gray
12:50 – 1:00	Genomic Drivers of Early-life Fitness in *Picea rubens*	Thibaut Capblancq
1:00 – 1:15	Session 3 Discussion Panel	

Session 4: Red Spruce – Climate Relationships

1:30 – 1:40	Dendroclimatic Analysis of Central Appalachian Red Spruce	Sophan Chhin
1:40 – 1:50	Variation in Climate-Associated Traits and Evidence of Local Adaption of Red Spruce (*Picea rubens* Sarg.) to Elevational Clines in the Southern Appalachian Mountains	John Butnor
1:50 – 2:00	From the Last Glacial Maximum to the End of the 21st Century: Research and Management Implications of Climate Change Effects on Red Spruce	Susanne Lachmuth
2:00 – 2:15	Session 4 Discussion Panel	
2:15 – 2:25	Day 1 closing remarks	Katy Barlow

Thursday November 5, 2020 --- ZOOM link Day 2

9:00 – 9:10	Welcome and housekeeping	Katy Barlow

Session 5: Wildlife Ecology

9:10 – 9:20	Evaluation of Created Wetlands as Amphibian Habitat on a Reforested Surface Mine	Michaela Lambert
9:20 – 9:30	Identifying Forest Bird Communities Associated with Remnant and Restored Red Spruce-Northern Hardwood Ecosystems in Central Appalachia	Hannah Clipp
9:30 – 9:40	Recovery and Monitoring of the West Virginia Northern Flying Squirrel	Alexander Silvis
9:40 – 9:55	Session 5 Discussion Panel	

Session 6: Cheat Mountain Salamander Ecology		
10:10 – 10:20	Microhabitat Associations for the Cheat Mountain Salamander in Relation to Early-Stage Red Spruce Restoration Areas	Donald Brown
10:20 – 10:30	Long-term Occupancy Dynamics of the Threatened Cheat Mountain Salamander and its Competitors in Relation to Linear Habitat Fragmentation	Lacy Rucker
10:30 – 10:40	Characteristics of Cheat Mountain Salamander (*Plethodon nettingi*) Habitat	Thomas Pauley
10:40 – 10:55	Session 6 Discussion Panel	

Session 7: Planning, Implementation, Monitoring		
11:10 – 11:20	Monitoring to Support Management Decision-making for the Cheat Mountain Salamander on Canaan Valley National Wildlife Refuge	Adrianne Brand
11:20 – 11:30	The Power of Power Analysis: A Case Study with the Cheat Mountain Salamander	Alexander Silvis
11:30 – 11:40	Twenty-four Years of Red Spruce Restoration in Maryland: Lessons Learned (Some Quickly Forgotten)	Deborah Landau
11:40 – 11:50	Opportunities for Red Spruce Restoration on State Land in West Virginia	Travis Miller
11:50 – 12:10	Session 7 Discussion Panel	
12:10 – 12:30	Conference closing remarks	Katy Barlow

ABSTRACTS (ORGANIZED BY SESSION)

Keynote

Are We Hitting the Mark for Red Spruce Restoration?

Jamie L. Schuler[1,*]

[1]West Virginia University, Division of Forestry and Natural Resources, 1145 Evansdale Dr., 322 Percival Hall, Morgantown, WV 26506
[*]Corresponding presenter: Jamie.Schuler@mail.wvu.edu

CASRI and many other advocates for red spruce forests in the Central Appalachian region strive to restore these high elevation forests. Through their efforts, many acres of forests have been re-established—some with clear goals and objectives, while others have taken a less organized approach. Clearly, metrics of success change and vary among landowners, person interests or

mandates, and an individual's specialization and training. I will advocate for a more holistic approach to ecological restoration. Given limited resources, restoration efforts need to be well-organized and directed with clear goals. I will discuss opportunities and considerations for restoration efforts in our highly altered landscapes in hopes of furthering our pursuit of increasing the extent of red spruce throughout the Central Appalachian region.

