Survey of Disjunct Red Spruce (*Picea rubens*) Stands in the Rich Mountain and Alarka Laurel Basins, North Carolina

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ABSTRACT

In the southern Appalachians, disjunct populations of red spruce (*Picea rubens*) persist at low latitudes. These populations, at the southernmost end of their range, are likely the first stands to experience the impacts of climate change. This study aims to assess the health and recruitment of the Rich Mountain and Alarka Laurel spruce bog basins in Nantahala National Forest, North Carolina. We assessed red spruce and stand dynamics to provide baselines for future studies. Using five 10 m wide belt transects per basin, we conducted surveys of the overstory and spruce saplings and seedlings. We measured overstory and sapling red spruce diameter at breast height (DBH), the height of seedlings, and the health of all spruce. We recorded the DBH of all overstory species ≥10 cm. Red spruce was the dominant overstory species, representing an average of 25.6% of all measured overstory trees. Great rhododendron (*Rhododendron maximum*) and mountain laurel (*Kalmia latifolia*) were dominant in the shrub layer, limiting open sky exposure. Seedlings and saplings were present throughout the basins, accounting for 72.8% of red spruce. Overall, red spruce were healthy, with some variability between age categories. These two red spruce populations are currently stable with healthy trees and large seedling banks and appear to be not yet affected by climatic warming, despite the southern latitude and relatively low elevation.

INTRODUCTION

RANGE

Eastern North America from Canada to North Carolina

(Whittaker 1956; Cogbill and White 1991)

HABITAT

- Cool, moist climate
- Montane, boreal, and subalpine forests

(Blum 1990)

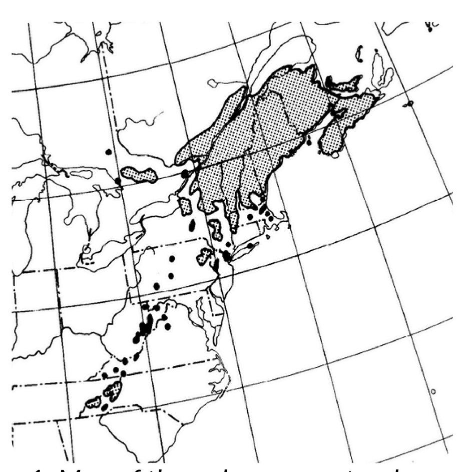


Figure 1. Map of the red spruce natural range. Blum 1990.

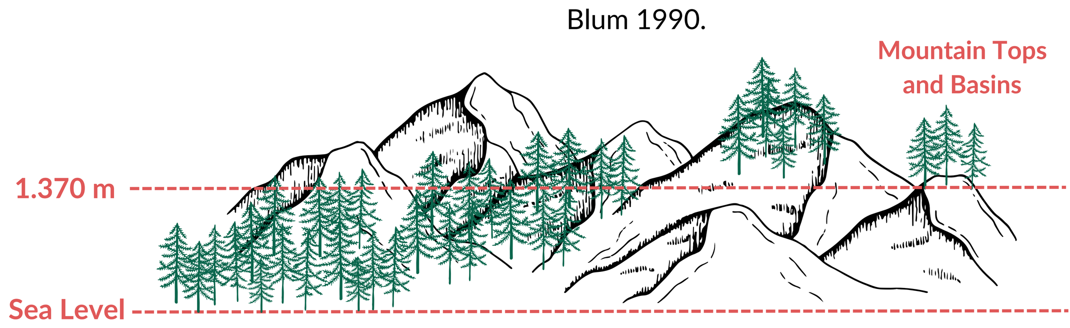
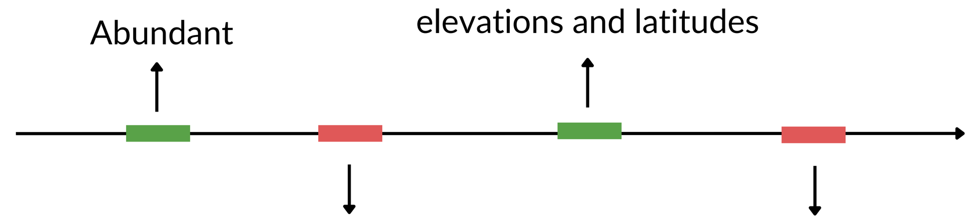


Figure 2. Red spruce elevational zonation based on latitude.

