Proceedings of the Appalachian Trail Landscape Science & Stewardship Symposium 2021

A.T. Conservation Perspectives:

Science, Research, and Tools to Inform the Next Century of Appalachian Trail Landscape Protection and Stewardship

A six-part virtual symposium dedicated to the exploration of contemporary science and research topics for the benefit of the Appalachian Trail Landscape Partnership and the advancement of conservation stewardship efforts throughout the Appalachian Trail Landscape.

October 2022

Contents

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Introduction

Inspiration for a Conserved Appalachian Trail Landscape
In 1921, a vision for an Appalachian Trail was first popularized by the American forester and conservationist Benton MacKaye. MacKaye saw that industrialization had transformed the places where we live and work, and few people had access to natural settings due to encroaching factories and urbanization. To MacKaye, having access to natural environments was vital for the health and wellbeing of all people.

Benton MacKaye, American forester and conservationist, visionary of the Appalachian Trail. Image courtesy of the Appalachian Trail Conservancy.

At this time, various small segments of trails existed throughout the Appalachian Mountains. MacKaye saw an opportunity to connect and expand these trails into one, great trail that followed the mountain skyline from Georgia to Maine. He believed that surveying the land from the skyline would help people gain perspective of their world. His vision of the trail extended beyond the ridgeline, however; in his 1921 article *An Appalachian Trail: A Project in Regional Planning*, he wrote "**a realm and not merely a trail mark the full aim of our efforts.**" He envisioned not only a single footpath, but a natural world of interconnecting trails dotted with campsites as a "sanctuary and refuge from the scramble of everyday worldly commercial life."

A Renewed Landscape Perspective
Today, the Appalachian Trail is the longest hiking-only footpath in the world, spanning approximately 2194 miles through 11 degrees of latitude from Maine to Georgia. Over three million people visit the Appalachian National Scenic Trail annually. The Trail crosses a diverse array of landscapes, including state and national parks, wildlife refuges, farms, roads, and developed areas. In the time since 1937, when the full length of the A.T. footpath was largely completed, conservation planners have increasingly turned their attention to protecting the important lands surrounding the Trail to preserve its remarkable natural setting and retain the exceptional recreational experience that trail users have

come to expect and enjoy. Today's A.T.-centered conservation efforts harken back to Benton MacKaye's vision of a natural realm in which the Trail and its surroundings are one inextricably connected whole. This renewed emphasis on landscape-scale conservation is bolstered by an increasing wealth of data-rich information and scientific analysis tools which can help conservation planners work towards this goal.

The Network for Landscape Conservation describes how landscape-scale conservation is vitally important for creating connected habitat, preserving biodiversity, sustaining healthy ecosystems, protecting water sources, and providing resiliency in a changing climate. Landscape-scale conservation also brings communities together through shared interests while creating opportunities for outdoor recreation and preservation of cultural heritage. This approach to conservation aims to integrate existing landscapes in thoughtful ways, considering the needs of urban, rural, and tribal communities, farmers, timber managers, and all other stakeholders while promoting ecosystem function and preservation of natural lands. A landscape-scale approach has been embraced by many conservation-focused agencies, such as the National Park Service, whose *Scaling Up: Collaborative Approaches to Large Landscape Conservation* initiative is an important and continuing goal of the agency's Centennial Challenge.

The Appalachian Trail Landscape Science & Stewardship Symposium utilizes the landscape-scale approach to envision the next phase of conservation within the A.T. Landscape, backed by the most recent science and innovations in conservation technology. The A.T. Landscape has been described at various scales by trail managers, scientific researchers, and other interested parties. For the purpose of this symposium, the term "Appalachian Trail Landscape'' should be seen as significantly larger than, and distinct from, the relatively narrow protected corridor that surrounds the footpath and which constitutes the Appalachian National Scenic Trail (ANST). The A.T. Corridor serves conceptually as the centerline or "spine" of the A.T. Landscape. Though no definitive boundary has been established for the A.T. Landscape, a good stand-in for its geographic extent is the outer perimeter of those USGS HUC10 watersheds that intersect the ANST. Though the extent of the A.T. Landscape is somewhat malleable and dependent on the resource topic or other context at hand, the "HUC10 shell" is commonly used by the conservation community and serves as a reference geography for several of this symposium's presenters. Over time, with additional analysis and conservation focus, a more definitive Appalachian Trail Landscape boundary could be adopted.

Science & Stewardship Symposium Purpose and Overview

The Appalachian Trail Landscape Science & Stewardship Symposium 2021 was conducted on behalf of the Appalachian Trail Landscape Partnership (ATLP), a consortium of more than 100 non-profit conservation organizations and public agencies. This partnership is co-convened by the Appalachian Trail Conservancy (ATC) and the National Park Service, Appalachian National Scenic Trail (NPS-ANST) who co-sponsored and organized the Symposium. The ATLP is focused on collaboratively accelerating work towards a unified vision of A.T. Landscape conservation to connect the wild, scenic, and cultural wonders of the Appalachian Trail and its surrounding landscape.

The Symposium utilized a landscape-scale approach to explore conservation tools for the A.T. Landscape, with a focus on current innovations in science and technology. This effort centered around a series of virtual workshops which highlighted existing and ongoing research in and around the A.T. Landscape. The themes of climate change, resiliency, connectivity, and biodiversity tied these sessions together and provided a foundation for the idea of protecting an Eastern climate corridor.

Through these workshops, the ATLP aimed to bring awareness to the tools, resources, and conservation approaches available to land managers and practitioners and to engage in meaningful discussions around the conservation topics most critical for the next century of A.T. Landscape protection and stewardship. The workshops showcased a variety of landscape conservation approaches by highlighting available data, analysis methods, and research findings. Through question-and-answer exchanges and open discussions, presenters and participants explored a range of ideas: what the data tell us about the nature and condition of the Appalachian Trail Landscape, how conservation priorities vary at differing scales, what communities benefit from conservation action, and many other topics. This document provides a summary of the research and analysis presented during each Symposium session, together with a collection of relevant resources, to serve as a lasting reference for the A.T. Landscape Partnership and all stakeholders interested in protecting and preserving the Appalachian Trail Landscape.

The theme of this symposium, A.T. Conservation Perspectives: Science, Research, and Tools to Inform the Next Century of Appalachian Trail Landscape Protection and Stewardship, hearkens back to a time, just over a hundred years ago, when an early vision for an Appalachian Trail as a grand public space was first being promoted. It likewise reflects a certain refocusing that has taken place over the intervening Century toward the ecological preservation of an even broader A.T. Landscape, as well as a growing adoption of science-based approaches to conserving this significant land area. In this next Century, innovative efforts of forward-thinking researchers and science practitioners such as those participating in this symposium must both be shared with, and utilized by, conservation decision-makers if the full potential of Appalachian Trail Landscape protection and stewardship is to be realized.

Watch the recorded sessions here:
https://appalachiantrail.org/our-work/conservation/science-symposium/

Preview of Sessions

The following sessions consist of science-based research that informs landscape conservation within the A.T. Landscape. Each session contains a discussion section in which Symposium participants discuss the tools, methods, and results of each project as well as conservation needs going forward.

Session 1: The Appalachian Trail Landscape: Status of a Critical Climate Corridor

Workshop date: March 31, 2021

Presenter Abigail Weinberg provided an analysis of protection priorities for a climate resilient A.T. Landscape. The A.T. Landscape offers the most effective migration route for northward and upslope migration across the Eastern U.S., which makes it an important location of climate change refugia for both plants and animals. This analysis identified a preliminary set of sites for future protection to ensure the long-term effectiveness of the A.T. Landscape as a climate-resilient migratory route and a critical forest carbon sink, safeguarding the connection and functionality of this natural migration corridor.

Session 2: An Assessment of Ecological Values in Protection Beyond the A.T. Corridor

Workshop date: April 21, 2021

Presenter Peter McKinley, PhD, offered an assessment of the gradients of biodiversity and ecological integrity in relation to the existing ownership and management status of trail segments, in order to identify gaps in protection of high value areas. This session highlighted where conservation work is most urgent in order to deliver the intended vision of the A.T. as a place of human refuge and discussed how to conserve the Eastern forest and all its inhabitants against the threats of large-scale habitat loss, fragmentation, and climate change.

Session 3: The Eastern Wildway & the I-40 & Pigeon River Gorge Wildlife Crossing Project

Workshop date: June 2, 2021

Presenters Ron Sutherland, PhD, and Jeffery Hunter provided examples of habitat connectivity and wildlife corridor projects at regional and continental scales. The Eastern Wildway is a continental-scale vision for reconnecting and rewilding habitat across Eastern North America, and the Appalachian Trail acts as a central corridor of the network. Wildlife crossings along the 28-mile stretch of Interstate 40, north of Great Smoky Mountains National Park, provide a regional example of a habitat connectivity project within the greater A.T. Landscape.

Session 4: The Maine A.T. 2020 Report

Workshop date: July 13, 2021

Presenter Simon Rucker highlighted the findings of the "Maine Appalachian Trail 2020" report, which provides a methodology for analysis and prioritization for land conservation of the A.T. region in Maine at a parcel scale. This report is driven by values laid out in the 2015 Appalachian National Scenic Trail Foundation Document. The methodology used in this report has been utilized to identify protection priorities in land parcels along the A.T. and its surrounding landscape in Maine. This flexible framework for land analysis could prove useful in other states that the A.T. crosses.

Session 5: Long Term Research and Monitoring in the Northeast Mountains

Workshop date: September 22, 2021

Presenters Sarah Nelson, PhD, and Georgia Murray discussed their research in the Northeast Appalachian Mountains, including studies of mountain pond chemistry, snowfall on high peaks, and plant phenology. The unique character of remote mountain ponds in this region enables them to serve as sentinels of climate change while changes in snowfall at the Northern A.T.'s highest peaks inform climate trends. Results from a mountain plant phenology study demonstrate the role citizen or community science can play in monitoring remote mountain landscapes.

Session 6: Assessing Natural Resources for the Appalachian Trail

Workshop date: December 8, 2021

Presenter Claire Jantz, PhD, showcased the Appalachian National Scenic Trail (ANST) Natural Resource Condition Assessment (NRCA), a multi-year effort to document and evaluate the current conditions of natural resources within the managed A.T. Corridor and its surrounding landscape. The NRCA is a tool that assists land managers and partners in identifying critical data gaps, trends, drivers, and stressors of natural resources within the park. This assessment of natural resources in the ANST is designed to assist in the development of planning, management, and stewardship activities.

Session 1: The Appalachian Trail Landscape: Status of a Critical Climate Corridor

Science-based approaches to identify high priority conservation areas that will enhance the A.T. Landscape's climate change resilience, habitat connectivity, water quality, equity, and more.

Presenter Bio

Abigail Weinberg is the Director of Conservation Research for the Open Space Institute (OSI). Abigail develops science-based approaches to climate change and water quality for foundations, nonprofits, and public agencies. Working with a small and effective team, she advances research, outreach, and grant programs to enable land trusts across the country to understand how local land protection contributes to landscape-scale solutions to global issues. Her work guides the Open Space Institute's land protection capital grant, informing the placement of millions of dollars for land protection across the Eastern U.S. each year. Abigail earned a Master of Forestry degree from Yale School of Forestry and a bachelor's degree from St. John's College, Santa Fe.

Introduction

Climate change and land use are influencing the largest extinction wave since the dinosaurs disappeared 65 million years ago, resulting in a **biodiversity crisis**. The ability for species to survive a changing Earth is known as **resilience**. The Open Space Institute uses science to inform conservation protection efforts in the changing Appalachian Trail Landscape by addressing the following questions: What attributes support adaptation? *Where are these resources located within the A.T. Landscape? What is the status of their protection? Are adaptation options provided for all plants and animals?*

Defining the landscape

The A.T. is a major migration corridor for mammals, birds, and amphibians (Lawler et al. 2015). For this research, the geographic focus was the 26-million-acre landscape defined using HUC10 watersheds that intersect the Appalachian Trail. Research for the eastern U.S. documents evidence of animal **migration** upslope at a rate of 36 ft per decade and 10 mi per decade northward (Thomas et al., 2012). The project asked: what lands in the study region are essential to maintaining this natural migration corridor?

In order to better understand what lands would maintain biodiversity and support migration patterns, researchers at OSI mapped enduring features in the landscape, such as **geology**, **elevation**, and **connectedness**. These landscape features have been shown to support biodiversity. In contrast, habitat fragmentation limits landscape connectivity and impairs the ecological function of the landscape. Researchers looked at **regional flow** patterns across these landscape features. Another important piece of data that informed this research was the **protected status** of land. The project sought to identify areas that are essential for resilience and migration that were not yet protected using data from the GAP Analysis Project. The Gap Analysis Project has created a framework that identifies the level of land protection, known as the GAP Status Code. Protection status is ranked from 1-4, with GAP 1 being the most protected, and GAP 4 being the least protected.