Session 1: History of CASRI

The Blister Swamp Conservation and Restoration Project Twenty Years Later

Alton C. Byers[1,*]

[1]Institute of Arctic and Alpine Research (INSTAAR), University of Colorado at Boulder, Campus Box 450, Boulder, CO 80309
[*]Corresponding presenter: alton.byers@colorado.edu

The Blister Swamp Conservation and Restoration Project (1999-present) Pocahontas County, WV was a partnership between the Dalen family of Franklin, WV and local government and non-governmental groups that included the USDA Natural Resource Conservation Service, The Nature Conservancy, The Mountain Institute, US Fish and Wildlife Service, West Virginia Highlands Conservancy (WVHC), Central Appalachian Spruce Restoration Initiative (CASRI), and private volunteers. The goal of the project was to protect and restore over 50 acres of unique circumneutral wetlands, a globally critically imperiled (GI) community in a high elevation limestone seepage swamp. The region had been heavily grazed and disturbed by cattle for over a century, and yet still showed signs of hosting globally rare plant populations that included Jacobs ladder (*Polemonium van-bruntiae*) and glade spurge (*Euphorbia purpurea*). Following completion of a 5,000' fence in 2000 by the landowners and project volunteers, significant recovery of these globally rare, plus many state-rare species, was documented during the first several years of protection and monitoring. Monitoring methods had to be changed after several years due to the spectacular recovery of rare species. The re-establishment of the original balsam fir (*Abies balsamea*) woodlands was also well underway by 2008, with seed-bearing cones noted on several individuals in September 2020. Natural disturbance regimes were restored as shrubs rebounded, providing food for beaver who re-colonized and greatly enhanced habitat for waterfowl and other species. Additional restoration planting immediately downstream on public land was initiated by the US Forest Service and WVHC in 2010, which collectively have helped stabilize headwater flows and protect baseflows of the East Fork of the Greenbriar River as the climate continues to change. The project is widely considered to be a model of private/public relationships, public sector partnerships, and restoration success. It was also one of the catalysts that led to the eventual formation of the Central Appalachian Spruce Restoration Initiative (CASRI), and fulfilled a long-term dream of the Dalen family.

Red Spruce in West Virginia: Early Reports from A. D. Hopkins and the W.Va. Agricultural Experiment Station

James S. Rentch[1,*]

[1](Retired) West Virginia University, Division of Forestry and Natural Resources, 1145 Evansdale Dr., 322 Percival Hall, Morgantown, WV 26506
[*]Corresponding presenter: jrentch2@wvu.edu

In August 1890 Andrew D. Hopkins, newly hired entomologist for the West Virginia Agricultural Research Station, traveled to Cheat Bridge in Randolph County to investigate reports of a large spruce die-of spruce die-off. Atop Cheat Mountain, he saw healthy forests to the south and east, but large areas of mortality to the west and north. He found patches of dead spruce ranging from 50 to 1,000 acres, 150,000 acres in total. In the bark of dead spruce, he found the likely culprit—spruce bark beetle, along with three parasites who were likely responsible for the end of the crisis. In his 1891 report, he provided the first description of spruce forests of West Virginia. In 1892, a similar beetle outbreak occurred in the pine regions to the east and south as well as spruce, this time, by the southern pine bark beetle, involving nearly four million acres. A.D. Hopkins was an unlikely scientist. With only a high school education, he nevertheless convinced the director of the Agricultural Station to hire him, provisionally, as state entomologist. He rapidly showed his brilliance, investigating the spruce and pine events, along with extensive travels throughout the state's hardwood forests. His 1893 "Catalogue of West Virginia forest and shade tree insects" remains comprehensive today. In 1899, he prepared a 425 page "Report on investigations to determine the cause of unhealthy condition in the spruce and pine, 1880-1893." This report details the life history traits, historic distribution, and natural enemies of spruce and pine in W.Va. In 1899, he became a collaborator with the Department of Agriculture, leading field trips to the Pacific Northwest, the Black Hills, and the Northeast. In 1902, he became Chief of Forest Insect Investigations, and his seminal monographs on bark beetles remain authoritative today, earning him the title, "Father of American Entomology."

Session 2: Soils and Vegetation

Informed Red Spruce Restoration and Conservation Planning using Soil Organic Carbon as an Indicator for Management Outcomes

James Leonard[1,*], James A. Thompson[1]

[1]West Virginia University, Division of Plant & Soil Sciences, 1194 Evansdale Drive, 3115 Agricultural Science Building, Morgantown, WV 26506
[*]Corresponding presenter: jeleonard@mix.wvu.edu

Two ecological site descriptions (ESD) have been developed for the high-elevation red spruce ecosystems in central Appalachia. These management tools have been developed by the Natural Resources Conservation Service (NRCS) to catalog ecological relationships and guide restoration activities based on differences in soil type. One important aspect of the soils associated with these red spruce ecosystems is the way they accumulate soil organic carbon (SOC), both at the surface and in the subsoil. The relationship of SOC to other dynamic soil properties is well documented. Increasing SOC can result in increased water holding capacity, lower bulk density, increased structure, and greater nutrient cycling rates, among others – all which contribute significantly to an ecosystems overall resilience and stability, resulting in minimized soil erosion, downstream flood abatement, and improved habitat for soil dwelling

organisms just to name a few. Understanding how dynamic soil properties such as SOC change in response to soil management can improve our ability to assess management outcomes in response to red spruce restoration and conservation activities and, therefore, better justify these management practices. Here we discuss the feasibility of using SOC measurements as a means to assess how red spruce restoration and conservation practices will affect SOC stocks and other important dynamic soil properties inherent to these ecological sites (ES). Understanding the soil-ecological relationship through the lens of SOC can help predict and quantify dynamic soil property changes seen as a result of restoration or other intensive management practices.