RANGE HISTORY IN THE SOUTHERN APPALACHIANS

PLEISTOCENE ICE AGE
2.58 million - 11,700 years ago
Abundant

LITTLE ICE AGE
1,600 - 1,900 C.E.
Returned and recolonized lower elevations and latitudes



WARMING PERIOD
Perished:
Pushed upward in elevation by 300-400 meters

CLIMATE CHANGE
*125 years ago - **today***
Remains on peaks, ridges, and mountain basins

Figure 3. Red spruce historical range shifts in the Southern Appalachians timeline.
(Whittaker 1956; Adams et al. 2010)

INDICATOR SPECIES

1. Climatic sensitivity
2. Experience range shifts before other species
3. Sensitivity makes them indicators of climatic changes in the region

(Cook and Johnson 1989; Ribbons 2014)

NON-CLIMATIC IMPACTS ON RED SPRUCE STANDS

1. Deforestation
2. Forest fires
3. Light availability
4. Acid deposition
5. Infestations: Southern Pine Beetle (*Dendroctonus frontalis*)
6. Organic layer thickness

(Busing 1985; Gorham 1998; Clarke and Nowak 2009)

METHODOLOGY

AIMS

Are red spruce affected by climate change?

- Understand the health and recruitment of southern disjunct red spruce stands
- Provide baseline data for future studies
  - Inform conservation efforts

VEGETATION SURVEYS

1. Overstory
   - Biodiversity and Stand Dynamics
     - Species
     - DBH: Basal Area
     - Health Score
2. Young Spruce
   - Recruitment Status
     - Seedlings: Height
     - Saplings: DBH
     - Health Score
3. Shrub Layer
   - Stand Dynamics
     - Every 20m: estimated shrub cover (%) below 2m