A critical consideration for resilience and migration is the diversity of geophysical settings such as geology and elevation. This is based on research that showed that the number of **geologies** (rock types) in a region is the strongest predictor of species diversity, followed by latitudinal range, amount of limestone, and elevation range (Anderson & Ferree, 2010). The correlation between these landscape factors and **biodiversity** is very strong, displaying a nearly one-to-one relationship. An important consideration was that low elevation and fertile geophysical settings tend to be underrepresented in land protection, with low elevation limestone and silt settings less than 3% protected in some of the landscape while high elevation granite is more than 80% protected in many places. This results in less available habitat for species that rely on these geologies. Therefore, lands targeted for protection should ideally include the full range of geophysical settings in a landscape. This concept is known as **landform diversity**, or a measure of the number of **microclimates** on the landscape. Landform diversity and connectedness are the primary drivers of the OSI resilience data. These landscape characteristics, together with geologic diversity, were used to create the Open Space Institute's priorities in their **Resilience Map of the A.T. Landscape**.

Results

The Resilience Map reveals which regions of the A.T. Landscape are naturally resilient due to their geophysical characteristics. Current observations in different geophysical environments within the A.T. Landscape have shown that limestone is the most developed and least protected, despite its importance to biodiversity. Productive, fertile, and moderate environments tend to be coveted by humans for development and agriculture. In contrast, steep, harsh, acidic settings that are undesirable for human development are the most protected. This arrangement impairs biodiversity because species are more likely to survive in landscapes that have a diverse array of microclimates within them. Researchers at OSI also mapped the protected status of land within the A.T. Landscape in order to help prioritize conservation initiatives.

The results of this research show that 24% of the A.T. Landscape is composed of "underrepresented settings" or unique habitats and microclimates. Notably, 88% of resilient, underrepresented settings in the A.T. Landscape are not protected and could be considered as areas of opportunity for conservation efforts. The connectedness results show that 12% of the region fall into "**pinch points**" that limit the ease of animal migration by creating a concentrated flow of movement due to natural and artificial barriers. Of these pinch points areas, only 43% of them are on protected land. These pinch points on unprotected lands within the A.T. Landscape can be improved by connecting them to protected lands that are located near the A.T.

When connecting the landscape, it is not as simple as connecting dots. The flow of the landscape must be considered in order to capture the three-dimensional reality of animal migration. The final focus areas recommended for conservation are based on the presence of underrepresented settings, above average ecological resilience, and areas of confirmed biodiversity. Using these qualities, high priority landscapes and areas worth exploring were identified.

Discussion

The A.T. Landscape is in a prime location to support the federal government's 2050 national climate goals and the 30 by 30 directive. This makes it a priority area for conservation. Going forward, there is still much work to be done. The boundaries of the A.T. Landscape as currently defined by the HUC10 watersheds disregards some critical migration options adjacent to the A.T. Corridor. Therefore, the study recommended expanding the region to include additional migration options that fall outside of the HUC10 borders.

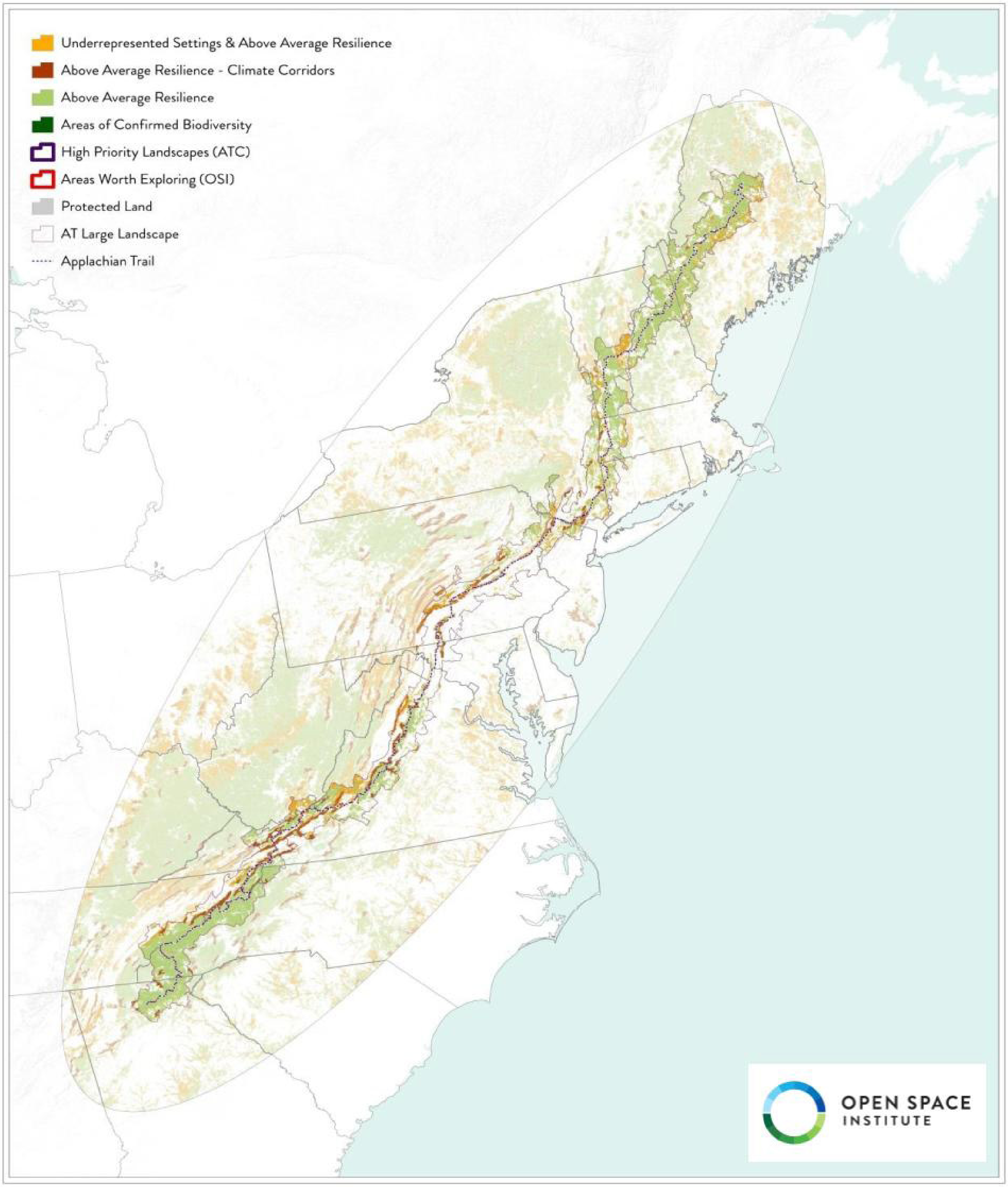

Figure 1: The Open Space Institute's Resilience Map of the A.T. Landscape

In much of this landscape, there is development pressure. A new dataset from Clark University maps hotspots of emerging forest loss due to development and could be useful for a future analysis of the benefits lost due to the conversion of these resources. Other needs going forward include field testing results, paring down priority areas, incentivizing carbon storage, equalizing conservation benefits, and equity. Where equity is concerned, underrepresented, under protected landscapes in the Mid-Atlantic region overlap a dense concentration of both superfund sites and African American communities. Additionally, the cultural and historical context of this landscape drives additional community-led efforts for conservation to restore land ties and stewardship access to Native American communities.

Tools & Resources for Landscape Conservationists

- The Nature Conservancy's Resilience Mapping Tool: This mapping tool can help landscape conservationists use data to evaluate their projects. Simply upload a shapefile or sketch an area of interest to get a resilience score and understand your location's local settings and pinch points. Existing maps and map packages from this project are also available for study. Find the tool here: https://maps.tnc.org/resilientland/
- HUC10 shell reference boundary: The A.T. HUC10 shell was established by selecting all 10-digit Hydrologic Unit Code watersheds that are within five statute miles of the protected A.T. land base. There are 236 HUC10 watersheds within this zone, all of which were subsequently merged into a single polygon to create the "shell". Watershed layers of this scale are often used in landscape-scale conservation planning based on their ecological relevance as opposed to assigning an arbitrary boundary to the landscape. Read more about why HUC10 hydrologic units are used in the Appalachian National Scenic Trail Forest Health Monitoring Protocol by the National Park Service. The HUC10 reference boundary layer can be accessed at the following URL: https://appalachian-trail-natural-resource-condition-assessment-clus.hub.arcgis.com/apps/reference-boundaries-for-the-appalachian-trail/explore

Session 2: An Assessment of Ecological Values in Protection Beyond the A.T. Corridor

Identifying gaps in protection of high value areas using gradients of biodiversity and ecological integrity beyond the protected and managed corridor of the Appalachian Trail footpath.

Presenter Bio

Peter McKinley, PhD, is a research ecologist and conservation planner with The Wilderness Society where he works to develop conservation priorities for national projects and campaigns, with a particular focus on the northern and southern Appalachians. His research program includes avian field studies in northern Maine and the southern Appalachians designed to help inform conservation and management decisions. Dr. McKinley serves on the boards of the Maine Appalachian Trail Land Trust, the High Peaks Alliance, and the Coastal Rivers Conservation Trust.

Introduction

In this presentation, Dr. McKinley shared insights from his paper "An Assessment of Ecological Values and Conservation Gaps in Protection Beyond the Protected Corridor of the Appalachian Trail" (2019). The National Park Service maintains a buffer around the A.T. footpath that is at least 30 m wide and is known as the A.T. Corridor. This paper looked beyond that protected corridor to calculate the **species richness, ecological integrity, and protection status** along one-mile segments of a one-kilometer buffer zone around the footpath. Each one-mile segment was characterized by its trail region, state, and managing trail club in order to help conservationists find the sections that are most relevant to them. This work can help to create a realm of natural landscapes around the A.T. Corridor. The data from this work is open access to allow landscape conservationists throughout the A.T. region to utilize its results in their planning efforts.

Ecology of the Appalachian Trail Landscape

The **species richness** of six major taxonomic groups (birds, fish, trees, mammals, amphibians, and reptiles) was analyzed alongside calculations of ecological integrity. **Ecological integrity** was defined as the inverse of human impact from land use conversion using a human footprint model. Results of this study show that the highest total species richness occurs predictably in the southernmost portion of the A.T., which is a result of climatic conditions combined with the landform diversity of the southern Appalachian Mountains. The exception was avian richness, which was comparable in the south and north. During the summer, ecological productivity increases in the north, and migratory breeding birds can take advantage of this change in northern landform diversity. In contrast to species richness, ecological integrity is highest in the north due to the relative absence of human development. Overall, 82% of the A.T. Landscape (as defined by the study's sampling method) scored above average for ecological integrity compared to average ecological integrity in all 14 states that intersect the Appalachian Trail. The combined species richness and ecological integrity of the A.T. Landscape may allow it to serve as an adaptive system for animal and plant species as they move along these gradients due to the pressures of climate change.

Protection Status

Protection status within the A.T. corridor and its one-km sampling zone ranged from federally protected with extremely limited human intervention to unprotected, privately owned lands. Results of this study show that only 33.4% of the buffered A.T. Corridor is known to be protected from potential future land conversion. The remaining two-thirds protected status remains unknown as it is held in private ownership. The private land ownership around the A.T. is highest in the New England and Mid-Atlantic regions. These lands are potentially vulnerable to conversion to another land use and/or ecological degradation, making them a potential target for landscape conservation.

Creating a Natural Realm Around the A.T. Corridor

Understanding the ecological value and protected status of lands within the one-km buffered A.T. Corridor can help conservationists plan the protection and stewardship of a natural realm beyond the A.T. footpath. The research revealed that there is high species diversity at the southern end of the A.T., where it is protected by federal multi-use management, and high ecological integrity exists in the northern end in privately owned timber forests. Different conservation strategies apply to each of these regions. The research also identified areas of inadequate protection along the entire extent of the A.T. Corridor. Expansion of the natural realm around the A.T. should include eastward and westward expansion since the Trail is currently primarily a narrow north-south corridor. **Lateral expansion** into surrounding areas will allow the A.T. Landscape to cover complete ecological gradients and encompass a variety of habitats rather than primarily just the rocky ridges that currently dominate the A.T. Landscape. The analysis showed that there is high ecological integrity to the west of the A.T. corridor, particularly in the Mid-Atlantic Region. This region is currently under high pressure of development, so it is important to act in a timely manner to protect A.T. adjacent lands in this area. In some areas, the A.T. is bound tightly on either side by existing human development; however, these areas may be prime for restoration efforts in the future. Going forward, the protection of connected and functional landscapes that expand much farther beyond adjacency to the A.T. and its managed corridor will be critical to creating an ecologically sustainable A.T. Landscape.