Methods for Increasing Native Plant Diversity on Minelands in the Red Spruce Ecosystem

Anna M. Branduzzi[1,*], Chris D. Barton[1,2], Carol C. Baskin[1], Rob Paratley[1], Todd Kuntz[3], Shane Jones[3], Amy Lovell[3]

[1]University of Kentucky, Lexington, KY
[2]Green Forests Work, Lexington, KY
[3]USDA Forest Service, Bartow, WV
[*]Corresponding presenter: Anna.Branduzzi@uky.edu

Surface mining for coal has left scars on landscapes and reduced ecosystem functions across Appalachia for over a century. In the Monongahela National Forest, WV, a restoration project has been going on since 2009 on legacy minelands that dissect the biodiverse high elevation red spruce ecosystem. Goals of the restoration project include: watershed improvement, soil building, enhancement of early successional habitat, and reforestation. Decompaction of the minelands is a critical step in the restoration process, and allows native vegetation to begin colonizing the site. Through this project, hundreds of vernal pools are constructed each year, and woody debris from non-native tree plantations is repurposed for habitat features. Increasing native tree and shrub diversity on the minelands has long been an objective, but herbaceous plants, which provide many benefits to soil formation and wildlife habitat, are underutilized. Transplants of four native flowering species important to pollinators were planted around constructed vernal pools and survival and cover were measured. Ten herbaceous and one shrub species were seeded on recently decompacted minelands, with and without protection by woody debris, to measure germination, cover, and survival of seedlings. The mineland seed bank was characterized and compared to adjacent forest plant community composition, and both were compared to pre- and post-decompaction plant communities. Results showed that decompaction increased plant species richness, and transplanting herbaceous plants to constructed vernal pools and direct seeding uplands are viable options for increasing plant diversity on minelands.

Session 3: Red Spruce – Growth and Genetics

Anamorphic Site Index Curves for Central Appalachian Red Spruce in West Virginia, USA

Eric Yetter[1], John P. Brown[2,*], Sophan Chhin[1]

[1]West Virginia University, Division of Forestry and Natural Resources, 322 Percival Hall, 1145 Evansdale Dr, Morgantown, WV, 26506
[2]USDA Forest Service, Northern Research Station, Princeton Forestry Sciences Lab, 301 Hardwood Lane, Suite B, Princeton, WV, 24740
*Corresponding presenter: john.p.brown@usda.gov

Traditional site index curves are frequently produced for shade intolerant species but are scarce for shade tolerant species. Red spruce (*Picea rubens*) can be found in three distinct geographic regions (northern, central, and southern) within the Appalachian Mountains. The one commonly used set of red spruce site index curves is over ninety years old. A definite need exists for a modern, regionally applicable set of site index curves. This research sampled 83 plots randomly located in the central Appalachians of West Virginia. Three sets of anamorphic site index curves were created after careful examination of height models built using Chapman-Richards and Meyer functions. One set of curves was constructed with traditional age height pairs. The second utilized a suppression corrected age and height pair. The third set examined dbh and height pairs. Fit statistics indicated better performance for the suppression corrected age height pair site index and the dbh height pair site index versus the traditional age height pair models. These new site index curves should provide utility for site productivity estimation and growth and yield modeling while aiding in restoration efforts for this important central Appalachian species.

An Assessment of Select Central Appalachian Red Spruce Allometric Relationships

Joseph M. Gray[1,*], Jamie Schuler[1], Melissa Thomas-Van Gundy[2]

[1]West Virginia University, School of Natural Resources, 1145 Evansdale Dr., 322 Percival Hall, Morgantown, WV 26506
[2]USDA Forest Service, Northern Research Station, P.O. Box 404, Parsons, WV 26287
[*]Corresponding presenter: jmg0071@mix.wvu.edu