SITES

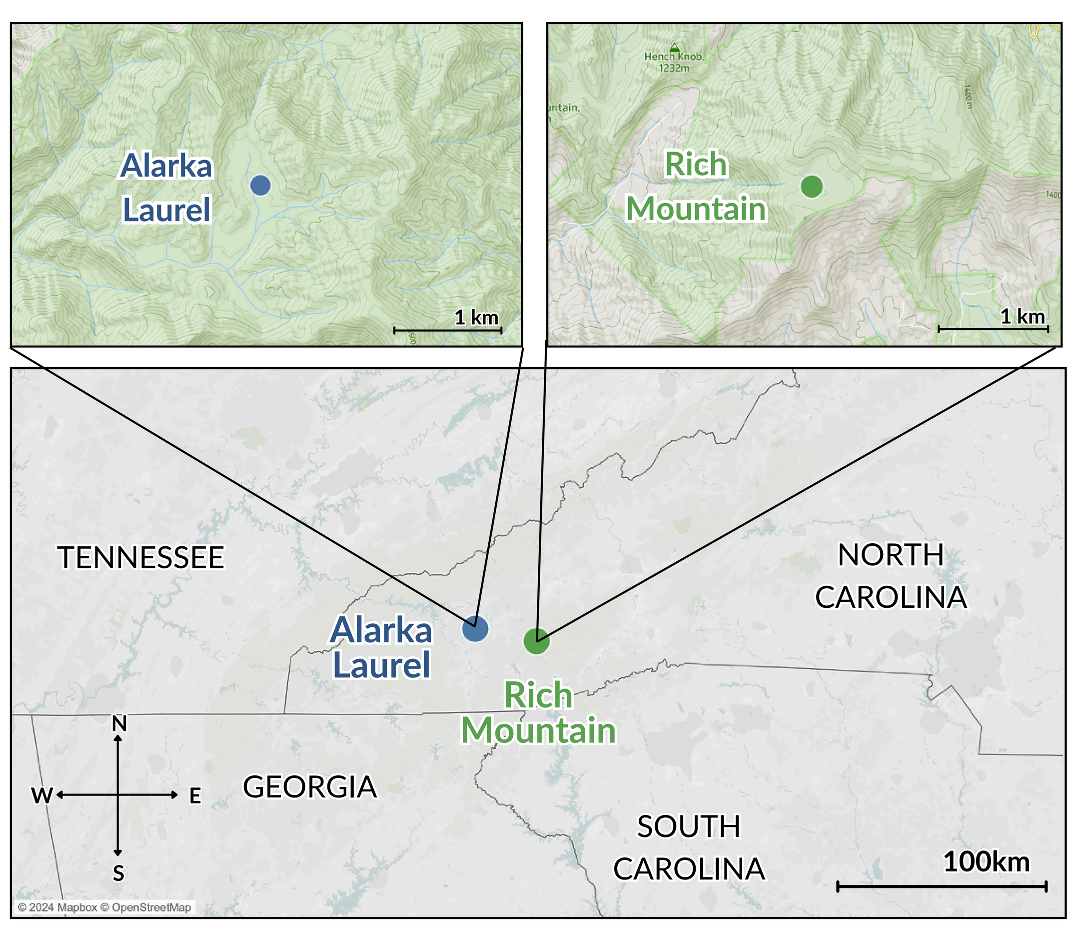


Figure 4. Map of Rich Mountain, N.C. and Alarka Laurel, N.C. spruce bogs.

SITE TRANSECTS

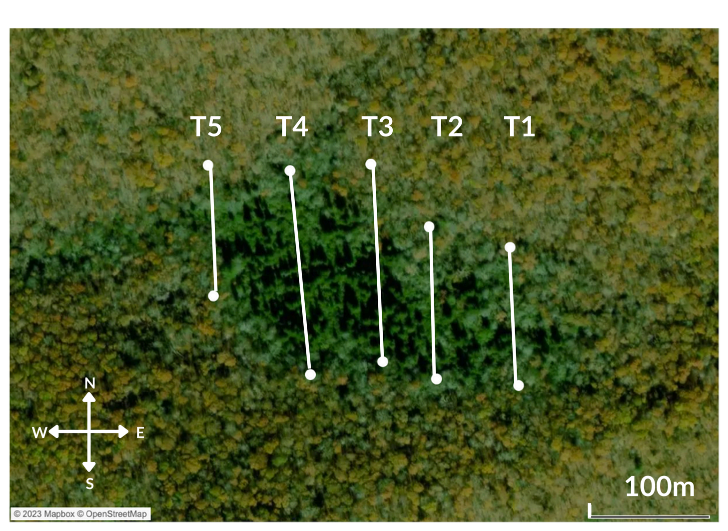


Figure 5. Aerial view of belt transects in Rich Mountain, N.C.

Rich Mountain

- Surveyed in 2023
- Elevation of 1,460 m
- Basin: 4 ha
- Transects: 0.7 ha, 69 plots

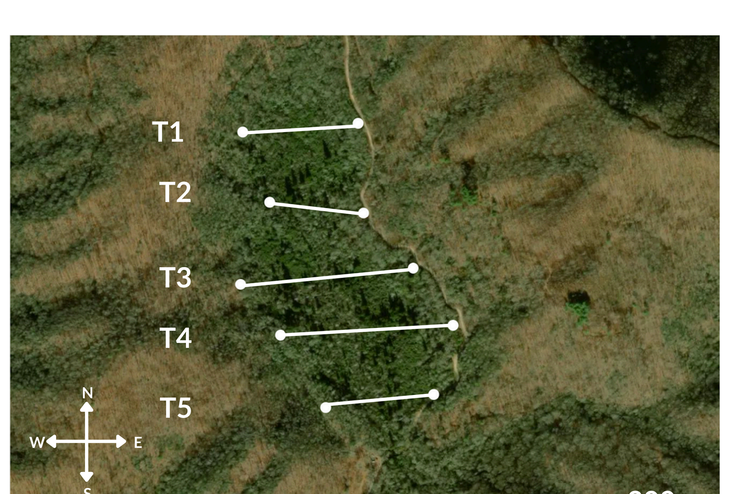


Figure 6. Aerial view of belt transects in Alarka Laurel, N.C.