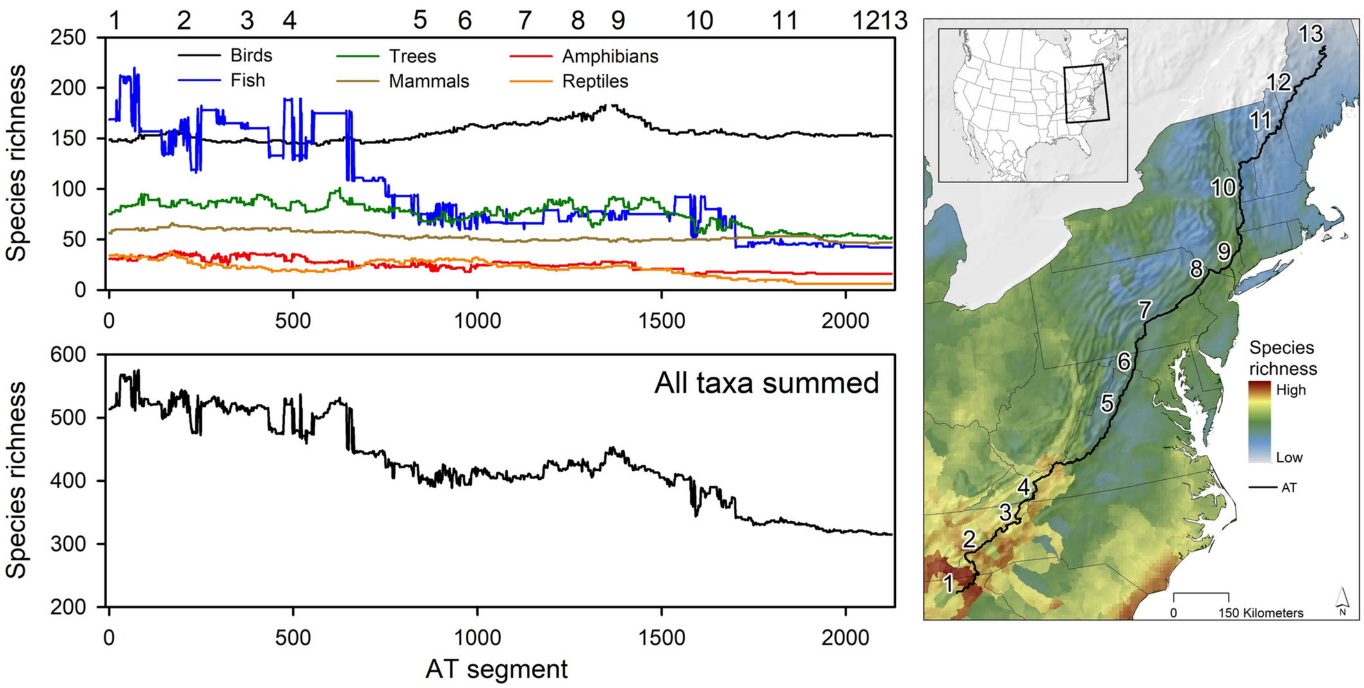

Figure 2: Species richness along the A.T. Corridor

1. Springer Mountain, Georgia, 2. Great Smoky Mountains National Park, 3. Roan Mountain, Tennessee, 4. Mount Rogers, Virginia, 5. Shenandoah, National Park, 6. Harpers Ferry, West Virginia, 7. Susquehanna River, Pennsylvania, 8. Delaware Gap, New Jersey, 9. Hudson River, New York, 10. Green Mountains, Vermont, 11. White Mountains, New Hampshire, 12. Hundred-mile Wilderness, Maine, 13. Mount Katahdin, Maine.

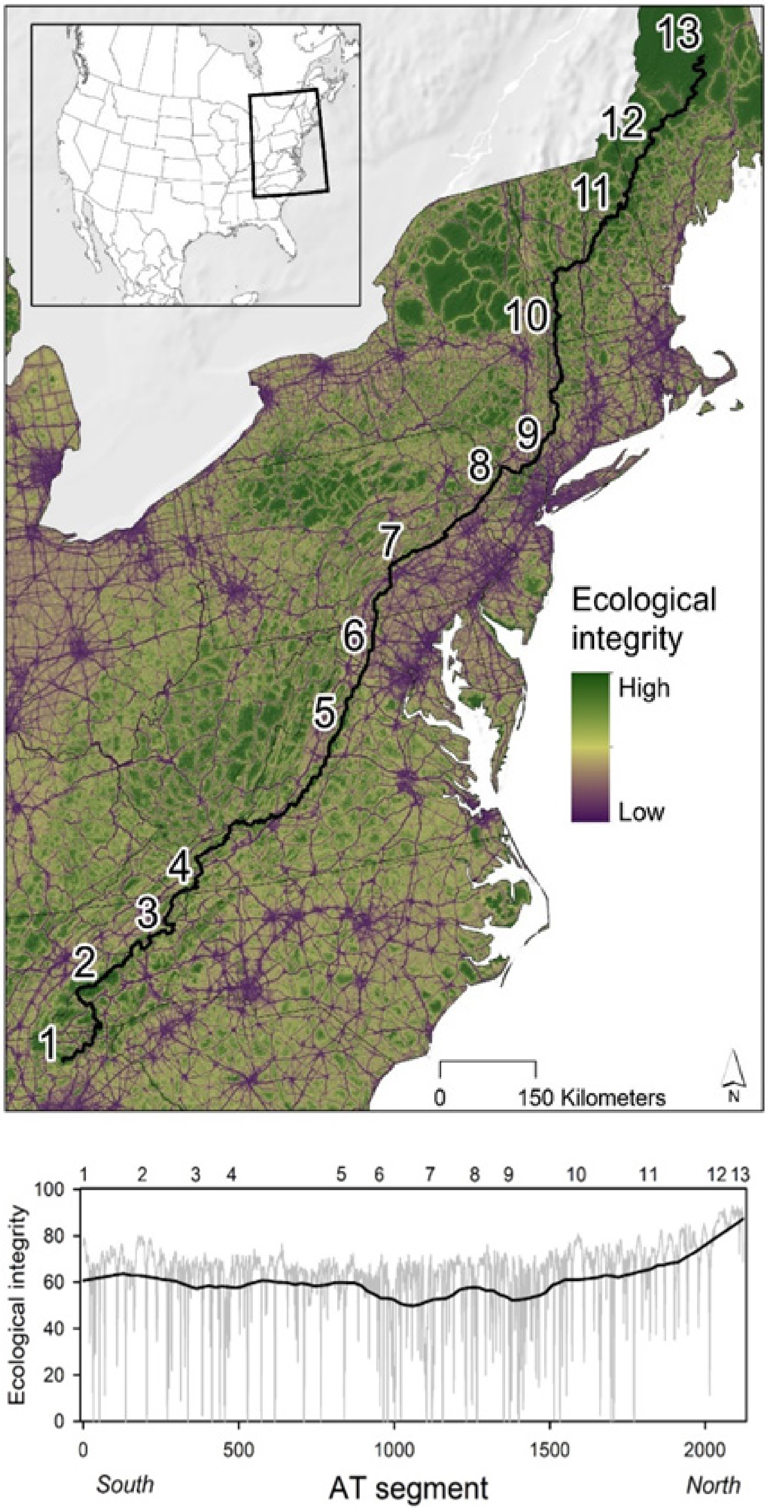

Figure 3: Ecological Integrity along the A.T. Corridor

1. Springer Mountain, Georgia, 2. Great Smoky Mountains National Park, 3. Roan Mountain, Tennessee, 4. Mount Rogers, Virginia, 5. Shenandoah, National Park, 6. Harpers Ferry, West Virginia, 7. Susquehanna River, Pennsylvania, 8. Delaware Gap, New Jersey, 9. Hudson River, New York, 10. Green Mountains, Vermont, 11. White Mountains, New Hampshire, 12. Hundred-mile Wilderness, Maine, 13. Mount Katahdin, Maine.

Discussion

The definition of ecological integrity used in this research was based on predicted fidelity to characteristics of the landscape prior to anthropogenic disturbance and is similar to existing ecological flow models. This model of ecological integrity is large-scale and coarse-grained and should be used in conjunction with smaller scaled and locally informed models and empirical inventories. As measured here, richness defines what native species can live within these zones based on natural landscape factors and climate. Therefore, both the ecological integrity and biodiversity models are theoretical in nature. They provide a good starting point for analysis, especially at a large scale.

Tools & Resources for Landscape Conservationists

- The species richness, ecological value, and protection status dataset can be found at the end of this journal article: https://conbio.onlinelibrary.wiley.com/doi/10.1111/csp2.30

Session 3 (Part I): The Eastern Wildway

A continental-scale vision for a connected network of habitat stretching from Florida to Maine.

Presenter Bio

Ron Sutherland, PhD, serves as the chief scientist for Wildlands Network, the nonprofit conservation group he has worked for since 2010. He received his PhD in Environmental Science and Policy from Duke University, and a Masters in Conservation Biology and Sustainable Development from the University of Wisconsin-Madison. At Wildlands Network, Dr. Sutherland runs a variety of investigations into carnivore conservation, road ecology, and habitat connectivity, and he acted as the principal architect for the ambitious Eastern Wildway design.

Introduction

The Eastern Wildway is a continental-scale vision for a connected network of habitat stretching from Florida to Maine. The goal of this ambitious plan is to provide guidance for protecting contiguous habitat across the eastern half of the country. Designed to inspire, this plan draws influence from the work of famed biologist E. O. Wilson and his call to protect half-earth. The origins of this plan date back to the creation of The Wildlands Project, which was a habitat connectivity project in Florida. Over time, the idea of **wildways** or continental-scale habitat connectivity corridors began to take hold in the field of conservation science. The Eastern Wildway builds off previous work in order to create a robust, large-scale vision for conservation in the eastern half of the U.S. This vision map of a **continental-scale habitat network** includes restoration opportunities which avoid areas that have hard constraints on landscape conservation, such as urbanization.

Figure 4: Vision map of the Eastern Wildway, Wildlands Network

Designing the Eastern Wildway

The Eastern Wildway plan was created using a diverse array of data, such as the Florida Ecological Greenways Network (Hoctor et al., 2016), Resilient Sites for Terrestrial Conservation in North America (Anderson et al., 2016), The Nature Conservancy's Resilience Map, the Southeast Conservation Adaptation Strategy Blueprint (SECAS, 2016), The Wilderness Society's protected corridors map (Belote et al., 2016), climate connectivity maps (McGuire et al. 2016; Haddad et al. 2016), as well as species-specific habitat maps. The first step of integrating these data included creating **core areas** of preservation where **protected and resilient lands** intersect. Then the connectivity datasets were used to connect these cores. Thus, the core areas and the **connectivity corridors** create one expansive Eastern Wildway network design. The latest version of the Eastern Wildway design includes habitat protection for 56% of the eastern half of the U.S. As the design for the Wildway continues to evolve, it will evaluate which vertebrate species are currently protected versus what the Eastern Wildway would protect if fully implemented, with the goal of protecting as diverse an array of wildlife as possible.

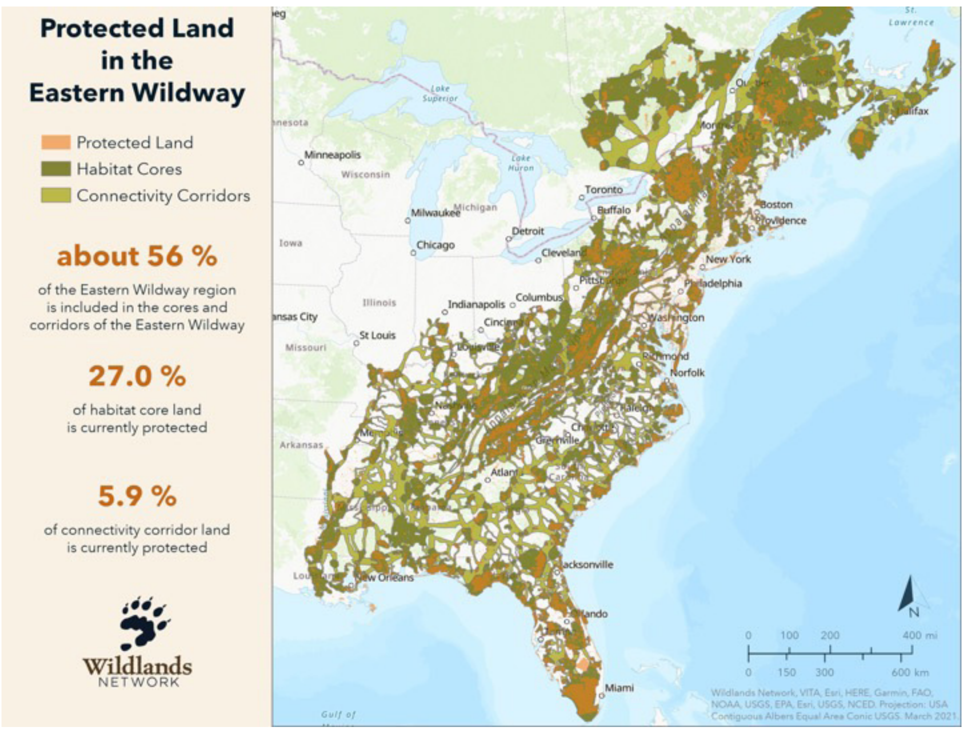

Figure 5: Protected land, habitat cores, and connectivity corridors of the Eastern Wildway, Wildlands Network

Connecting the Eastern Wildway

The results of Wildlands Network's analysis of protected lands revealed that 27% of core areas within the Wildway design are protected while only 5.9% of connectivity corridors are protected. Historically, areas between protected lands have not been the focus of landscape conservation, which explains this low level of protection in the connectivity corridors. Yet these connectivity corridors are an important opportunity for improving the ecological health of the landscape, and they should be a primary focus for landscape conservationists who operate within the A.T. Landscape.