Red Spruce (*Picea rubens*) was a highly prized timber species in West Virginia. Exploitive logging in the late 1800s through the early 1900s greatly reduced its presence across the landscape. Consequently, data on red spruce growth and diameter–crown relationships in the Central Appalachian region is underrepresented in current literature. We destructively sampled and aged understory red spruce on an array of high elevation sites on federal and state lands in West Virginia to develop allometric relationships for stem diameter and various crown metrics. We compared these to existing relationships documented in other regions in red spruce's natural range. Compared to published equations from outside the region, seedlings and saplings in West Virginia had reduced radial and apical stem growth. Age was found to be a poor predictor of tree height, diameter, and crown size for shade tolerant understory red spruce. Diameter at breast height as a predictor of tree height and crown diameter were the strongest relationships followed by tree height as a predictor of crown diameter. The addition of this regionally specific information will allow for more effective management of red spruce in the spruce-northern hardwood forests of the Central Appalachian region.

Genomic Drivers of Early-life Fitness in *Picea rubens*

Thibaut Capblancq[1,*,†], Helena Munson[1,†], John R. Butnor[2], Stephen R. Keller[1]

[1]Department of Plant Biology, University of Vermont, Burlington, VT 05405
[2]USDA Forest Service, Southern Research Station, University of Vermont, Burlington, VT 05405
[†]Authors contributed equally to this work
[*]Corresponding presenter: thibaut.capblancq@gmail.com

Red spruce (*Picea rubens*, Sarg.) is a coniferous tree with a highly fragmented range in eastern North American montane forests. It serves as a foundational species for many locally rare and threatened taxa and has therefore been the focus of large-scale reforestation efforts aimed at restoring these montane ecosystems, yet genetic input guiding these efforts have been lacking. To tackle this issue, we took advantage of a common garden experiment and a whole exome sequencing dataset to investigate the impact of different population genetic parameters on early-life seedling fitness in red spruce. The level of population inbreeding, genetic diversity and genetic load were compared to different fitness traits for over 5,000 seedlings from 340 mother trees and 65 different populations distributed across the species range. We identified an overall positive influence of genetic diversity and negative impact of genetic load and population-level inbreeding on early-life fitness. Those associations were most apparent for the highly fragmented populations in the Central and Southern Appalachians, where lower genetic diversity and higher inbreeding were associated with lower germination rate, shorter height and reduced early-life fitness of the seedlings. These results provide unprecedented information that could be used by field managers aiming to restore red spruce forests and to maximize the success of future plantations.

Session 4: Red Spruce – Climate Relationships

Dendroclimatic Analysis of Central Appalachian Red Spruce

Eric Yetter[1], Sophan Chhin[1,*], John Brown[2]

[1]West Virginia University, Division of Forestry and Natural Resources, 1145 Evansdale Dr, 322 Percival Hall, Morgantown, WV 26506
[2]USDA Forest Service, Northern Research Station, 301 Hardwood Ln, Suite B, Princeton, WV 24740
[*]Corresponding presenter: Sophan.chhin@mail.wvu.edu

We used dendrochronology data to conduct historic dendroclimatic analyses and construct future growth projections for red spruce throughout the central Appalachians. This research involves the use of tree core data collected from over 18 sites across red spruce's range throughout the Monongahela National Forest. Major results of this research show red spruce is sensitive to extreme warming temperature conditions. Temperature extremes in the summer growing season can potentially lead to increased tree respiration which causes temperature induced drought stress. Increasing minimum temperatures in the fall have positive effects on spruce growth. This is a result of an extended growing season that allows red spruce to store more carbohydrate reserves which are necessary for next year's growth. Growth projection results under a future

climate change scenario show that future expected increases in maximum monthly temperatures will have negative effects on future spruce growth. These negative future growth effects may be mitigated by an extended nontraditional growing season, which allows the tree to accumulate more growth reserves for next year's growing season. Dendroclimatic results and future growth projections should be considered when identifying locations that are most suitable for future red spruce restoration activities.

Variation in Climate-Associated Traits and Evidence of Local Adaption of Red Spruce (*Picea rubens* Sarg.) to Elevational Clines in the Southern Appalachian Mountains

John R. Butnor[1,*], Brittany M. Verrico[2], Kurt H. Johnsen[3], Christopher A. Maier[4], Victor Vankus[5], and Stephen R. Keller[2]

[1]USDA Forest Service, Southern Research Station, Burlington, VT
[2]University of Vermont, Department of Plant Biology, Burlington, VT
[3]USDA Forest Service, Southern Research Station, Bent Creek Exp. Forest, NC
[4]USDA Forest Service, Southern Research Station, RTP, NC
[5]USDA Forest Service, National Seed Laboratory, Dry Branch, GA
[*]Corresponding presenter: john.butnor@usda.gov