Alarka Laurel

- Surveyed in 2007 and 2022
  - 2007 survey conducted by Collins et al. 2010
- Elevation of 1,220 m
- Basin: 16 ha
- Transects: 1.3 ha, 128 plots

RESULTS

OVERSTORY COMPOSITION

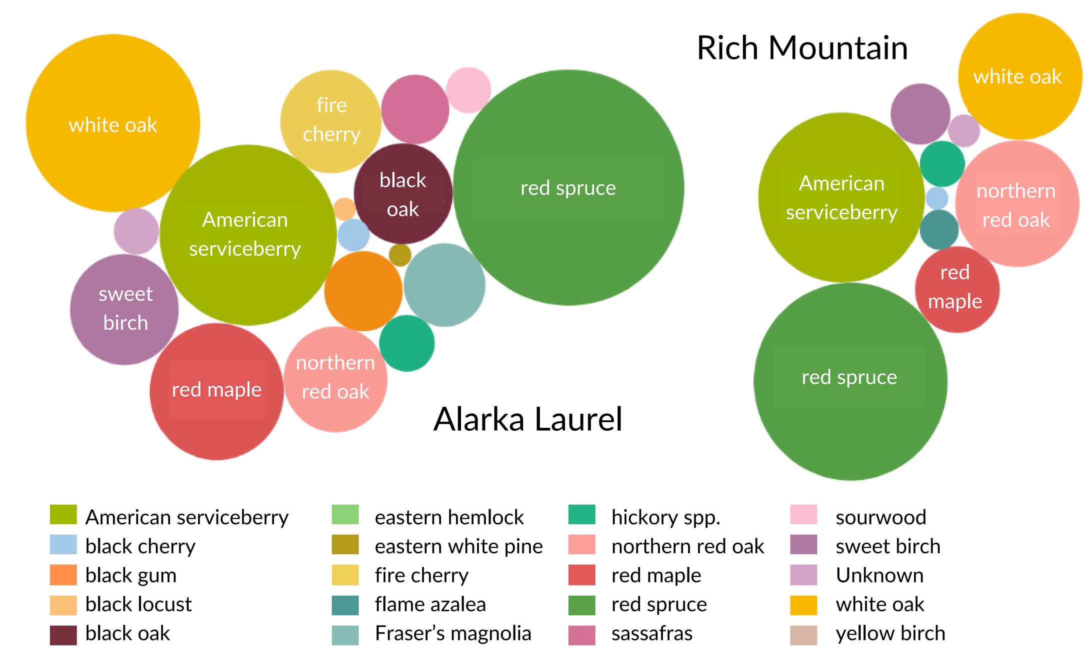


Figure 7. Composition of overstory tree species for Rich Mountain and Alarka Laurel in 2023.

- Red spruce: dominant overstory species
- More diverse overstory in Alarka Laurel
- Disturbances, canopy gaps
  - Effects of canopy gaps: minimal effect on moisture, increased light availability, and decaying coarse woody debris
    - Desired conditions for spruce recruitment
    - Expect increased recruitment and growth

(Busing 1985)

RECRUITMENT

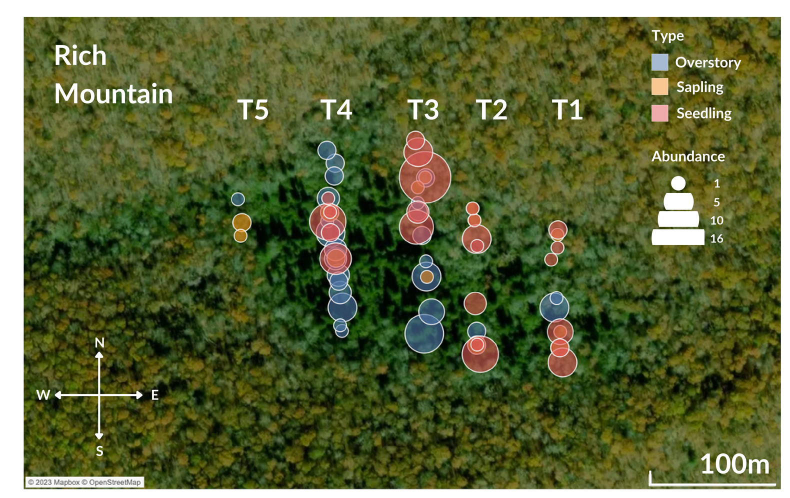


Figure 8. Aerial view of Rich Mountain basin showing abundance of red spruce seedlings, saplings, and overstory trees