The Appalachian Trail is the **central thread** running through the Eastern Wildway design. Because the A.T. already spans more than 2,000 miles of the eastern United States, it is the natural central focus for expanding connectivity throughout this region. Therefore, researchers at Wildlands Network focused on identifying hotspots of high conservation value and low protection lands along the A.T., similar to the work done by The Wilderness Society (Session 2).

Conservation hotspots were identified by stacking the six connectivity datasets on top of each other in order to create a single conservation value index within a 10 mi buffer of the Appalachian Trail. These data were then broken up into regional areas at which point regional data were added. The end result was about a dozen hotspots in the southern, central, and northern regions of the trail. Wildlands Network plans to track their progress in creating protected, connected habitat, which is easily done through comparing their maps over time. This project was inspired by the Yellowstone to Yukon Conservation Initiative.

Wildlife crossings along major roadways are a highly important aspect of the Eastern Wildway Design. There is bipartisan support for **policy initiatives** that support wildlife crossings at both the state and federal level, such as state wildlife corridor acts that have been passed in New Mexico, Virginia, and Oregon. At the federal level, the Wildlife Corridors Conservation Act has passed the House of Representatives and must make it through the Senate. Next steps include working on getting funding for wildlife road crossing in federal and state transportation bills. One particularly important area for wildlife crossings is along I-40 in the Great Smoky Mountains. This area is the highest priority for wildlife crossings in the entire eastern half of the United States due to the high level of biodiversity here combined with a major interstate passing through this region.

Discussion

Participants of the virtual presentation asked how the researchers chose which species to study, and if vegetation and water quality will be considered in future planning. The Eastern Wildway design focused on seven wildlife species in the southeast and coastal plain region that require habitat connectivity such as black bears, Florida panthers, rare snakes, box turtles. In the northeast, researchers at Wildlands Network used martens and wolves to plan connectivity corridors. More work on species-level research could improve this design for habitat connectivity, especially at the regional scale. Furthermore, the Wildway design did not include vegetation modeling due to a variety of issues. Plants need to migrate just as animals do, and northward expansion will be especially important due to climate change.

The creation of wildways can facilitate plant and animal migration, but they can also be a conduit for invasives. Many questions remain when considering these issues, such as how to promote the spread of different types of forests and grasslands, how to limit the spread of invasive species, and how to incorporate aquatic species into the Eastern Wildway design. Wildlife corridors should encompass high quality rivers and streams, but there is a divide between terrestrial and aquatic conservation planning that needs to be bridged. Other needs going forward include a system to incentivize private landowners to restore land, similar to Farm Bill conservation programs, since most land that is mapped for future connectivity is privately owned.

Tools & Resources for Landscape Conservationists

- The Eastern Wildway Interactive Map: Find the potential natural core areas and habitat corridors near you. Find the map here: https://wildlandsnetwork.org/resources/eastern-wildway-map

Session 3 (Part II): The I-40 and Pigeon River Gorge Wildlife Crossing Project

Reconnecting wildlife habitat at a regional scale in the Great Smoky Mountains.

Presenter Bio

Jeffrey Hunter is the Southeast Regional Senior Program Manager with the National Parks Conservation Association (NPCA). Before coming to NPCA, Jeffrey led the Tennessee Wild wilderness campaign which focused on permanently protecting nearly 20,000 acres in the Cherokee National Forest. He also led the Bodie Hills Conservation Partnership which focused on sage grouse restoration in eastern California. Now based in Asheville, NC, Jeffrey works on issues related to Great Smoky Mountains National Park, the Blue Ridge Parkway, and the Appalachian National Scenic Trail. He spends much of his time coordinating a collaborative project focused on improving wildlife's ability to safely cross I-40 in the Pigeon River Gorge north of the Smokies.

Introduction

Located among the Great Smoky Mountains and the Appalachian National Scenic Trail, Pigeon River Gorge is an area of extremely high biodiversity. Interstate 40 passes directly through this region, creating an animal migration barrier, especially for north to south migration. This confluence of animal and human movement has led this section of the I-40 to become known as a wildlife mortality hotspot with reports of many black bears being killed in traffic incidents. The National Parks Conservation Association's headquarters is located in this region, and they initiated a collaborative project that assessed wildlife crossings over a 28-mi section of the interstate corridor, with the following research objectives: 1) assess wildlife road mortality 2) assess wildlife activity within highway right of way 3) assess wildlife use of existing structures 4) identify and predict elk road crossing locations using movement information from GPS collared elk. The results from this research can be used to plan successful wildlife crossings.

Protecting Wildlife and Limiting Roadway Accidents

In 2016, The Twelve Mile Project, an elk habitat restoration project in Pisgah National Forest, sought to expand elk habitat on both sides of I-40. Concerns were raised that this project might result in more elk on the roadway, making the habitat restoration project a potential threat to **public safety** unless the elk could safely cross the road. Another project followed the movements of black bear, elk, and whitetail deer. These animals were chosen because they are the most often involved in costly roadway accidents. **Wildlife crossings** could help protect these animals and improve public safety. Additionally, wildlife crossings could benefit other plant and animal species due to improved **habitat connectivity**.

Tracking Wildlife Movements

This Pigeon River Gorge Wildlife Crossing project utilized a variety of methods to track the movement of wildlife throughout the Pigeon River Gorge region. Mortality roadway surveys were used, and **wildlife cameras** (heat or motion trigger) monitored **crossing points** such as metal culverts, box culverts, underpasses, river bridges, and a traffic tunnel. The first study site for this research was a natural land bridge that covers a tunnel section of the I-40. Black bears, coyotes, and bobcats were observed crossing the natural land bridge. During the study period, over 25,000 unique events (camera triggers) occurred. Black bears and whitetail deer were most often recorded. However, a large diversity of wildlife was observed. Researchers noted that wildlife was sometimes reluctant to use existing structures to cross the road. For example, deer cannot use corrugated culverts due to the structure of their hoofs. Small culverts were generally avoided by wildlife and even large underpasses intimidated some animals from crossing.

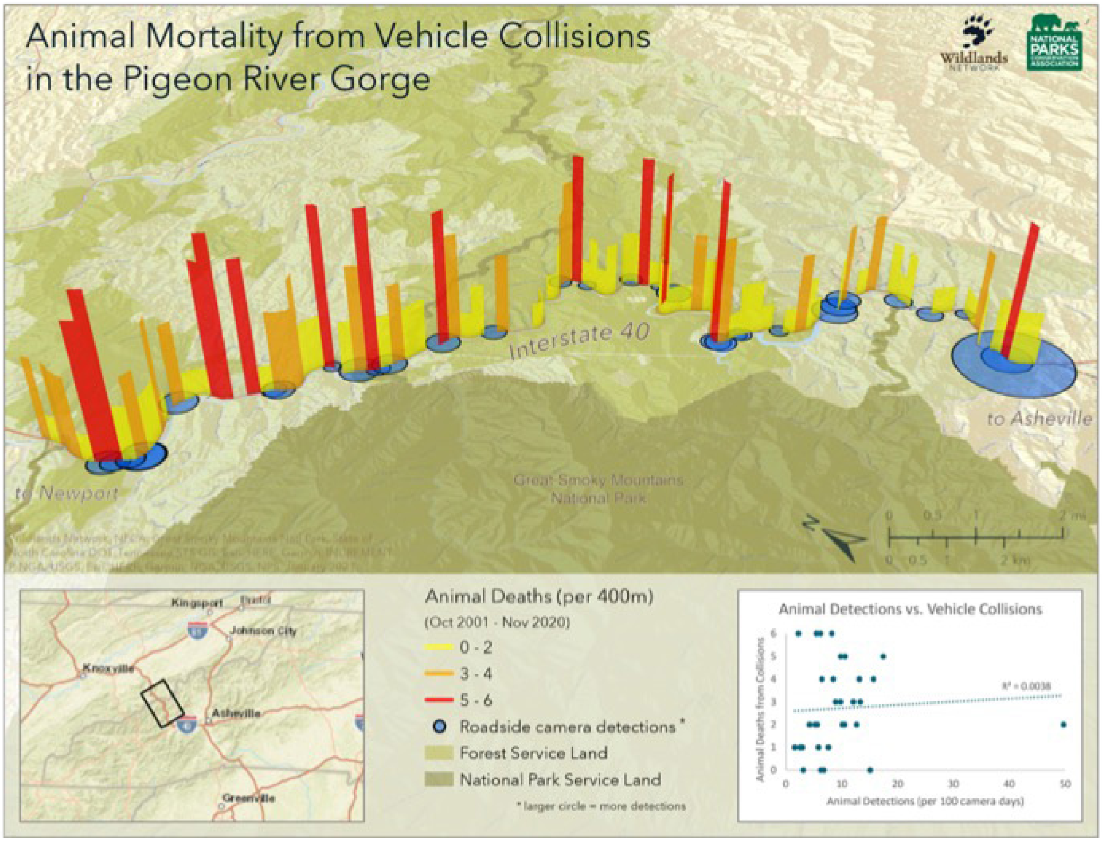

Figure 6: Animal mortality from motor vehicle collisions on I-40 near the Great Smoky Mountains, Wildlands Network & National Parks Conservation Association

Creating Wildlife Crossings

The National Parks Conservation Association used roadway crossing mortality data to help inform the placement of wildlife crossings in the Pigeon River Gorge. This project was inspired by the successful implementation of other wildlife crossings, such as wildlife overpasses in Banff, Alberta along the Trans-Canada Highway. This location experienced high elk mortality and blocked grizzly migration. A series of fenced overpasses and underpasses were constructed which **separated** and **funneled** wildlife over and under the highway. Some species were found to prefer to go under roadways, whereas others prefer to go over. For example, deer prefer large open spaces, but bears will travel through small areas.

While this research was being conducted, five bridges in the Pigeon River Gorge region were in the process of being replaced. NPCA reached out to the North Carolina Department of Transportation (NCDOT) and explained their wildlife migration study. As a result, the NCDOT was willing to work with NPCA to integrate wildlife design into the bridge work, including privately funded fencing and changing the footprint of the bridges to better facilitate **wildlife crossings**. The Tennessee Department of Transportation was also willing to work with conservation agencies to identify wildlife crossing locations to promote habitat connectivity and create safer roadways.

Discussion

Participants asked how to make wildlife crossings more appealing to animals and how to get funding for wildlife crossings. Crossings tend to be more successful when they mimic natural environments, such as making culverts appear natural by covering them with forest materials, duff, and natural substrate improves their appeal to wildlife. Identifying a minimum corridor width is still a topic of debate, and it depends upon the species in question. Wider corridors tend to serve more species; some researchers suggest a minimum width of two kilometers (Keeley et al., 2017). This question of minimum corridor width is still being studied and is dependent upon the species in question. However, even very narrow corridors have been shown to facilitate the passage of wildlife. Funding is the primary impediment to constructing more wildlife overpasses/underpasses. Federal and state transportation projects can be an important source of funding for wildlife crossings. Because wildlife crossings are designed to mitigate vehicle-wildlife collisions and increase public safety, they often have broad political support. The number one factor to implementation of a successful wildlife crossing project is collaboration among different groups at the local, state, regional, and federal levels.

Tools & Resources for Landscape Conservationists

- Learn more about wildlife crossing projects in the Great Smoky Mountains on this website: https://smokiessafepassage.org/

Session 4:
The Maine A.T. 2020 Report

Analysis and prioritization of land conservation in the A.T. region of Maine.