Red spruce (*Picea rubens*) is a long-lived tree species that thrives in cool, moist environs. Its ability to adapt to rapidly changing climate is uncertain. In the southern Appalachian Mountains, red spruce reaches its greatest abundance at high elevations, but can also occur across a range of mid and lower elevations, suggesting the possibility of a correlation between genetic variation and habitat. To assess clinal phenotypic variation in functional traits related to climate adaptation, we collected seed from 82 maternal sib families located along replicated elevational gradients in the Great Smoky Mountains National Park, TN (GSMNP) and Mount Mitchell State Park, NC (MMSP). The percentage of filled seeds and seed mass increased with elevation, indicating that successful pollination and seed development was greatest at the highest elevations. Seedlings sourced from GSMNP displayed a strong relationship between elevation and bud set when grown under common garden conditions. High elevation families set bud as many as 10 days earlier than low elevation families, indicating adaptation to local climate. Across parks, no effect of elevation was noted for bud flush. Our results demonstrate that red spruce in the southern Appalachian Mountains displays clinal variation in bud set that may reflect local adaptation to climate, although this varied between the two parks sampled. We suggest that genetic adaption of red spruce to different climate regimes, at both local and broad spatial scales and should be carefully considered when selecting seed sources for restoration.

From the Last Glacial Maximum to the End of the 21st Century: Research and Management Implications of Climate Change Effects on Red Spruce

Susanne Lachmuth[1,*,†], Thibaut Capblancq[2,†], Stephen R. Keller[2], Matthew C. Fitzpatrick[1]

[1]Appalachian Lab, University of Maryland Center for Environmental Science, Frostburg, MD 21532
[2]Department of Plant Biology, University of Vermont, Burlington, VT 05405

[†]Authors contributed equally to this work
[*]Corresponding presenter: susanne.lachmuth@umces.edu

To understand the threats of anthropogenic climate change for natural and managed ecosystems it is crucial to explore how past climate fluctuations influenced species demography and range dynamics. We used climate suitability projections, genomic data, and a spatially explicit model to simulate the demographic and population genetic dynamics of red spruce (*Picea rubens*) from the Last Glacial Maximum (LGM) to the end of the 21st century. Our results suggest that *P. rubens* spread from a large glacial refugium at low elevations south of the Laurentide Ice Sheet to rapidly recolonize the Appalachians and north-eastern coastal regions, eventually stabilizing its current range about 5,000 years ago. Model projections suggest future drastic reduction and northwards shift of suitable habitat, the pace of which is likely to exceed natural migration rates of red spruce and will involve severe genetic diversity loss in the southern part of its range. The climatic and demographic changes projected for the 21st century would be unprecedented in the history of red spruce since the LGM. However, our models likely underestimate the natural realized niche of red spruce and thus may overestimate the detrimental effects of climate change. For specific mountainous regions of the distribution of *P. rubens*, our projections might thus be too pessimistic for the immediate future. Nevertheless, they lend strong support to restoration and conservation action that is already underway for red spruce. Our results further show the need for small-scale habitat suitability projections and exploration of local adaptations. Both may serve to inform management planning including the prioritization of geographic areas, maintenance of genetic diversity or development of assisted migration programs.

Session 5: Wildlife Ecology

Evaluation of Created Wetlands as Amphibian Habitat on a Reforested Surface Mine

Michaela Lambert[1,*], Christopher Barton[2], Andrea Drayer[2], Steven Price[2], Wendy Leuenberger[3]

[1]Kentucky Division of Water, Watershed Management Branch, 300 Sower Blvd, Frankfort, KY 40601
[2]University of Kentucky, Department of Forestry and Natural Resources, 730 Rose Street Lexington, KY 40546
[3]Michigan State University, Department of Integrative Biology; Ecology, Evolution, and Behavior Program, East Lansing, MI 48824
[*]Corresponding Presenter: michaela.lambert@ky.gov

Reclaimed mines often lack pre-mining habitat due to soil compaction and lack of natural features. If soils are de-compacted and natural features restored, new habitats can be created, such as wetlands for amphibians. It is important to understand which factors affect amphibian use of wetlands to estimate the efficacy of created wetlands as habitat. I sampled 40 wetlands among 4 ages (2, 4, 6, and 8 years) on a reforested surface mine to: 1) characterize differences in wetland habitat across age classes, 2) estimate amphibian occupancy, 3) investigate estimated abundance of 4 amphibian species (*Lithobates sylvaticus, L. clamitans, Notophthalmus viridescens,* and *Ambystoma maculatum*) and 4) identify wetland characteristics most important for amphibian utilization of wetlands. Over 2,200 amphibian captures were recorded. There were 8 species found

in 8 year-old wetlands, 5 in the 4 and 6 year-old wetlands, and 6 in the 2 year-old wetlands. Wetland age, specific conductance of water, vegetation cover, and canopy cover were predictors of amphibian occupancy and abundance. Water quality was better than described in streams affected by mining that exhibited limited amphibian occupancy and abundance. My results indicated that created wetlands on reforested surface mines provide suitable breeding habitat for pond breeding amphibians.