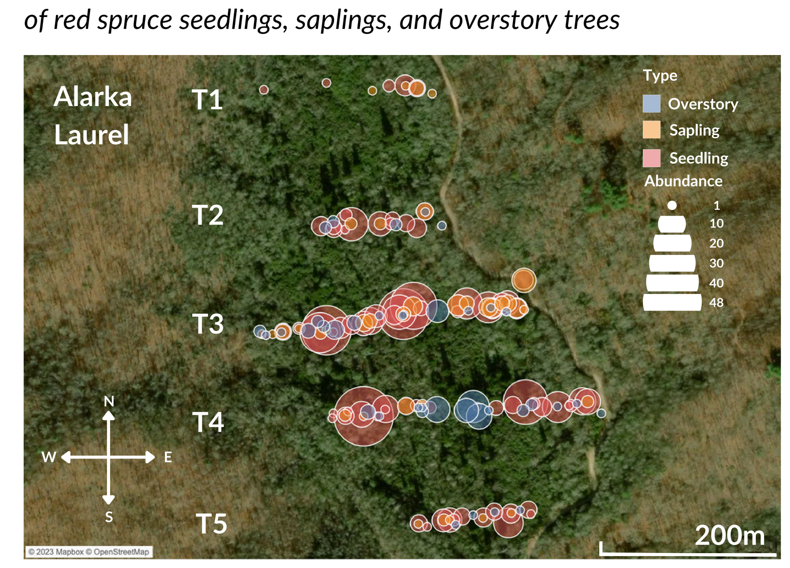


Figure 9. Aerial view of Alarka Laurel basin showing abundance of red spruce seedlings, saplings, and overstory trees

- Robust recruitment in both stands
- Young spruce greatly outnumbered overstory spruce
- Alarka had continuous recruitment over the past 15 years
- Management of the shrub layer could address the light competition, allowing the releasure of suppressed seedlings

HEALTH

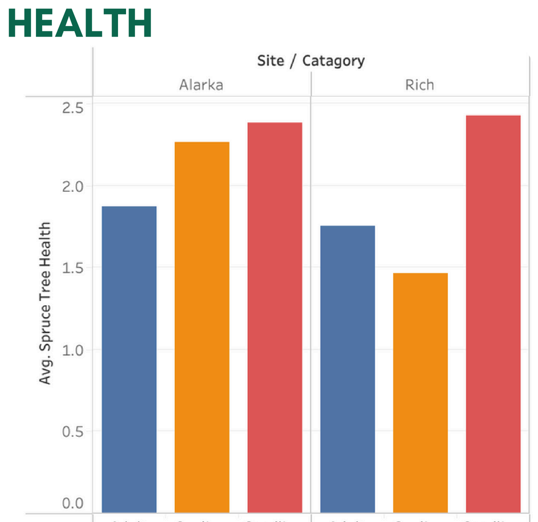


Figure 10. Health rating comparison by the proportion of spruce trees categorized by age class (overstory, sapling, and seedling) for Rich Mountain and Alarka Laurel

- Rich Mountain
  - Seedlings were the healthiest
  - Saplings were the least healthy
  - No signs of infestation
- Alarka Laurel
  - Seedlings were the healthiest
  - Overstory were the least healthy
  - Beetle infestation rates decreased over the last 15 years — may rise again as the climate warms
  - Recent presence of galls

LIGHT AVAILIBILITY

- Most seedlings located in low light-availability conditions
- Weak-positive relationship between light and height
  - More light corresponds to taller seedlings
- Light-availability release phenomenon
  - Builds seedling banks
- Continuing research
  - Light Detection and Radar (LiDAR) canopy cover data