Presenter Bio

Simon Rucker is the Executive Director of the Maine Appalachian Trail Land Trust (MATLT), whose mission is to protect the land along the A.T. in Maine for public benefit. He formerly worked in the legal department for The Trust for Public Land and for a New York City entertainment law firm. He is a member of the Portland Land Bank Commission and a Maine Appalachian Trail Club maintainer. Previous presenter Peter McKinley (Session 2) co-authored the Maine A.T. 2020 Report and joined Rucker for this presentation.

Introduction

Maine enjoys some of the most ecologically resilient lands along the Appalachian Trail. This region of Maine is located entirely within the traditional territory of the Wabanaki Confederacy. Today, this landscape maintains much of its wild character, but conservation is necessary to maintain this landscape. The Maine A.T. 2020 report is a methodology for analysis and prioritization of land conservation within the Appalachian Trail region of Maine. It is an example of how the data and resources available for the Appalachian Trail can be used to focus on a parcel-level analysis and assess how protection can conserve values necessary to maintain and support the A.T. Landscape. This work was inspired and informed by several outside resources, including the Open Space Institute's Resilience Map (see Session 1), The Wilderness Society's ecological assessment and protection status report (see Session 2), National Park Service guidance, and other A.T. Landscape Partners. The findings of this report can be used to help inform local conservation projects in the A.T. region of Maine or as a model for regional conservation planning in other areas along the Appalachian Trail.

Creating the Maine A.T. 2020 Report

The Maine Appalachian Trail Land Trust drew from multiple sources to create this report. While MATLT was researching background information on what values are most important to conservation, the National Park Service suggested referencing the 2015 Appalachian National Scenic Trail Foundation Document which identifies the fundamental resources and values of the Trail, as well as the park's 2015 Business Plan which outlines its operational priorities. Other sources included the National Park Service Centennial initiative Scaling Up: Collaborative Approaches to Large Landscape Conservation and The Appalachian Trail Conference's An Appalachian Greenway: Purposes, Prospects, and Programs (1974). These resources helped to define those values fundamental to the Trail for this report.

Five categories were defined by MATLT as the most important values of the A.T.: 1) **scenery** along the treadway 2) **views** beyond the corridor 3) **natural resource quality** and **ecological connectivity** 4) **visitor experience** and 5) **American heritage**. These categories were chosen in part because they are mappable. Other values, such as education and the volunteer experience, are also critical but difficult to map. Guided by these values and a diverse set of pre-existing data, MATLT created a matrix for natural resource quality and ecological connectivity. This spatial dataset was then combined with Maine parcel data within one mile of the A.T. in order to evaluate conservation projects.

"A Practical Tool to Generate Real World Results"

It can be difficult to prioritize conservation based on getting the best value per dollar spent. Different conservation focuses, such as historical, tribal, agricultural, water, recreation, can complicate this process. The results of the Maine A.T. 2020 Report quantify these resources and show where they exist within this region. The researchers used a **GIS tool** known as **MATGIC** which provided data on the percent of land per parcel that is undeveloped, its viewshed acreage, ecological resilience, active river area, and more for each of the 3,391 tax parcels within one mile of the Appalachian Trail in Maine. Using this tool, they were able to create a scorecard for each project when conservation partners come to them to ask for information about a specific parcel. Currently, the parcels included in the report extend up to one mile from the Appalachian Trail, although they plan to extend this to include a two-mile buffer. The scorecard shows the natural resource quality and ecological connectivity rankings of a particular parcel or parcels

MAINE Appalachian Trail LAND TRUST

Maine A.T. 2020 Scorecard

Project Name: Grafton Forest
Parcel: FID 486, 978, 2485, 476

Indicators - Natural Resource Quality and Ecological Connectivity

Data		Rank (of 3144)	Percentile
Acres TNC Ecoregional	6,524.24	27	99.14%
Percent TNC Ecoregional	32.60%	642	79.58%
Acres TNC Ecoregional - Far Above Average	12.005931	149	95.26%
Percent TNC Ecoregional - Far Above Average	0.22%	225	92.84%
Acres TNC Ecoregional - Above Average	6,512.23	26	99.17%
Percent TNC Ecoregional - Above Average	32.54%	624	80.15%
Acres TWS 5000-acre Forest Block	4,009.99	57	98.19%
Percent TWS 5000-acre Forest Block	20.03%	282	91.03%
Acres TNC Active River Area	3,045.99	21	99.33%
Percent TNC Active River Area	15.22%	2070	34.16%
Acres MNAP Rare Natural Communities and Plants	96.98	92	97.07%
Percent MNAP Rare Natural Communities and Plants	0.48%	173	94.50%
Acres MNAP State Listed Animal Habitats	1,034.74	54	98.28%
Percent MNAP State Listed Animal Habitats	5.17%	225	92.84%

Figure 7: Example scorecard from the Maine A.T. 2020 Report

The researchers stressed that these data must be interpreted by local land conservation agencies. Data tables aren't enough to fully capture the scope of an area of interest. For example, local knowledge can provide better insight into historical sites and development.

Data derived from the Maine A.T. 2020 Report methodology can also be used to find previously unknown characteristics of parcels and aggregate small parcels into larger projects. Additionally, this dataset is portable to other landscapes; the tool creates a framework that local data can be added to, allowing it to be applied to other regions. Finally, the research team also noticed that GIS data can also be used to find conservation priority hotspots where they weren't looking before and to create priority focus areas, such as the Hundred-Mile Wilderness. They found that the results were in most instances comparable to previously identified "focal points" for conservation, but the support of additional data can help justify funding for projects and makes it easier to convince others to participate in conservation efforts.

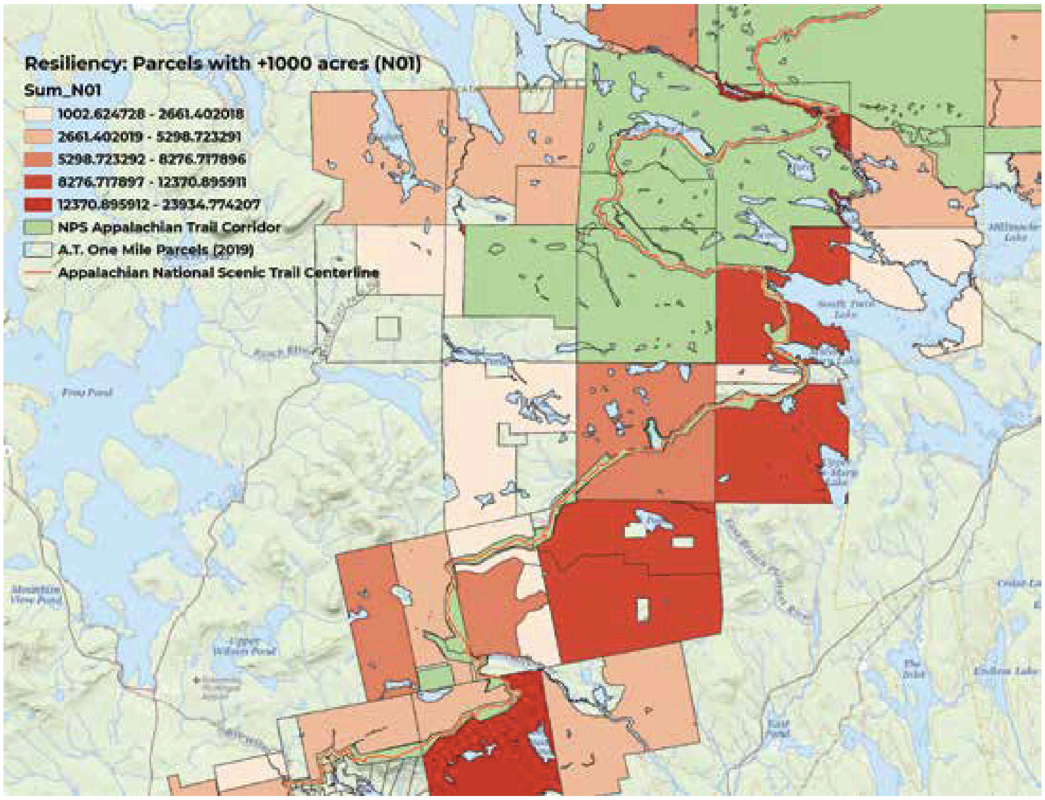

Figure 8: Priority Focus Area #1: Hundred-Mile Wilderness

The next iteration of the Maine A.T. Report will highlight improvements to the mapping methodology and identify which areas should be the focus of conservation. It will also expand upon its data by incorporating forest carbon data, tribal land data and access, viewsheds, vacant vs. non-vacant parcels, and adjacency to other conservation lands.

Discussion

During the discussion of this presentation, participants had questions about parcel data and creating a similar tool for the entirety of the Appalachian Trail. Parcel-scale data are often important in conservation planning as land ownership plays a critical role. In Maine, most "unincorporated" tax parcels are freely available on the state GIS website, but some data are not available for small towns. There are often different rules on a state-by-state basis, and currently parcel data for the entire Appalachian Trail is not available. The Maine A.T. 2020 Report supports the goal of the A.T. as a climate corridor through habitat connectivity based on the resilience data used in the analysis. Currently, the MATLT is considering sharing their data on ArcGIS Online or another online platform. However, individuals who know the landscape can interpret the data are needed to evaluate the results as they pertain to a particular area of interest. Although all of the GIS data are not currently publicly available, the framework used to create this tool can be utilized for other regions. The total cost for this project was about $40,000-$50,000 including all staff hours and GIS consulting. It would be difficult to scale this process up to include the entire A.T., but other states and local agencies could replicate it. In the future, a confederation of 14 working groups representing each state along the Appalachian Trail could create a combined resource for landscape-scale planning. This process would be difficult for one large organization to pull off by itself. Local knowledge is key to creating the best planning tools because locals know the best data, where to find it, and are involved in local partnerships.

Tools & Resources for Landscape Conservationists

- Read the full Maine A.T. 2020 Report here: https://matlt.org/matltwordpress/wp-content/uploads/Maine-Appalachian-Trail-2020-FINAL.pdf

Session 5 (Part I): Northeastern Mountain Ponds as Sentinels of Climate Change

How remote mountain ponds serve as indicators of climate change as well as changes in emissions, air quality, and water quality.

Presenter Bio

Sarah Nelson, PhD, is the Director of Research at the Appalachian Mountain Club (AMC). Previously, she worked at the University of Maine as an Associate Research Professor in the School of Forest Resources and as Director of the Program in Ecology and Environmental Sciences. Her research focuses on understanding the effects of atmospheric pollution and climate change on forests, food webs, and fresh water in remote and protected ecosystems. Current research projects include analyses on geochemistry in lakes, climate change with a focus on changing winters, and mercury contamination. Research approaches include long-term monitoring, bio-sentinels, and citizen/community science.

Introduction

The Appalachian Mountain Club's mission is to foster protection, enjoyment, and understanding of the outdoors. They use credible science and analysis to support policy and advocacy work, and they are also involved in trail building and stewardship. This organization focuses mostly on the northeastern section of the A.T. and the surrounding wild lands. This section of the A.T. is ruggedly mountainous and contains unique habitats, including many high elevation ponds and lakes. Northeastern mountains can serve as climate change refugia as plants and animals migrate northward and upslope to escape rising temperatures (Morelli et al., 2016). These mountains tend to be remote and relatively undisturbed, which is part of what makes them valuable as sentinels of climate change. The main focus of this presentation draws on the findings from Dr. Nelson's collaborative research paper, "Northeastern mountain ponds as sentinels of change: Current and emerging research and monitoring in the context of shifting chemistry and climate interactions." This research was informed by a variety of sources on alpine forest biomes, including the Nature Conservancy's migration corridors map, Publicover's research and map on northeastern high elevation areas, and ongoing work by Tourville et al. (SUNY-ESF & AMC) re-mapping the alpine tree line.

Alpine Pond Characteristics

Alpine ponds are often characterized by being above the tree line and having low dissolved organic carbon, which makes them very clear (Moser et al., 2019). In the U.S., alpine environment research is usually focused on the West where elevation is highest. In the Northeast, higher-elevation ponds are referred to as mountain ponds; they exist at lower elevation and are more forested than western alpine ponds. Northeastern mountain ponds play an important role in the identification of biological and physical responses to regional and global stressors such as acidic deposition, which has a downward trend, and climate change, which is accelerating in the region.

Lakes and ponds are **sentinels of change** because they integrate signals of change occurring in both terrestrial and aquatic environments. They are also related to the landscape through their watershed and airshed. The small watersheds of mountain ponds combined with limited disturbance and a highly protected landscape makes it easier to observe chemical and physical changes driven by non-point source anthropogenic stressors like **acid rain** and **climate change**. Research on these ponds started in 1986 and was concerned with acid rain. The signal of acid rain was clearer in mountain ponds than in lower elevation lakes, which made mountain ponds important markers for measuring changes in acid rain deposition.