Identifying Forest Bird Communities Associated with Remnant and Restored Red Spruce-Northern Hardwood Ecosystems in Central Appalachia

Hannah L. Clipp[1,*], Donald J. Brown[1,2], Christopher T. Rota[1], Petra B. Wood[1,3]

[1]West Virginia University, School of Natural Resources, 1145 Evansdale Drive, 322 Percival Hall, Morgantown, WV 26506
[2]USDA Forest Service, Northern Research Station, P.O. Box 404, Parsons, WV 26287
[3]U.S. Geological Survey, West Virginia Cooperative Fish and Wildlife Research Unit, Morgantown, WV 26506
[*]Corresponding presenter: hlclipp@mix.wvu.edu

Degraded red spruce-northern hardwood ecosystems are the focus of restoration efforts across high-elevation landscapes in the Central Appalachians region. To promote ecosystem function and long-term sustainability of restored forests, it is important to understand the associated biota, including bird communities. However, contemporary and statistically rigorous studies of red spruce bird communities in this region are lacking. Therefore, the purpose of this study was to use indicator species analyses to determine which Central Appalachian bird species are primarily associated with red spruce and northern hardwood forest types, red spruce cover classes, and stand size classes. Community-wide avian point count survey data were collected from May–July in 2010–2019 at 645 study sites located in forest stands throughout the Monongahela National Forest in West Virginia. We used three sets of multivariate regression trees to group sites into clusters and explore relationships between detection-corrected maximum species counts across years and GIS-derived categorical forest types, red spruce cover classes, and stand-specific size classes. We then ran indicator species analyses for each set of clusters. We identified a distinct suite of several significant indicator species associated with: (1) red spruce forests and stands with >50% red spruce cover (including golden-crowned kinglets [*Regulus satrapa*] and Blackburnian warblers [*Setophaga fusca*]); (2) red spruce forests and stands with 10–50% red spruce cover (including magnolia warblers [*Setophaga magnolia*] and dark-eyed juncos [*Junco hyemalis*]); and (3) northern hardwood forests (including black-throated green warblers [*Setophaga virens*]). This study has implications for future qualitative and quantitative measures of success for restoration of the red spruce-northern hardwood ecosystem in Central Appalachia. Moreover, the distinctiveness of the bird community in red spruce forests and strength of those associations highlight the critical need for and importance of these restoration efforts in the Central Appalachians to ensure long-term maintenance of regional avian diversity.

Recovery and Monitoring of the West Virginia Northern Flying Squirrel

Alexander Silvis[1,*], Jack Wallace[1], Rick Doyle[1], Craig Stihler[2]

[1]West Virginia Division of Natural Resources, Elkins, WV 26241
[2](Retired) West Virginia Division of Natural Resources, Elkins, WV 26241
[*]Corresponding presenter: Alexander.Silvis@wv.gov

After a federal listing, de-listing, re-listing, and re-de-listing, the West Virginia northern flying squirrel now is in the second half of the 10-year post-delisting monitoring period for the re-de-listing. Following a review of the first 5-years of post-delisting monitoring data, it is apparent that the species continues to persist within known historically occupied sites, including within 100% of 7 core areas identified by the USFWS. Similarly, population parameters, including 1) litter size; 2) proportion of females in the population; 3) proportion of reproductive females captured in spring; and 4) average annual birth rate, all are consistent with long-term trends through 1988 and are considered healthy. Moreover, habitat management activities have resulted in creation of ~983 acres of new and future habitat, and ~4,762 acres of habitat have been restored. Monitoring activities will continue through the second half of the post-delisting monitoring period, augmented by acoustic surveys conducted jointly by the WVDNR and Monongahela National Forest.