DISCUSSION

CLIMATIC IMPACTS

- Climatic changes cause a decline in recruitment, health, and range
- Bog populations are tolerant of short-term fluctuations
- By 2040, in regions where temperatures are predicted to increase 2–4°C, red spruce will decline by >95%
- Other threats:
  - Habitat degradation
  - Competition with migrating lower-elevation species

(Ribbons 2014; Koo et al. 2015)

FUTURE STUDY

Future monitoring of disjunct stands is warranted, given their:

1. Rarity
2. Vulnerability to climatic change
3. Efficacy as an indicator species

CONCLUSION

- Healthy
  - Sustainable recruitment rates
  - Healthy overstory spruce
- Further intensification of climate change could have detrimental effects

REFERENCES

1. Adams, H.S., S.L. Stephenson, A.W. Rollins, and M.B. Adams. 2010. The isolated red spruce communities of Virginia and West Virginia. p. 1-12. *In*: Rentch, J.S. and T.M. Schuler (eds.). Proceedings of the symposium: Ecology and management of high-elevation forests in the central and southern Appalachian Mountains. Gen. Tech. NRS-P-64. USDA Forest Service, Northern Research Station, Newtown Square, Pennsylvania.
2. Blum, B.M. 1990. *Picea rubens* Sarg. p. 250-259. *In*: Burns, B. M., and B. H. Honkala (eds.). Silvics of North America. Volume 1. Conifers. US Department of Agriculture, Washington, DC, USA.
3. Busing, R.T. 1985. Gap and Stand Dynamics of a Southern Appalachian Spruce-Fir Forest. Ph.D. dissertation, University of Tennessee, Knoxville, Tennessee.
4. Clarke, S.R., and J.T. Nowak. 2009. Southern Pine Beetle. Forest Insect & Disease Leaflet 49. Portland, Oregon: USDA Forest Service, Pacific Northwest Region (R6).
5. Cogbill, C.V. and P.S. White. 1991. The latitude-elevation relationship for spruce-fir forest and treeline along the Appalachian mountain chain. Vegetation 94:153-175.
6. Collins, B., T.M. Schuler, W.M. Ford, and D. Hawkins. 2010. Stand dynamics of relict red spruce in the Alarka Creek headwaters. p. 22-27. In: Rentch, J.S. and T.M. Schuler (eds.). Proceedings of the symposium: Ecology and management of high-elevation forests in the central and southern Appalachian Mountains. Gen. Tech. NRS-P-64. USDA Forest Service, Northern Research Station, Newtown Square, Pennsylvania.
7. Cook, E.R., and A.H. Johnson. 1989. Climate change and forest decline: A review of the red spruce case. Water Air Soil Pollut. 48:127-140.
8. Gorham, E. 1998. Acid deposition and its ecological effects: A brief history of research. Environmental Science & Policy 1:153-166.
9. Koo, K.A., B.C. Patten, and M. Madden. 2015. Predicting effects of climate change on habitat suitability of red spruce (*Picea rubens* Sarg.) in the Southern Appalachian Mountains of the USA: Understanding complex systems mechanisms through modeling. Forests 4:1208-1226.
10. Ribbons, R.R. 2014. Disturbance and climatic effects on red spruce community dynamics at its southern continuous range margin. PeerJ 2:e293 (doi: 10.7717/peerj.293).
11. Whittaker, R.H. 1956. Vegetation of the Great Smoky Mountains. Ecological Monographs. 26:1-80.

ACKNOWLEDGEMENTS

We express gratitude to Gary Kauffman and Maria Dunlavey of the USDA Forest Service for their mentorship and introduction to the Rich Mountain basin. Special thanks to Dr. Beverly Collins of Western Carolina University for granting permission to use data from her 2007 survey and offering mentorship in research design. We acknowledge the contributions of her research collaborators for the 2007 study. Dr. Paul Manos of Duke University and Ken Donny-Clark of the USDA Forest Service deserve thanks for their assistance with plant identification during fieldwork. Our gratitude also goes to Dr. Rada Petric and Noa Meiri of Highlands Biological Station for their support in statistical analysis. Finally, we appreciate the USDA Forest Service, Nantahala Ranger District, for granting permission to conduct the study

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