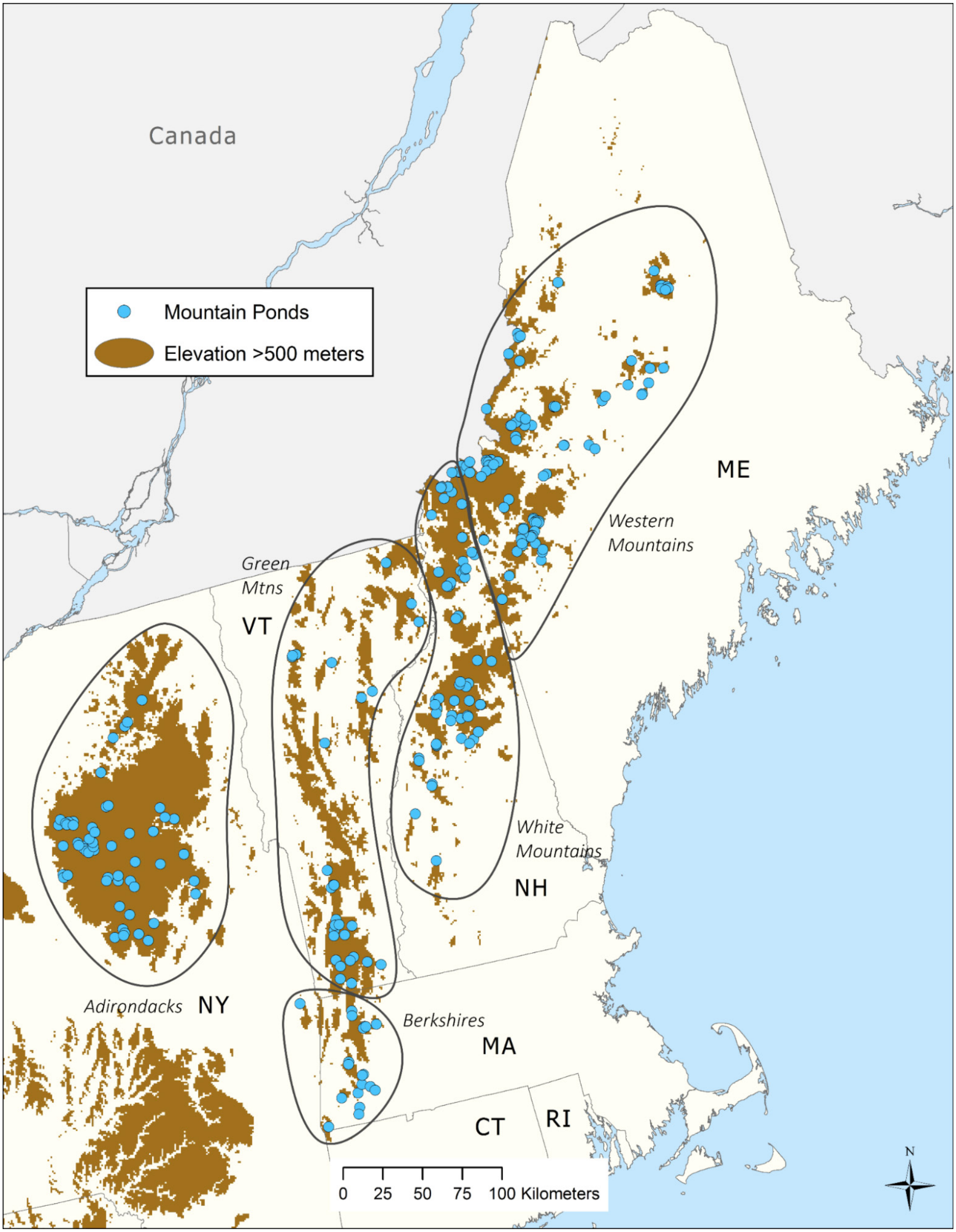

Figure 9: Northeastern mountain ponds included in this research. Reprinted from Atmospheric Environment, 264, 118694, Nelson, S., Hovel, R., Daly, J., Gavin, A., Dykema, S., & McDowell, W., Northeastern mountain ponds as sentinels of change: Current and emerging research and monitoring in the context of shifting chemistry and climate interactions, p. 4, Copyright (2021), with permission of Elsevier.

Monitoring Mountain Ponds

In the northeastern mountains, there are strong indications of climate trends including: increasing extreme events (e.g., heavy precipitation), warming winters, precipitation and temperature increases, and loss of snowpack. Measurements of dissolved organic carbon in Maine high elevation lakes are increasing and linked to recovery from acid rain, reduction in sulfate deposition, and climate change (Gavin et al. 2018). In order to study changes in Appalachian Trail adjacent mountain ponds, Dr. Nelson's research team compiled water chemistry data collected by various state agencies such as the Environmental Protection Agency, USDA Forest Service, state agencies, and academic researchers. They also used information supplied by local contacts and unpublished data on these ponds. Data were compiled for 257 ponds situated above 500 meters of elevation. Sampling of the ponds occurred between 1978-2019. The researchers focused on small ponds with small watersheds near the Appalachian Trail and the Adirondack Mountains. About half of these ponds intersect HUC10 level watersheds of the A.T.

The results from the study indicate that the ponds tended to be very dilute (low conductivity), slightly acidic, not affected by road salt or marine influence, and contained moderate levels of dissolved organic carbon. The ponds serve as good indicators of acid rain because northeastern mountain ponds are basically "mountain top rain collectors" within small watersheds which reflect deposition as it occurs, whereas in other watersheds, deposition that cycles through complex flowpaths and large watersheds may be more complicated. Dilute ponds amplify the relative effect of small changes in geochemical and climatic drivers. In 95% of the ponds, there was a decrease in sulfate, decreasing by 44% on average. This indicates a **decline in sulfur emissions**, likely as a result of the Clean Air Act Amendments of 1990. These findings correlate with sulfate emission data from the National Atmospheric Deposition Program.

The researchers also noted that mountain ponds generally experienced increasing pH (declining acidity) across all regions since the 1970s/1980s. Acidification can increase during high flow, making it episodic in nature, even in lakes and ponds (Strock et al. 2016). The cause of an observed increase in dissolved organic carbon over the four decades requires further study, but it may be due to **increased precipitation** flushing carbon into ponds from terrestrial sources, increased soil microbe activity due to **warming temperatures**, or a combination of these factors. Another study of a subset of these mountain ponds in Maine led by University of Maine Farmington faculty Hovel and Daly integrated thermal-chemical-biological data of mountain ponds. This research found that dissolved organic carbon concentrations were correlated to thermal and biological conditions in Maine mountain ponds, which experienced a **thermal increase** and **biological decrease** (declining total chlorophyll and zooplankton density). More integrated monitoring would help to understand these results. Using these data, an integrated conceptual model was created to help understand northeastern mountain ponds and lakes in relation to biota, the food web, and atmosphere.

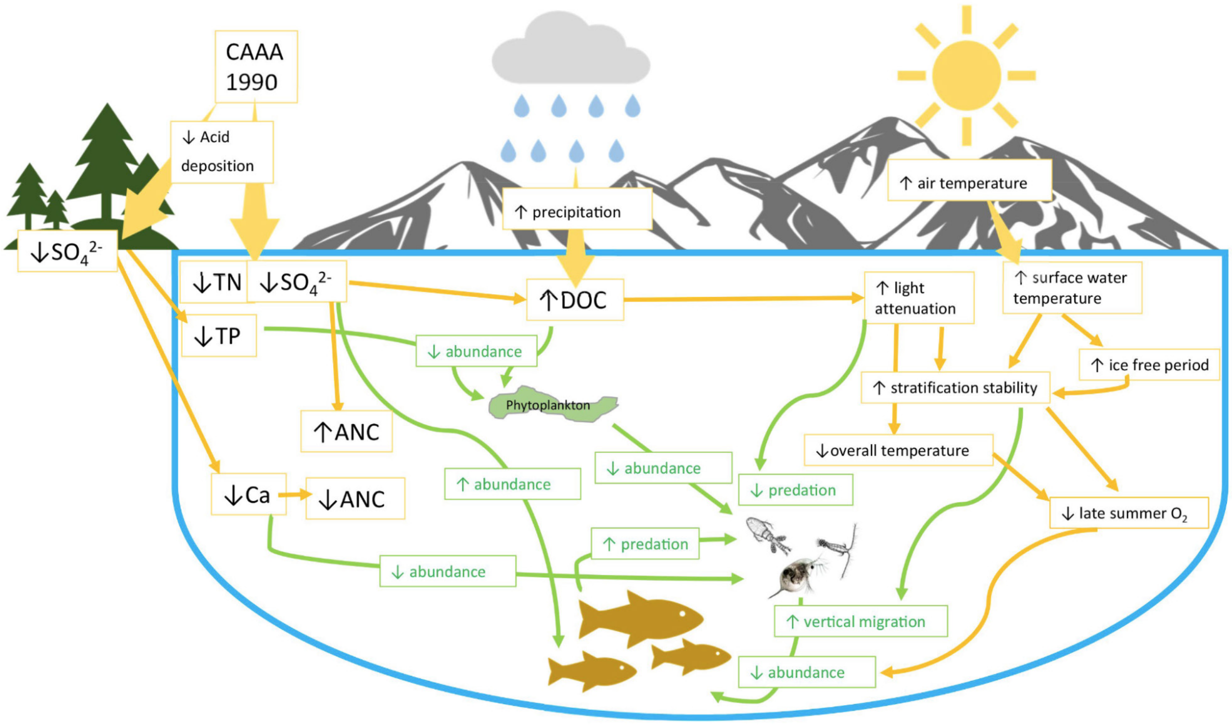

Figure 10: Integrated conceptual model of northeastern mountain ponds biogeochemical cycling. Reprinted from Atmospheric Environment, 264, 118694, Nelson, S., Hovel, R., Daly, J., Gavin, A., Dykema, S., & McDowell, W., Northeastern mountain ponds as sentinels of change: Current and emerging research and monitoring in the context of shifting chemistry and climate interactions, p. 11, Copyright (2021), with permission of Elsevier.

At the end of this presentation, Dr. Nelson introduced the Dragonfly Mercury Project, which uses dragonfly larvae as bio-sentinels for mercury contamination in national parks, forests, wildlife refuges, and other protected lands, with initial sampling at two sites in the A.T. Landscape in Maine in 2021. Major recommendations from the results of the mountain pond study include continuing and expanding data collection and sampling, including weather and climate monitoring in the mountains where these measurements are sparse.

Discussion

During the discussion of this research, participants asked if there are any implications for flora/fauna as dissolved organic carbon increases in alpine ponds. Dissolved organic carbon keeps light from penetrating into deeper layers of these ponds, resulting in changes in temperature stratification. This inhibits the growth of aquatic plants and influences the food web. At this time, harmful algal blooms are not known to be an issue in northeastern mountain ponds, but they could be a possible threat if dissolved organic carbon continues to increase and does so rapidly.

Tools & Resources for Landscape Conservationists

- Read Dr. Nelson's full journal article here: https://www.sciencedirect.com/science/article/abs/pii/S1352231021005161?dgcid=author
- TNC's migration corridors map: https://maps.tnc.org/migrations-in-motion/#4/19.00/-78.00
- Publicover's high elevation map of the U.S.: https://www.arcgis.com/home/item.html?id=bde622c793a8456997d6ed9794ad0f07
- National Atmospheric Deposition Program: http://nadp.slh.wisc.edu

Session 5 (Part II): Plant Phenology as a Bioindicator in Mountains

Identifying northeastern mountain climate trends using community science to monitor native plant phenology.

Presenter Bio

Georgia Murray is a Staff Scientist with the Appalachian Mountain Club (AMC). She has conducted biogeochemical research for the Marine Biological Laboratory's Ecosystem Center at Toolik, Alaska, a long-term ecological research site. She also worked at the University of Washington maintaining a long-term small watershed monitoring site within Olympic National Park. Murray currently oversees the Appalachian Mountain Club's ambient air pollution program in cooperation with the U.S. Forest Service including mountain-based monitoring of cloud, rain, and stream water chemistry in Wilderness areas in the White Mountain National Forest. She also leads AMC's plant phenology monitoring work, which incorporates community science while conducting mountain climate research.

Introduction

Winter conditions are changing in northern forests based on observable data over the past 100 years. **Increasing temperatures**, decreasing snow, and decreasing winter durations have all been observed. The winter season has shortened by three weeks since 1917, and spring has started earlier based on first leaf and first bloom (Monahan et al., 2016; Contosta et al., 2020). In New Hampshire, **high peaks** have been used to measure **climate trends** (Grant et al., 2005; Seidel et al., 2009; Murray et al., 2021). The results of this research show that all seasons are warming at mid elevations and spring and fall at a site above the tree line. Winter in particular is changing in the region but remains variable (not significantly warming) in alpine areas. There are fewer frost days, fewer snow days before Christmas, more thaw days, and more mud days. A longer growing season and decreased snowpack depth have also been recorded across elevations. Murray and her colleagues at the Appalachian Mountain Club monitor these changes in northeastern mountains through analyzing changes in the tree line, temperature, plant phenology, canopy phenology, and community snow observations.