Session 6: Cheat Mountain Salamander Ecology

Microhabitat Associations for the Cheat Mountain Salamander in Relation to Early-Stage Red Spruce Restoration Areas

Donald J. Brown[1,2,*], Lacy E. Rucker[1,*], Catherine Johnson[3], Shane Jones[4], Thomas K. Pauley[5]

[1]West Virginia University, School of Natural Resources, 1145 Evansdale Dr., 322 Percival Hall, Morgantown, WV 26506
[2]USDA Forest Service, Northern Research Station, P.O. Box 404, Parsons, WV 26287
[3]National Park Service, Northeast Region, Narragansett, RI 02882
[4]USDA Forest Service, Greenbrier Ranger District, Bartow, WV 24920
[5](Retired) Marshall University, Department of Biological Sciences, 1 John Marshall Drive, Science Building 270, Huntington, WV 25755
[*]Corresponding presenter: donald.brown1@mail.wvu.edu

One goal of CASRI is to increase availability and enhance quality of habitat for wildlife species of conservation concern, including the federally threatened Cheat Mountain salamander (CMS; *Plethodon nettingi*). Restoration of red spruce (*Picea rubens*) stands within and near forest patches currently occupied by CMS could facilitate connectivity and enhance long-term viability of CMS populations. While we have a good understanding of forest structural characteristics associated with occurrence of CMS, little research has been conducted to quantify microhabitat characteristics of CMS-occupied forest patches or spruce restoration sites. The purpose of this research was to compare microhabitat characteristics of early-stage spruce restoration sites in relation to habitat quality for the CMS (restoration site study), and to compare microhabitat characteristics between known-occupied CMS sites and proximal unoccupied sites (CMS site study). For the restoration site study, we sampled a known-occupied CMS site (REFERENCE), and mine land restoration (MINELAND), hardwood thinning (HT; including sampling within low and high spruce density), and red spruce thinning (RST; including sampling within the

thinned area, along the edge of the thinned area, and in the adjacent interior forest) sites. For the CMS site study, we sampled four known-occupied CMS sites, surrounding forest where the species has not been detected (ND-ADJACENT), and additional forest patches with qualitatively high quality habitat where the species has not been detected (ND-HIGH). We compared five microhabitat variables for the restoration site study (sub-canopy air temperature, ground-level air temperature, light penetration, soil pH, and soil moisture), and two microhabitat variables for the CMS site study (soil pH and soil moisture). Compared to the REFERENCE site, sub-canopy air temperature, ground-level air temperature, and light penetration were higher at the MINELAND site and the thinned and edge portions of the RST site, but did not significantly differ for the HT sites or the interior forest portion of the RST site. Soil pH was higher, and soil moisture was lower, at all spruce restoration sites compared to the REFERENCE site. For the CMS site study, soil pH did not differ among the sites, but soil moisture was lower at ND-ADJACENT and ND-HIGH sites. Our study indicates that soil moisture may be an important characteristic of CMS microhabitat quality.

Long-term Occupancy Dynamics of the Threatened Cheat Mountain Salamander and its Competitors in Relation to Linear Habitat Fragmentation

Lacy E. Rucker[1,*], Donald J. Brown[1,2], Thomas K. Pauley[3]

[1]West Virginia University, School of Natural Resources, 1145 Evansdale Dr., 322 Percival Hall, Morgantown, WV 26506
[2]USDA Forest Service, Northern Research Station, P.O. Box 404, Parsons, WV 26287
[3](Retired) Marshall University, Department of Biological Sciences, 1 John Marshall Drive, Science Building 270, Huntington, WV 25755
[*]Corresponding presenter: ler0005@mix.wvu.edu

Amphibians are declining globally and while many factors are contributing to this decline, habitat loss and degradation caused by climate and land use changes are among the most critical. Habitat degradation and increased interspecific competition are both concerns for long-term viability of the federally-threatened Cheat Mountain salamander (*Plethodon nettingi*) which is endemic to high elevations in West Virginia. In this study, we quantified the impacts of linear habitat fragmentation (i.e., a linear forest clearing for creation of a ski slope) on local colonization and extinction probabilities in adjacent forested habitat for the Cheat Mountain salamander and two co-occurring competitor species, eastern red-backed salamander (*Plethodon cinereus*) and Wehrle's salamander (*Plethodon wehrlei*). We also quantified long-term changes in occupancy of the competitor species within the high elevation study area. We surveyed the salamander community annually from 1988–2016 using diurnal natural cover object searches at 43 plots, with 1988 representing three years following linear habitat fragmentation. For each species, we used dynamic occupancy models to identify and model influential covariates for initial occupancy, colonization, extinction, and detection probability. We found that distance to fragmentation was positively correlated with colonization probability and negatively correlated with extinction probability for Cheat Mountain salamanders, indicating negative edge effects of the linear forest clearing. Distance to fragmentation was negatively correlated with colonization probability for eastern red-backed salamanders and Wehrle's salamanders, potentially indicating these species benefited from increased solar radiation or reduced competition from Cheat

Mountain salamanders. Predicted occupancy of eastern red-backed salamanders increased over the 28 year monitoring period, indicating potential for increased competitive interactions. Our study suggests that extensive linear habitat fragmentation could result in degraded habitat for Cheat Mountain salamanders in the adjacent forest, and that potential for interactions with competitor species is increasing.