Plant Phenology Monitoring and Citizen Science

Phenology is the timing of recurring plant and animal life stages and relationships with weather and climate. It includes seasonally driven events such as leaf on, leaf off, and flowering. **Plant phenology** can serve as a **bioindicator** of climate change as these events occur earlier or later in the season. **Citizen science** played an important role in the plant phenology research conducted by AMC. Hikers and other groups helped with collecting data in a Northeast alpine focused project. Baxter State Park, the Adirondack Mountain Club, Green Mountain Club, and other organizations also pitched in. Initially, phenology data were collected using the Nature Phenology Network's (NPN) monitoring protocol and their system, Nature's Notebook. In 2019, AMC received a grant from the National Geographic Society to help better engage the half million visitors that go through the White Mountains every year using **iNaturalist**. The researchers used iNaturalist to create a program called the Northeast Alpine Flower Watch, which has collected thousands of observations to date, and uses the monitoring protocols created by the Nature Phenology Network. This dataset is still being analyzed. Before being analyzed, the data goes through quality control and curation. Every plant identification must have at least two confirmations.

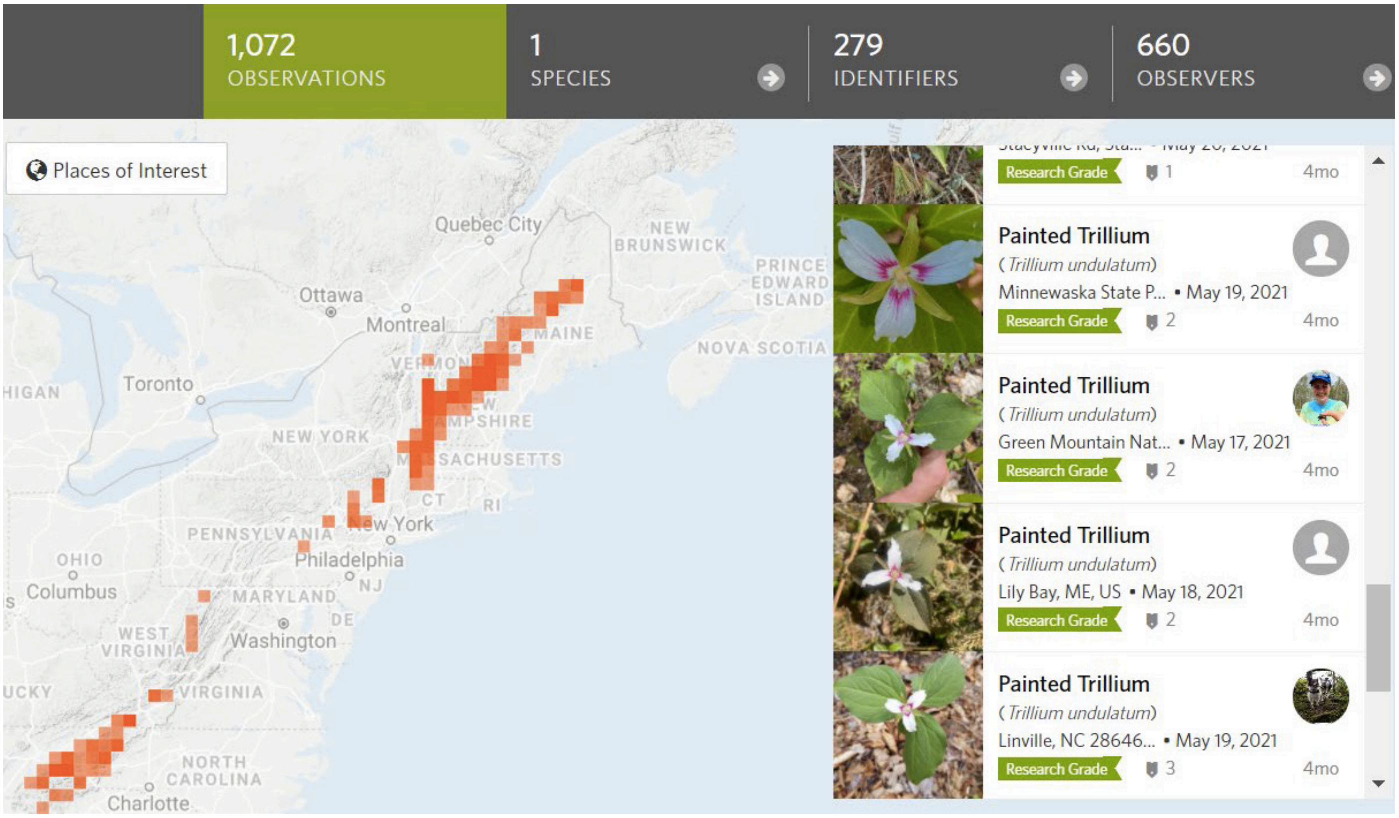

Figure 11: Volunteer observations of painted trillium in iNaturalist

Observations from iNaturalist provided 3.5 times more data than the National Phenology Network's established observation plots for Diapensia lapponica. The iNaturalist data also had earlier flowering times than the NPN plots because people tend to take photos of flowers as they are naturally drawn to their blooms. The increase in flowering observation data helps better capture the start of spring. The AMC also launched another iNaturalist project called Flowers and Fauna Along the Appalachian Trail Corridor. These programs target a specific set of native plant species, including Canada mayflower and painted trillium. The results from the data show that open flowering time was correlated with longitude, latitude, and elevation as expected. The success of this project has inspired AMC to undertake more citizen science related projects that use smartphones and basic observations, such as the Community Snow Observation Project. This project uses remotely sensed data and citizen collected field snow depth measurements to create improved snow models.

Discussion

Symposium participants asked questions about nighttime temperature differences, how to facilitate successful community science, and how to reach broad audiences about phenological change. Minimum nighttime temperatures are increasing the fastest, especially at Pinkham Notch, NH due to nighttime layering of the atmosphere which results in a shallow boundary layer. This is similar to how winter temperatures are changing fastest where the boundary layer is shallowest. Shallower air masses allow faster warming to happen. This phenomenon is consistent across multiple regions.

Knowing your audience and what they are capable of is most important in facilitating effective community science. Community science must also fit well with the project concept and is limited by volunteer time commitments. Volunteers may only be visiting on vacation and/or not committed to going back to the same location again and again. Other aspects to consider are how much volunteer training is needed and how it will be provided. The National Phenology Network used core volunteers who are more dedicated, whereas iNaturalist works well for a more general volunteer base where each volunteer might contribute only one observation. Raising awareness about phenological and climate change is still ongoing. The AMC notes that they are very willing to share data and training with interested parties.

Tools & Resources for Landscape Conservationists

- NASA's Community Snow Observation Project: https://communitysnowobs.org/
- National Phenology Network's Phenology Visualization Tool: https://www.usanpn.org/data/visualizations
- AMC's iNaturalist Project Flowers and Fauna along the Appalachian Trail: https://www.inaturalist.org/projects/flowers-and-fauna-along-the-appalachian-trail-corridor
- AMC's iNaturalist Project Northeast Alpine Flower Watch: https://www.inaturalist.org/projects/northeast-alpine-flower-watch

Session 6: Assessing Natural Resources for the Appalachian Trail

Evaluating the health of this National Park through a multidisciplinary synthesis of existing data and creating an online, living library of the A.T. Landscape.

Presenter Bio

Claire Jantz, PhD is a professor in the Geography-Earth Science department at Shippensburg University and the director of Shippensburg University's Center for Land Use and Sustainability. As a lifelong supporter of public lands, she has worked on many projects involving NPS units, beginning back in college at the University of Tennessee where she spent a summer as a social science aide for the Great Smoky Mountains National Park. With expertise in land use science, a strong interest in large landscape conservation, and a personal connection to the A.T., she is proud to lead the Natural Resource Condition Assessment team for the Appalachian National Scenic Trail.

Introduction

The Natural Resource Condition Assessment (NRCA) is a program run by the National Park Service that evaluates natural resources within national parks. At least 170 national parks have had an NRCA completed since the program started. The Appalachian National Scenic Trail (ANST) is among the last parks to undergo this assessment. This assessment involves evaluating the health of each park including its "vital signs," a multi-disciplinary synthesis of existing data, and a summary of the condition assessment. The NRCA for the Appalachian National Scenic Trail utilized a large collaborative team composed in part of students from the Center of Land Use and Sustainability at Shippensburg University, led by Dr. Jantz. A stakeholder survey was also used in this assessment. The NRCA is designed to compile existing datasets rather than to create new data. An Appalachian Trail hub website was also created as part of this project.

Data & Results from the Natural Resource Condition Assessment

The research team used HUC10 boundaries to define the area of interest around the Appalachian Trail. This HUC10 shell is available on the A.T. hub website, along with a variety of other geospatial data relevant to the Trail. Counties, ecoregions, and the Inventory and Monitoring Division network boundaries were also included.

The results of the stakeholder survey indicate that the most critical management challenges for the ANST are **funding** and **staffing**, the use of manageable spatial units, and stressors to natural resources such as **climate change**, **vegetation change**, **water quality**, **air quality**, **land use change**, and **invasive species**. Other management challenges include how to prioritize projects based on identifying critical resources, decision support such as data visualization and manipulation tools, access to information including an index of available information that highlights existing gaps and needs, and outreach using easy to share materials that use terms everyone may understand.

The final report has not yet been published but will include nearly 30 resource elements and dozens of metrics on natural resource conditions, status, trends, and confidence level of the results. The hub site is available for use, although it is a dynamic site that is still being updated regularly. This site includes a variety of data, including some of the data used in the earlier symposium presentations. The hub site data includes a protected areas dataset, the Eastern Wildway plan, water quality data, climate trends, phenology data, bird species diversity along the A.T., forest growth, human demographics (income, diversity, age, housing unit density, seasonal housing unit density), and a variety of other natural resource spatial data along the A.T.

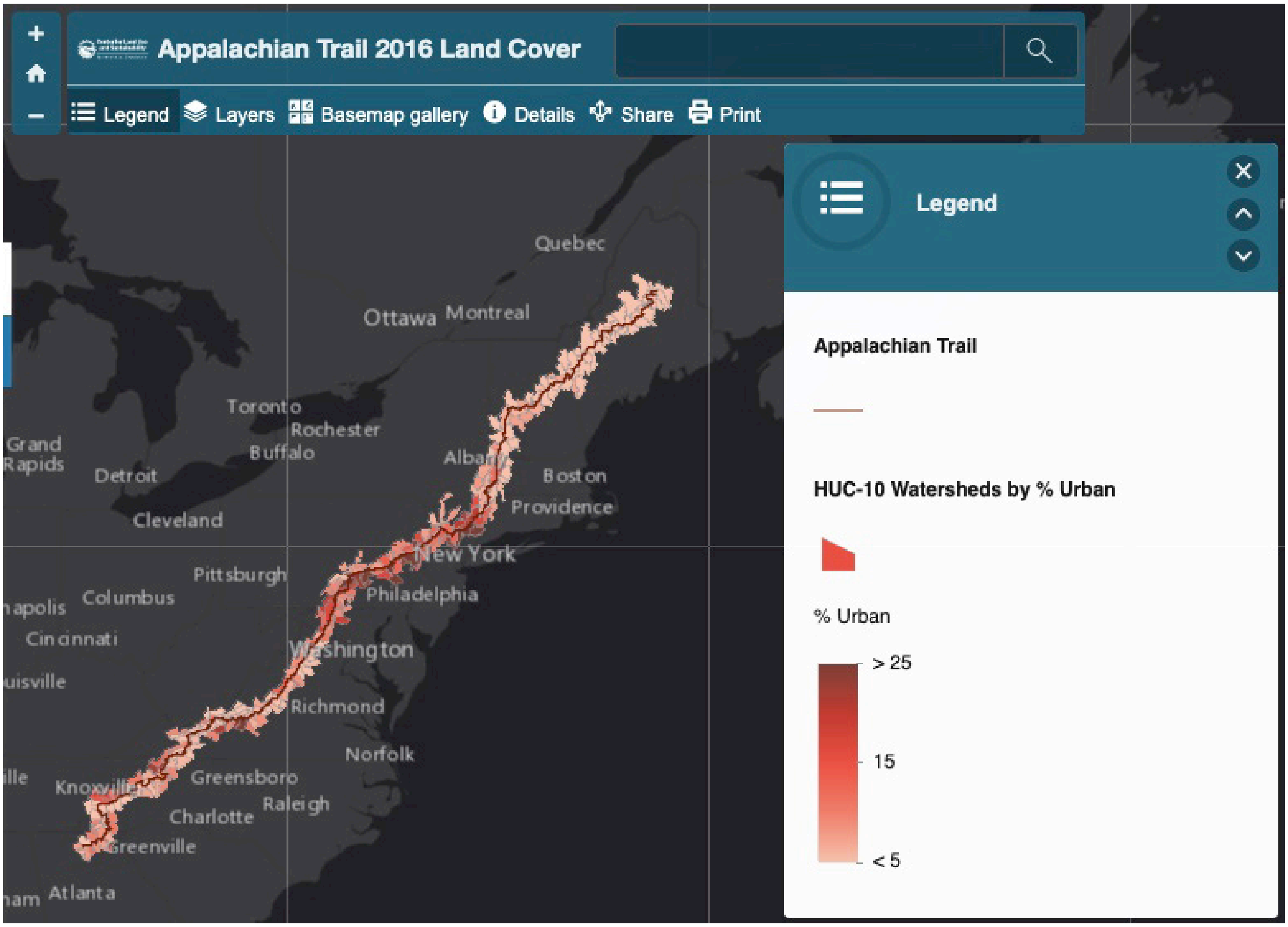

Figure 12: A screenshot from the A.T. NRCA hub site displaying urban land cover in HUC10 watersheds that intersect the A.T. Corridor.