Characteristics of Cheat Mountain Salamander (*Plethodon nettingi*) Habitat

Thomas K. Pauley[1,*]

[1](Retired) Marshall University, Department of Biological Sciences, 1 John Marshall Drive, Science Building 270, Huntington, WV 25755
[*]Corresponding presenter: pauley@marshall.edu

I began studying the Cheat Mountain Salamander in 1976. During these 40+ years, I have searched more than 1,300 sites for this species and in doing so determined the northern and southern limits of the total range as well as the elevational ranges. The total range from north to south extends approximately 92 km from Blackwater Canyon (Tucker County) south to Thorny Flat on Cheat Mountain (Pocahontas County). The west to east range varies in distance from less than 3.2 km at the southern end of the range to approximately 31 km near the northern end. The elevational range extends from approximately 610 m in Blackwater Canyon to 1482 m on Spruce Knob. To date, there are 81 known populations, and 60 of these are located on federal or state-owned land. At these 81 populations, I recorded tree species in the canopy, ground cover vegetation, elevational range, and cardinal and ordinal directions of the mountain slopes. I also recorded the cover objects of 2,133 Cheat Mountain Salamanders and categorized the use of cover objects by sex, size class, and season of the year. The highest percentage of Cheat Mountain Salamanders occurred in red spruce forests with *Bazzania* ground cover and a northerly aspect. Logs, followed by rocks, were the predominant cover objects used.

Session 7: Planning, Implementation, Monitoring

Monitoring to Support Management Decision-making for the Cheat Mountain Salamander on Canaan Valley National Wildlife Refuge

Adrianne Brand[1,*], Dawn Washington[2], Evan H. Campbell Grant[1]

[1]USGS Patuxent Wildlife Research Center, 1 Migratory Way, Turners Falls, MA 01376
[2]USFWS Canaan Valley National Wildlife Refuge, 6263 Appalachian Hwy, Davis, WV 26260
[*]Corresponding presenter: abrand@usgs.gov

A decision facing Canaan Valley National Wildlife Refuge staff is to choose among actions to best maximize the occurrence of the federally threatened Cheat Mountain salamander (*Plethodon nettingi*) under current and future climate conditions, which may require habitat management. The salamander is currently known to occur in patchy distributions on the refuge, all of which are part of the refuge Habitat Management Plan. Refuge staff have been conducting surveys to document presence in known populations, but the current design is insufficient to estimate

changes in occurrence over time, to fully describe the species range, or to forecast the effects of management actions on *P. nettingi* to improve habitat and therefore the viability of populations. The monitoring program uses occupancy as a state variable and is designed to help address key uncertainties for this decision. In particular, knowledge gaps include: the extent of occupied habitat and habitat covariates that relate to occupancy, the extent of suitable but unoccupied habitat, density of occupied sites and abundance in the current range, the effect of competition from other *Plethodon* species, and the predicted impacts of climate change on the habitats in which the species occurs.

The Power of Power Analysis: A Case Study with the Cheat Mountain Salamander

Alexander Silvis[1,*]

[1]West Virginia Division of Natural Resources, Elkins, WV 26241
[*]Corresponding presenter: Alexander.Silvis@wv.gov

Every study must balance logistical realities with the need to collect sufficient data to document metrics of interest. Although not widely used in ecological studies, power analysis and simulations provide means by which to both proactively select efficient and effective monitoring designs and assesses impacts of changing levels of survey intensity on inference. This talk will use the recently developed Cheat Mountain salamander monitoring plan as a case study to demonstrate the utility of power analysis and simulations in designing and implementing monitoring plans.

Twenty-four Years of Red Spruce Restoration in Maryland: Lessons Learned (Some Quickly Forgotten)

Deborah Landau[1,*]

[1]The Nature Conservancy, MD/DC Chapter, 425 Barlow Place, Bethesda, MD 20814
[*]Corresponding presenter: dlandau@tnc.org

Planting “rescued” red spruce with volunteers in western Maryland in the 1990’s was very much a trial-by-error experience. Over subsequent decades we’ve honed our techniques, streamlined our planting process, and learned that no matter how good we think we’ve gotten, there’s always room for error, but also the satisfaction of planting a site with multiple generations of planted spruce in view.