Discussion
Symposium participants asked a variety of questions related to what data were used in the NRCA, and what gaps in data still exist. About twenty different natural resources were evaluated in this assessment. Air quality data were provided by the NPS and included visibility, ozone concentration, nitrogen deposition, sulfur deposition, and particulates. Change in land cover was included and presented as an ArcGIS StoryMap that shows changes in agriculture, urban, forest, and shrubland covers. A forest fragmentation analysis was also included in this analysis. Though not a natural resource, it was noted that there is limited visitor use data, making it difficult to analyze visitor pressure on the park and its natural resources. Crowd-sourced data from iNaturalist and eBird were considered. These sources provide valuable wildlife observations, but these data suffer from irregular timelines, unstructured sampling patterns, and random participation, which makes it difficult to incorporate, although it may be added at a later time.

Going forward, other gaps in data have been identified, including an environmental justice analysis overlay of the study area. The National Park Service is also working to establish closer relationships with indigenous communities. Growing degree days (the number of days that a minimum temperature is met for plants to grow) is another area that needs improvement due to the low resolution of available data. Enhanced collaboration among stakeholders is needed so that different organizations are not all struggling to do the same thing.

Trail managers and other stakeholders can use the hub site to see what datasets are available all in one place. The goal of the hub site was to create a living library to see what is happening in the A.T. Landscape and to make these datasets publicly available outside of the NRCA report. A hotspot analysis will be added to this report which will show where to prioritize conservation efforts. Areas that have not undergone change can serve as refugia for climate change, which makes them a priority for conservation. Landscape conservationists can use the hub site to locate The Nature Conservancy, Wildlands Network data, and many other datasets in one place that can help identify these areas.

Tools & Resources for Landscape Conservationists

- A.T. National Resource Condition Assessment hub site: A library of publicly available spatial data for the A.T. is available here https://appalachian-trail-natural-resource-condition-assessment-clus.hub.arcgis.com/
- A.T. NRCA webpage: Learn more about the A.T.'s NRCA here https://centerforlanduse.org/projects/appa/

Closing

Research presented during the Appalachian Trail Landscape Science & Stewardship Symposium 2021 revealed important resource information, analysis tools, and other resources available to anyone interested in land conservation within and beyond the A.T. Landscape. Presenters and workshop participants explored themes of biodiversity, habitat connectivity, plant and animal migration, ecological integrity, climate resilience, resource monitoring, and protection status. A consistent thread running through these workshops was the role of collaborative conservation action in protecting this unique and globally significant landscape. The research presented during the Symposium, along with an ever-growing catalog of datasets and tools, provides conservation practitioners with useful resources to characterize the landscape of the A.T., refine its natural and cultural extents, and identify hotspots for conservation prioritization at multiple scales.

Moving forward, there is still much work to be done. Throughout the Symposium, conservation hotspots, pinch points, and various focal areas were highlighted through the application of different methodologies. Regardless of the analysis methods used, these areas must be further evaluated by local stakeholders to better steer limited resources into initiatives that maximize the conservation impacts across the landscape. Furthermore, local partners often know the needs of their local areas best. Collaboration among local, state, and national agencies will continue to be key—including those agencies whose missions are not primarily conservation-focused. For example, wildlife corridors generally require close collaboration with state transportation departments in order to be successful. Ongoing data collection is necessary at multiple scales to assess resource conditions and monitor trends in human and natural communities. Community or citizen science can play an important role in data collection through applications such as iNaturalist and NASA's Community Snow Observations, among others. Funding is often limited for conservation projects, which makes low-cost, creative opportunities such as community science that much more valuable.

During the Symposium sessions, presenters and participants repeatedly noted the global significance of the Eastern U.S. as a natural network for safeguarding biodiversity and mitigating the impacts of climate change. Also discussed was the dynamism of the human dimension in this important landscape and the role people play in protecting it. Development decisions associated with human population growth often result in fragmentation of natural ecosystems in the populated East, and human-influenced climate change is increasingly exposing a broad range of ecological vulnerabilities. These threats to the natural landscape also increase community risks to public safety, infrastructure integrity, and economic wellbeing. Use of community data and social science research were frequently highlighted and promoted during session discussions. To truly be successful in protecting the A.T. Landscape, conservation practitioners must increasingly engage with community stakeholders, who are critical in driving many priorities.

Data show that marginalized communities continue to benefit least from conservation funding, perpetuating environmental justice concerns regarding access to natural areas and the co-benefits of clean water, clean air, and local food systems (Sims et al., 2022). Such communities have been disproportionately affected by decisions resulting in Superfund sites and have been subjected to numerous environmental pollutants in a legacy of contamination. One relevant resource is the U.S. Environmental Protection Agency's EJScreen Tool that screens for critical demographic and environmental quality indicators, allowing for increased transparency in how environmental justice is considered when identifying conservation priorities. Another useful tool for this landscape is the

Appalachian Mountain Club's Access to Trails, Parks, and Green Spaces in Springfield, Massachusetts. Increasingly, indigenous communities and tribal governments across the country are working to advance conservation initiatives, often with a focus on reconnecting with ancestral and historic lands. Equity in conservation planning and decision-making is an essential need, though resources and data for the A.T. Landscape have not yet been fully explored or developed. Benton MacKaye's vision for an Appalachian Trail described a place of natural beauty serving as a refuge to all people. To realize a vision of an A.T. Landscape accessible to and benefitting all people, substantial investment is needed to improve community-level data and to engage diverse communities in conservation planning and implementation.

The Appalachian Trail Landscape Science & Stewardship Symposium 2021 highlighted numerous resources available to conservation practitioners and showcased a number of noteworthy projects. At a continental scale, the Open Space Institute's Resilience Map of the A.T. Landscape; Peter McKinley's analysis of species richness, ecological integrity, and protection status of lands surrounding the Appalachian National Scenic Trail; and the Wildlands Network's Eastern Wildway habitat cores and connectivity corridors provide valuable frameworks for large-scale conservation planning. The Symposium also featured a number of regionally focused research and conservation initiatives such as the Maine Appalachian Trail 2020 report that featured the MATGIC decision support tool; the Pigeon River Gorge Wildlife Crossing project in the Great Smoky Mountains; and the Appalachian Mountain Club's studies of Northeastern mountain ponds featured in Sarah Nelson's presentation, to name a few. As demonstrated throughout the presentations, the success of such work almost always hinges upon close collaboration between the scientific community, conservation organizations, government agencies, local communities, and various other partners, regardless of the underlying scope and scale.

Effective stewardship of the A.T. Landscape depends heavily upon innovations such as those demonstrated by the Symposium's dedicated presenters. Maximizing the adoption and application of research methods and analysis tools such as those highlighted during the Symposium's six virtual workshop sessions is critical to the success of the Appalachian Trail Landscape Partnership and other advocates working to accelerate the pace and scale of conservation for this globally significant landscape. By continuing to develop and utilize science-based tools such as those presented here, and by leveraging combined resources and efforts, conservation partners will undoubtedly increase the likelihood of achieving ecosystem resiliency, improving community wellbeing, and realizing a shared conservation vision for the Appalachian Trail Landscape through the 21st Century and beyond.

List of Resources and Tools for Conservation Planners

The following list of resources and tools for conservation planners within the A.T. Landscape includes a comprehensive collection of the tools and resources mentioned in this report.

- Access to Trails, Parks, and Green Spaces in Springfield, MA (by the Appalachian Mountain Club)
  Explore this interactive tool that can be used to highlight areas of unequal access to outdoor recreation spaces.
  https://experience.arcgis.com/experience/85aae29231f442f790a91350104621cd

- Appalachian Mountain Club's iNaturalist Project Flowers and Fauna along the Appalachian Trail
  Participate in the Appalachian Mountain Club's community science monitoring project or learn how to create a similar project.
  https://www.inaturalist.org/projects/flowers-and-fauna-along-the-appalachian-trail-corridor

- Appalachian Mountain Club's iNaturalist Project Northeast Alpine Flower Watch
  Another community science monitoring project by the Appalachian Mountain Club.
  https://www.inaturalist.org/projects/northeast-alpine-flower-watch

- Appalachian Trail Natural Resource Assessment Hub Site: A living library of publicly available geospatial data for the A.T. Landscape
  Use this website to find existing public use geospatial data for A.T. Landscape projects, including HUC10 watershed boundaries, the A.T. centerline, and many more.
  https://appalachian-trail-natural-resource-condition-assessment-clus.hub.arcgis.com/

- The Climate Atlas
  View the health and status of a landscape, learn about its protection status, carbon storage capabilities, biodiversity, and more.
  http://www.theclimateatlas.org

- Community Snow Observations
  Participate in NASA's community snow observations tool.
  https://communitysnowobs.org/

- Completed Natural Resource Condition Assessments for national parks
  View existing natural resource condition assessments.
  https://www.nps.gov/subjects/science/tradnrca.htm

- The Eastern Wildway Interactive Map
  Find the potential natural core areas and habitat corridors near you.
  https://wildlandsnetwork.org/resources/eastern-wildway-map

- EPA environmental justice screening tool
  This tool can be combined with other planning resources to prioritize conservation efforts.
  https://www.epa.gov/ejscreen

- Forests of the Appalachian National Scenic Trail
  Learn about the forests within the A.T. Landscape.
  https://rfia.netlify.app/at/

- High elevation areas of US mapping tool
  Use this spatial dataset to locate high elevation areas in the US.
  https://www.arcgis.com/home/item.html?id=bde622c793a8456997d6ed9794ad0f07

- Information on Hydrologic Unit Codes
  Learn about hydrologic unit codes and their uses.
  https://enviroatlas.epa.gov/enviroatlas/DataFactSheets/pdf/Supplemental/HUC.pdf

- Interactive Wildlife Crossing
  Learn more about wildlife crossings here.
  https://www.nytimes.com/interactive/2021/05/31/climate/wildlife-crossings-animals.html

- Maine A.T. 2020 Report
  Read the full report here, including their project scorecard methodology.
  https://matlt.org/matltwordpress/wp-content/uploads/Maine-Appalachian-Trail-2020-FINAL.pdf

- National Atmospheric Deposition Program
  Learn more about atmospheric monitoring.
  http://nadp.slh.wisc.edu

- National Phenology Network's Phenology Visualization Tool
  Explore phenology data and maps.
  https://www.usanpn.org/data/visualizations

- Northeastern mountain ponds as sentinels of change: Current and emerging research and monitoring in the context of shifting chemistry and climate interactions
  Read Dr. Nelson's collaborative journal article here.
  https://www.sciencedirect.com/science/article/abs/pii/S1352231021005161?dgcid=author

- NRCA background site
  Learn more about National Resource Condition Assessments.
  https://www.nps.gov/orgs/1439/nrca.htm

- Science Symposium Website
  View the live session recordings here.
  https://appalachiantrail.org/our-work/conservation/science-symposium/

- Smokies Safe Passage
  Learn about wildlife crossing projects in the Great Smoky Mountains.
  https://smokiessafepassage.org/

- Species richness, ecological integrity and protected status data
  This journal article includes spatial data for species richness, ecological integrity, and protection status along the A.T. https://conbio.onlinelibrary.wiley.com/doi/full/10.1111/csp2.30

- The Nature Conservancy's Resilient Lands mapping tool
  Use this tool to find climate resilient lands.
  https://maps.tnc.org/resilientland/

- The Nature Conservancy's Migration Corridors map
  This map shows migration routes across North and South America.
  https://maps.tnc.org/migrations-in-motion/#4/19.00/-78.00

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